# Promoting Sustainable Development by Creating Enterprises on Renewable Energy Technologies in Nepal

## *Case Studies Based on Micro Hydropower Projects*

Vom Promotionsausschuss der
**Universität Flensburg**
zur Erlangung des akademischen Grades:
**Doktor der Wirtschaftwissenschaften**
Genehmigte Dissertation

von

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Internationales Institut für Management (IIM)

Flensburg, 2006

**ISBN 3-00-017882-1**

## Acknowledgement

I am deeply indebted to Prof. Dr. Gerd-E. Famulla, Director of Institut für Politik und Wirtschaft und Ihre Didaktik for his moral and all types of supports during my study in Germany. He was not only „Doctovater“ but also my guardian in Germany. Without his guidance, support, and encouragement, I could not have completed my study.  Similarly, I am grateful Prof. Dr. Olav Hohmeyer, Director, Internationales Institut für Management for his guidance and useful discussions during my study. Thank also goes to Prof. Dr. Binayak Bhadra of Nepal for being my supervisor in Nepal and providing me moral supports.

I am also very much grateful to Heinrich Böell Stiftung for providing me financial support for my study in Germany, without which it would have not possible to complete my study in Germany. Especially thanks goes to Prof. Dr. Grothaus and Frau Grothaus and Ms. Kathrin Bock-Famulla for their moral supports and encouragements. Similarly, I would like express my gratitude to all friends in Flensburg, Hamburg, Germany and in Nepal for their continuous encouragements and supports. I am also equally grateful to Fördegesellschaft Universität Flensburg e. V. of Universität Flensburg.

Lastly, I would like to give a big thanks to my wife who supported me in every moments of my life and without her help and support I would not completed my study.  Similarly, my sons Gokul and Girish, my parents, my brothers and all relatives are also equally thankful for their advices and encouragements.

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## Acronyms and Abbreviations

| | |
|---|---|
| ADB/N | Agriculture Development Bank Nepal |
| AE | Appropriate Engineering/ Butwal, Nepal |
| AEPC | Alternative Energy Promotion Centre (Nepal) |
| AG | AG Power Company Pvt. Ltd. |
| BAU | Business as Usual |
| BCR | Benefit Cost Ration |
| BYS | Balaju Yantra Shala/Kathmandu, Nepal |
| CBS | Central Bureau of Statistics |
| CDM | Clean Development Mechanism |
| CERs | Certified Emission Reduction |
| CFL | Compact Fluorescent Lamp |
| CO2 | Carbon Dioxide |
| CO2e | Carbon Dioxide equivalent |
| CRT/N | Centre for Rural Technology Nepal |
| DANIDA | Danish International Development Assistance |
| DC | Developing Country |
| DDCs | District Development Committees |
| ESAP | Energy Sector Assistance Program of Danida |
| FY | Fiscal Year |
| GDP | Gross Domestic Product |
| GE | Gautam Engineering/Butwal, Nepal |
| GEF | Global Environment Fund |
| GHG | Green House Gas |
| GNP | Gross National Product |
| GTZ | German Agency for Technical Cooperation |
| HDI | Human Development Indicator |
| HH | Household |
| HMG/N | His Majesty' Government of Nepal |
| HPI | Himalayan Power Industries |
| HSC | Housing Services Co. (P) Ltd. |
| ICIMOD | international Center for Integrated Mountain Development |
| IFAD | International Fund for Agricultural Development |
| (I)NGO | International Non Governmental Organizations |
| IPCC | Intergovernmental Panel on Climate Change |
| IREF | Interim Rural Energy Fund |
| IRR | Internal rate of Return |
| KG | Krishna Grill and Engineering Woks (P) Ltd. |
| KMI | Kathmandu Metal Industries |

| | |
|---|---|
| LPG | Liquefied Petroleum Gas |
| MLD | Ministry of Local Development |
| MOF | Ministry of Finance |
| MOPE | Ministry of Population and Environment |
| MOWR | Ministry Of Water Resources |
| MPPU | Multi Purpose Power Unit |
| MHP | Micro Hydro Power |
| MW or kW | Mega Watt or Kilo Watt |
| KL | Kilo Liter |
| NEA | Nepal Electricity Authority |
| NHE | Nepal Hydro-Electric Pvt. Ltd. |
| NLSS | Nepal Living Standard Survey by Central Bureau of Statistics |
| NMSS | Nepal Machine Steel and Structure, Nepal |
| NPC | National Planning Commission |
| NPP | National Power Company |
| NSE | National Structure and Engineering |
| NSEC | National Structure and Engineering Company |
| NYSE | Nepal Yantra Shala Energy |
| PAT | Pump As Turbine |
| PCI | Per Capita Income |
| R&D | Research and Development |
| R&M | Repair and Maintenance |
| RE | Renewable Energy |
| RECAST | Research Center for Applied Science and Technology |
| REDP | Rural Energy Development Program |
| RETs | Renewable Energy Technologies |
| RSEW | Radha Structure and Engineering Works |
| SE | Siddhartha Engineering |
| TEAT | Third Eye Appropriate Techniques, Nepal |
| TEI | Thapa Engineering Industries, Butwal, Nepal |
| UMN | United Mission to Nepal |
| UNDP | United Nation Development Program |
| UNFCC | United Nations Forum for Climate Change |
| VDC | Village Development Committee |
| WB | World Bank |
| WECS | Water and Energy Commission Secretariat |

**Currencies and Exchange Value (at the time of dissertation writing)**

| | |
|---|---|
| NRs (or Rs.) | Nepalese Rupees |
| 1 Euro (€) | NRs. 80 (average rate of exchange) |
| 1 US $ | NRs. 75 (average rate of exchange) |

## Executive Summary

Sustainability or sustainable development issues came up after realizing the unceasing negative impacts of human activities upon the ecological systems, in one side, while on the other side, to guide the future development path to accomplish well being of all humankind and its living space forever, so that past misdeeds, in the course of development, will not be repeated. The sustainability issues are still prevailing more strongly mainly because of 'weakness and stubbornness'. The weakness - not being able to avoid unsustainability - is connected mainly with the lack of resources and capacities, whereas stubbornness results mainly out of negligence in policy. These hindrances are still prevailing although roots of sustainability can be traced back to different time horizons of the past with different perspectives. In the course of formulation of operational sustainability strategy, several definitions from parochial thoughts to holistic verbiages came into prominence and still going on. Moreover, ambiguities in definitions still exist.

However, the definition is mainly stratified by strong and weak sustainability. These contemplations are dominating operational strategies. Resources use or exploitation, their value in development dynamism, trade offs in development process and modes of economic development are the main conflicting areas in both types of sustainability. Daly (1977, 1991, 1996, 1999), Costanza et al (1997), Hohmeyer (1997), Goodland (1992, 1999), have advocated that only through strong sustainability approach, sustainability is achieved. This school of thought has been categorized, in this dissertation, as "ecological determinism" because it puts more stress on ecology. Beckerman (1974, 1995) boasted that the weak sustainability approach is the best way to achieve well-being of human society. This dissertation regards with the exemplifications that this approach is not a sustainability approach per se. Pearce et al (1990, 1994, 1996) and Enquete Kommission (1994, 1997) stood mainly in the center but accepted both school of thoughts about sustainability. "Maintain critical natural resources" was the gist of Pearce et al's and Enquete Kommission's sustainability paradigm. Azar et al (1996, 2001) and Clayton et al (1996) have given a substantial concern to other dimensions but did not explicate which sustainability they prefer.

Nevertheless, both of these contemplations are lacking completeness from the perspective of sustaining and progressive development. They lack holistic perspective. A 'complete

sustainability' that is achievable only through "holistic determinism", has been discussed by this dissertation. Holistic determinism is three-dimensional and to categorize any development process as sustainable, all three dimensions must be progressive and bring about positive results individually if any. Without fulfilling this condition, no development activities can promote complete sustainability. Those development activities that fit into two-dimensional or one-dimensional approaches can promote sustainability partially if they do not have negative impacts in other dimensions.

At the project level, an operational strategy of sustainability is more complex than a theoretical conjecture at global level. A tiny project cannot make the world sustainable. Projects are implemented to promote sustainability at community, village or regional level, although, impacts of different scales can be made even at global level. Therefore, in the decision making process of a sustainable project and its implementation, interest of all stakeholders are to be brought in, i.e. covering all dimensions of development. At the project level, sustainable development or sustainability has three different reference parameters in each dimension: carrying capacity, scale and equity. A project has to satisfy the set of conditions according to its reference parameters through developed indicators.

However, before a project is consistent with the reference parameters, three factors have to be defined: time horizon, system quality and system boundary (space). These factors can sculpt the project's grading showing their 'sustainabilityness'. These three factors are to be decided considering the scale of projects and their impacts. Although, it is very difficult to define rigorously these three factors at a project level, thoughtful assumptions are to be made. Energy projects are even more complex because they have multifold impacts.

To make our biosphere sustainable, the energy system that supplies us with energy must be sustainable. A sustainable energy system has several dimensions. Unsustainability problems occur due to rampant use of energy causing global problems like climate change, etc. on the one hand and on the other hand, lack of useful energy for the large number of people in developing countries forcing them to use vulnerable resources. The insufficiency of clean energy is a state of energy poverty. Energy poverty has linkages with overall poverty and causes several impacts on economic, social and ecological life in a long-term perspective. Energy poverty has causal linkages with several indicators of livelihoods.

Energy related problems in developed as well as in developing countries could be reduced once renewable energy resources are developed. Developed countries, after switching to renewable energy, would reduce global impacts and on the other side, developing countries can alleviate their energy poverty by leapfrogging into renewable energies. Nepal is also trapped into energy poverty because its average energy consumption is about 0.340 ton of oil equivalent (TOE) whereas, a normal human being need about one TOE of energy. As there is a huge disparity between urban rich and rural poor, the rural people are having abject energy poverty. This abject energy poverty is inducing drudgery, health impacts, economic poverty, ecological paucity and dependencies on external resources. On the other hand, rural people are surviving with subsistence farming and with little opportunity of employment and income generation – little chances of poverty alleviation. Sustainable, locally available, community level, manageable and employment intensive energy technologies is to be implemented to rescue the rural communities from this pathetic situation.

Several development plans and policies in Nepal implicitly envisaged the development of the energy sector to alleviate energy poverty and synergize other sectors. However, even after almost five decades with nine development plans and several policies and acts, energy development, up to now, can hardly provide electricity to one fifth of population in Nepal. One of the main reasons is the dream of gigantism among other hindrances and obstacles. Fortunately, for Nepal with her more than 6,000 rivers and rivulets and century old artisan technology it was possible to crawl in the Micro Hydro Power (MHP) sector to break up the precious grain mainly yielding through hard labor of children and women so that they do not have to do extra labor before it is served to the bowl. Later few rural huts were started to be illuminated and people are being connected to outside world via audio and videos. However, the process is still slow to catch the demand. The multifaceted benefits of technology are still to be known to the policy makers, project designers and evaluators. The macro as well as micro benefits of MHP are yet to be realized by the country.

Therefore, in this dissertation, an approach of analyzing MHP is developed by including several factors because traditional methods are still parochial. Equity issues, basic need issues, distribution issues, risk and uncertainty issues and externalities are being included and discussed in one or other aspects of analysis. Human development index and comparison of real cost of electricity and people's paying capacity are some baseline on which equity and basic needs issues could be addressed. Externalities of the sectors, sub-sectors and areas concerned with MHP were found. There are qualitative as well as quantitative values of externalities. Subsidy, ecological impacts, biased custom duties are some of the externalities. The “subsidy externalities” in the sub-sector of lighting, end-uses which replaces kerosene, dry cells and diesel, is, on the average, about Rs. 366 (US$ 4.88, *one US$ = Rs. 75.00*) per family per year. Considering all socio-economic as well as ecological aspects there is, on the average, about Rs. 2,045 of “pecuniary externalities” per year per family. Many other externalities are being just mentioned qualitatively in this dissertation.

MHP technology as a whole is analyzed from the sustainability perspective. Each component of sustainability, i.e. ecological, economic and social, was looked upon separately. ***Ecologically***, MHP are causing no significant negative impacts but improvement in some cases through afforestation, soil stabilization activities after the project implementation. From climate change and global warming perspective, MHP is reducing about 1.376 tons of CO2e per kW per year in the “business as usual” case. However, if one electric bulb of 25 watt is considered equal to one kerosene wick lamp, about 4.266 tons of kerosene per kW per year is avoided. Not only that, the use of about 312 pairs of dry cells per kW per year is avoided preventing local soil, water pollution and bad health effects.

***Economically***, the broader benefit of MHP technology in Nepal is the creation of industrial base of hydropower development in the long-term. At the current situation, GDP contribution of MHP is about one percent of the manufacturing sector in Nepal. Quantitatively, it is still very negligible; however, the future scope is there. The MHP manufacturing sector is employing about 20.35% people compared to the total manufacturing sector of energy, hydropower and electricity related components, although investment in MHP manufacturing sector is less than 0.1% of the total national level investment in similar component manufacturing sector. Looking at the investment in MHP technology implementation sector, about Rs. 483 million has already been invested in the stand-alone systems until the end of 2001. The figure will be almost doubled, if we take into account the mechanical turbine and peltric set systems. This figure is tiny as compared to big hydro based on the grid system but significant if we compare employment opportunities. On the other side, the country is saving almost Rs. 13,000 per kW per year avoiding import of kerosene for the family who are using MHP electricity now.

MHP technology based activities are creating employment opportunities in a decentralized manner. From the production, manufacturing, implementation to operation and maintenance of MHP, there is, on the average, one-person year employment opportunity per kW of installed MHP, if the average size of MHP happens to be 20-30 kW. Similarly, after the implementation, about 0.25 person year job opportunities are available per kW of MHP for regular operation and maintenance, based on the above assumption. From this aspect, there would be significant job opportunities available in Nepal for skilled, semi-skilled and non-skilled human power. In the end-use sector that utilizes electricity from MHP, on the average, about 3-4 people are being engaged locally in each site of 20-30 kW plant.

In ***socio-economic*** aspects, poverty reduction through employment opportunities, saving in energy expenses and enhanced economic activities are observed. On the average, Rs. 2,095 per month has been earned by the operators and managers of the plant of average size 20-30 kW. The earning is almost 68% more than the per capita income of an average Nepalese. Whereas, people are paying almost 40% less amount of money for lighting energy after the implementation of MHP. This has also helped to reduce the poverty. Similarly, enhanced economic activities through end-use enterprises are also alleviating poverty of engaged families.

From the **social** aspect, drudgery of about two hours per day per family in agroprocessing has been reduced as new agroprocessing mills replaced old manual tools. People are having better living environment as smoke and fumes from kerosene is no more inside the house. People are participating and making decisions themselves as MHP plant belongs to the community. Revenue earned is being collected by the community and could be utilized for the community development activities. Tariff fixing decisions are made by the communities themselves. Children are having better light and comfortable learning environment. In few cases, school enrollment has also been increased after MHP, however, there is no strong causality to support this case. People are now linked with the outside world as they have access to Radio and TV. Village safety, especially from wild animals has been better now. Qualitative indirect impacts of electrification are better sanitation, improved health and reduced urban migration especially among the pension receivers.

The future perspective of MHP looks very promising if bottlenecks and hindrances are removed. Alternatives to MHP in the rural and remote area electrifications or 'energization' through clean energy, from the holistic aspects, are not feasible comparatively. Only complementary technology like biogas can be combined with MHP for non-electrical energy use, especially cooking and lighting only. Altogether, tentatively 80 MW of MHP could be implemented within the next 20 years. It would be sufficient to provide electricity, energy for small-scale end-use services for about 721 thousand families living in the hilly and mountain regions of Nepal. Additionally, about 31.5 thousand people will get employment and job opportunities and about at least 12.9 thousands of people will be employed by the same number of end-use enterprises in the rural areas of Nepal. To realize these projects, mobilizing local resources for participatory investment, gradual internalization of externalities, carbons selling through CDM for CERs thus mobilizing investment resources are some of the policies needed. Communities can even feed the electricity into the grid and earn more revenue for social development of their areas once the regional grid network would be developed in accessible areas.

MHP projects are from the holistic perspective sustainable although from the financial perspective because of externalities and other reasons they are not always viable. Technologically, Nepal can even export MHP components in some Asian and African countries. There is the technical capability of implementing at least three MW yearly, from the manufacturers and installers perspective. Policies, regarding the empowering of the local bodies and communities are being made favorable. Overall, MHP with friendly policies and good implementation strategies, as a community energy enterprise can be implemented in Nepal in large scale. This sector will contribute significantly to the rural energy sector and alleviates the poverty noticeable in the hilly and mountain regions of the country thereby promoting the sustainability in Nepal.

Firstly, formulation of sustainability analysis approach, namely holistic deterministic approach based on complete sustainability is the major thrust of this dissertation as a part of theoretical underpinnings. The holistic determinism has tried to incorporate issues left out by other approaches and tried to illustrate how this approach can be brought into the operationalization level of projects and programmes. Secondly, as one of the major empirical analysis in the context of Nepal, it has also been tried to calculate the externalities of energy uses in rural Nepal considering few sectors and sub-sectors. This is new to the Nepalese context, especially for renewable energy technology like MHP. This endeavor of finding approximate data could be the beginning but it lays the basis and guidelines for the further studies in this aspect, which will ultimately instigate the policy formulation to support RETs in Nepal based on the facts.

Thirdly, this dissertation has tried to analyze the MHP cycle (from manufacturing to operation and management) from the economic perspective both at micro and macro level. Finding the job or employment creation scenario by the MHP sector could be the pioneer work in Nepal that has been done in this dissertation. This work will help to develop input-output economic model of hydropower development in Nepal and understand the backward and forward linkages of renewable energy enterprise like MHP.

Fourthly, based on the existing data and analysis, future financing modalities with new approaches have been suggested which will help to reframe the existing MHP extension approaches and will promote the sustainable MHP development activities in the future. This dissertation has explicitly tried to explain that the development promoted by renewable energy enterprises like MHP is a social process based on both qualitative as well as quantitative indicators. Creation of enterprise does not mean establishing only private entrepreneurs, which are installing energy systems, but also development of social institutions that will empower local societies to share the benefits as well as costs of those entities and run such enterprises sustainably. Development of MHP enterprises in rural Nepal should also be seen from that perspective for the promotion of sustainable development.

# Chapter one

# Introduction

## 1.1 Background

Sustainability or sustainable development, nowadays, as a terminology, has been used almost everywhere. Although as an issue, it is not new in human civilization. Discussions on sustainability emerged because of the perception of physical indicators that did not coincide with human expectations. Human beings, to some extent, have realized significant negative impacts from developmental activities, at least observed by some parts of society. Discussions on sustainability and envisage of alternative thoughts and strategies for the developmental activities came from different roots in different times. Developmental activities that were carried on are getting plenty of feedback and input to improve, modify, or change the path as well as pace in some well-known development fields. Economics has been dominating the issues even regarding ecological or social aspects, which are concerned with sustainability.

In addition to that, as being an important resource that is needed for the present as well as for the future generations, energy has been dominating major sustainability debates, in which technicians, politicians, economists or civil societies in developed or developing countries have been engaged. Nevertheless, such sustainability debates have produced several conflicting theoretical as well as strategical definitions (e.g. Daly 1999, WECD 1987, Lélé 1991, Beckermann 1999, Neumeyer 1999, Holand 1999, Dobson 1999). Adhering to such divergent perceptions and thoughts, the move from sustainability discussions into operationalization phase has been reinforced - a step forward from theoretical analyses and definitions. The operationalization principle has also been taxonomized into several aspects based on energy and resources issues. The main concern of sustainability is not only the economic system or energy but also the biodiversity considering economy as a subsystem & energy as a prime mover. The main logic behind sustainability could be the rational use of "critical natural resources" for intra-and intergenerational equity.

In this context, Nepal, as one of the poorest countries in the world, has been dragged into several poverties next to energy poverty and economic poverty; it is leading towards ecological poverty as indicated by several data, facts, and studies (e.g. Pandey 1998, Dahal 1999). To alleviate such poverties there are few options, if developmental paradigms are formulated and implemented in accordance with local, regional, as well as global sustainability principles. The existing taxonomy of sustainability may hardly bring hurdles down unless and until paradigms are brought, formulated, and put into action. Nevertheless, leap forging is needed in the context of energy development and such action can be made inconsistent with the best policy that is possible. Being an economically poor would not be a big hurdle, but stubbornness in accepting failures of past activities and policies and refusal of formulating better alternatives could be the bottleneck for future development.

There are several opportunities and resources to eliminate existing paucity. As comparatively rich in water resources, Nepal could use its indigenous technology to harness sustainable energy from rivers and rivulets criss-crossing the country to start alleviating one dimension of poverty – energy poverty. Energy poverty, which has a causal relationship with overall poverty, is one of the major factors of unsustainability. Energy poverty can be alleviated with means of a decentralized form of renewable energy technologies, which have spin-off effects on other social, economical, as well as ecological welfare parameters.

Less than one third of Nepalese houses possess electrical light; whereas the other two third of families, especially those in remote rural villages, have to do without for several years or even decades. According to on going national policies of liberalization and privatization, the 'rational capitalist' will have to serve these families. Because in the absence of several conditions required for such capitalist this concept does not work in the remote villages. Such fallacy would certainly marginalize those who are not able to play a money game in the market, i.e. do not possess the capacity to pay. Unquestionably, such paucity cannot be alleviated or combated with the 'market rationality' alone, especially in the remote hamlets of the hill and mountain regions of Nepal, the home of nearly two million families.

As there are good natural bestowed resources like water resources, this pathetic situation of energy could be improved with effective policies and implementation programmes that could bring not only energy services to the country but also social changes through decentralization and participation, environmental benefits through preservations of ecological values, and significant economic benefits through employment generation and enhanced economic activities. Micro hydropower (MHP) could be one of the best options to uplift the livelihood of the people. Small and medium sized industry would be promoted in the manufacturing sector because of the production of MHP components as well as end-use sectors that utilize the produced electricity for value addition. Decentralized backup technical service centers could also bring technical skills and services to local people in rural as well as remote areas. Such activities could lead to the improvement of rural livelihoods, especially of poor people living in the remote hill and mountain areas.

MHP projects are to be analyzed not only from the point of view of energy services and energy products but also from the perspective of empowerment and fulfillment of basic needs. The competing energy technologies may not have local, regional as well as national benefits or at least differ from decentralized renewable energies. The decades old practices, experiences, technological innovations and intuitiveness among the Nepalese manufacturers are not comparable with imported ready-made technology from socio-economic perspectives. The externalities of competing technologies should be internalized and decision-making tools must be modified to provide equal level playing fields to all renewable energy technologies. The remote and difficult terrains in the hills and mountains and more than 6000 rivers criss-crossing such valley and parishes could have several uses as compared to imported, unhealthy and uncertain kerosene used for lighting the huts in remote hamlets. Such unsustainable and unreasonable resources should be priced higher than the locally produced sustainable products.

Community initiatives and community ownership are the niche mechanisms that work better in the hills and mountain regions of Nepal. From the point of resource conflicts over ownership, such community enterprises will bring social harmony and thus enhancing social capital. Once social capital is enhanced, social sustainability processes are induced (e.g. ICIMOD 1999, Dobson 1999). If MHP are implemented through community ownership as a community enterprise in energy sector, sustainability in energy sector could be promoted. That is why community MHP in the hills and mountains of Nepal could provide the way towards sustainability to nearly 850 thousand families in rural areas. MHP in Nepal needs in depth analysis to make sure its forward and backward linkages in all aspects of sustainability are to be illustrated for the promotion of sustainable development in Nepal.

### 1.2 Research questions

Since the seventies MHP has been implemented initially for mechanical milling to replace either existing diesel mills or to provide relief to women and children in agroprocessing in Nepal. These mills were installed by motivated villagers in their vicinity. Later a dynamo (electrical generator) has been added to the system to light neighboring households in the mill areas. Since the late eighties, with the support of the government or national as well as international agencies, stand-alone electricity generation units have been installed for rural electrification. Such MHP systems were provided with subsidies on an ad hoc basis.

Several case studies as well as impact studies were carried out with the results that they all univocally came to the conclusion that MHP brings socio-economic as well as environmental benefits (ICIMOD 1993, ITDG 1998, Baskota et al 1997). Moreover, subsidies or other forms of supports to MHP have strongly recommended. There are also a few studies indicating that the support provided by the authorities are not helping the target groups (Nepal 2000). Despite several studies neither of them has analyzed the community owned system from the perspective of sustainability nor developed a tool or concept to analyze these decentralized systems broadly by including externalities, social and ecological issues. Without such broader analysis, no valid conclusion could be drawn and all efforts dissolve in egg and chicken discussions. Therefore, small-scale intervention through MHP technology has not always been well recognized because:

- decision making processes based on traditional economic analysis,
- externalities of competing technologies and resources are neglected in analyses,
- ecological benefits of MHP are not given due weight,
- social benefits of MHP are not considered in decision-making and in quantitative analysis, giving narrow financial tools a major role in decision making,
- electricity is seen only as a commercial product not as a catalytic agent, which has spin-off effects,
- low risk, local investments and decentralization aspects are also neglected and
- economic benefits at macro as well as micro levels are not illustrated.

Therefore, there is a greater need to develop an appropriate tool to evaluate and analyze the MHP from the perspective of sustainability. Without such tools, which encompasses all dimensions of sustainability the real benefits of the MHP at micro as well as macro level could not be illustrated. There are several methods to analyze or appraise a project or plan such as multi-criteria analysis, input-output models, logical framework analysis, cost benefit analysis of different types (e.g. social, improved, etc.). The existing analytical or decision-making tools are not enough to analyze sustainability because of their predilection towards economic components only and either leaving ecological and social dimension as pre memoire issue (p.m.) or neglected them. However, these existing tools are part of sustainability analysis. To illustrate the real outcomes of MHP in Nepal, new approaches of analysis based on broad sustainability criteria are needed to promote MHP as an enterprise.

Therefore, the main questions are: Is there a proper definition for sustainability? Are MHP projects suitable to promote sustainability? How exactly does Nepal benefit from MHP? Is there a way to analyze the question of sustainability on a project level? Will Nepal be able to provide its people a minimum level of energy? What are the problems, issues, and past activities that were hindering to harness abundantly available energy resources to improve the current state of energy poverty? Can all competing energy technologies be compared? What are the externalities of such different systems especially in the rural energy sector and could they be internalized?

### 1.3 Hypothesis

First, as often quoted the majority of Nepalese are subsistence (better to say poor) farmers. Due to increasing population and lack of significant development activities to create employment opportunities the pressure on ecologically fragile hilly lands is permanently increasing. In order to reduce the pressure on agricultural land other sources of getting bread and butter have to be generated, even from environmental or ecological perspectives. Without reducing pressure on such limited land resources and providing the people other non-farm opportunities, there would be no sustainable development. Among different alternatives, utilization of locally available water resources is the one, which has multiple benefits: clean energy, employment opportunity and a catalytic role for cottage industries – thus improved economic activities and income.

Second, even though less in density, use of fossil fuels is increasing. Available forest is no longer sustainable because the consumption rate is higher than the regeneration rate. Both evidences are inducing other economic, social and ecological consequences for the poor farmers. To ameliorate the situation simple and locally sustainable interventions are needed. Among the choices, indigenous micro hydropower technology could be the better alternative. MHP can promote sustainability in Nepal because,

- it utilizes local resources that are abundantly available even in rural and remote valleys and perishes,

- it is geographically suitable because of rugged, remote and difficult terrain with scattered settlements in the country that makes grid electricity technically and economically unmanageable,
- it does not have significant negative impacts on the environment,
- it creates jobs locally, and enhances local income-generating activities thereby alleviates the poverty more effectively than other infrastructure related rural development activities,
- technology is available in Nepal, the appropriate manufacturing facilities can meet the demand of MHP components needed for the country,
- through manufacturing, installations and operation of MHP components and MHP plants local job opportunities will be enhanced from industrial level to remote rural areas,
- it helps to reduce green house gases (GHG) and pollution thus helps to reduce the risk of climate change and health,
- it helps to reduce the burden of importing kerosene and dry-cells for rural lighting and diesel for rural industries, especially for mills,
- it helps in empowering rural communities – thus decentralization and institutional development through enhanced skills to manage decentralized local energy systems and
- it reduces social drudgery – especially of women and children, thus improves their health and reduces gender biasness.

**1.4 Objectives**

This dissertation has following objectives:

- to define sustainability based on the existing milieu of energy poverty and MHP projects in Nepal as well as on the global ecological and socio-economic problems,
- to analyze global as well as national aspects of sustainability and energy poverty,
- to illustrate the existing state of the art MHP in Nepal,
- to develop conceptual analytical frame work for MHP project on the perspective of sustainability and its components,
- to indicate how a development project is to be analyzed or pursued,
- to analyze and quantify the externalities of the rural energy sectors to compare with MHP,

- to perform sustainability analysis of community owned MHP projects on economic, social and ecological perspectives,
- to analyze the comparative benefits of MHP in rural energy supply in Nepal, and
- to recommend a possible future course of action i. e. development of MHP in different scenario and financing modalities.

### 1.5 Methodology

The study is based on the following methods:

#### 1.5.1 Literature review

It is a major aim of this study to develop conceptual analytical methods of sustainability as well as to formulate a definition of sustainability, based on past thoughts, activities, critics, and studies. Especially Daly (1977, 1991, 1996, 1999), Pearce et al (1989, 1990, 1993), Clayton et al (1996), Bell et al (1999) and WCED (1987), Lovins (1977) and Hohmeyer (1988, 1997) are providing the inputs to the discussions. In order to gain an overview of existing studies, policies, energy issues, developmental activities on energy and MHP in Nepal as well as in other parts of the world numerous books, publications, internet sites, and journals were consulted. An equal number of grey literatures, i.e. unpublished reports, were also consulted, and especially related to the project activities in Nepal.

#### 1.5.2 Managing data needed

Before any analysis on MHP has to be begun, the following data and information must be gathered and analyzed. Such information is needed to quantify and weigh the inputs and outputs of the projects. To analyze the project even from the sustainability aspects, it needs the quantitative and qualitative data to verify the sustainability indicators. Because, "…the evolution of sustainability as a paradigm inevitably leads to a need to quantify sustainability; hence sustainability indicators were developed as a mean of keeping the paradigm alive" (Bell & Morse 1999:31). It could have been enough to the people who are benefiting through sustainability project, to convince them that the project is sustainable by showing even physically all the outputs. But to the outsiders, donors, moneylenders, planners and decision-makers the quantified or illustrated analysis is needed. It is needed mainly because of two objectives: firstly to replicate the ideas and secondly, to realize the benefits of sustainability by others who are not the beneficiaries. Therefore, the following data are collected in the case of MHP projects:

- community’s sufficiency on food production, employment, total agriculture production, type of agriculture, sufficiency of agro goods, etc.,
- non-farm activities and its economics: people’ profession or activities and facilities available to the people and existing industrial and commercial activities,
- geographical specificities, distance from nearest road head, conditions of accessibility in the future transportation, the existing grid network or big power-plant, etc,
- available potential energy and existing or potential conflicts on available resources,
- purchasing power of the people or such potential, willingness to pay for electricity,
- uses of energy, costs, investment and overall socio-ecological and economic impacts.

#### 1.5.2.1 Secondary data

Several monthly, quarterly as well as annual reports of Rural Energy Development Programme (REDP) of UNDP Nepal central office and district offices were taken into analysis. Secondary data were also used from several publications of different ministries of HMG Nepal, local authorities and other organization in Nepal. Few secondary data are also verified with primary data as well, like kerosene consumption per family in the hilly and mountainous regions of Nepal.

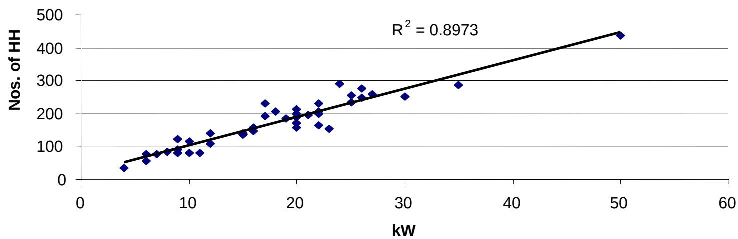
#### 1.5.2.2 Primary data

Primary data were mainly collected during the author’s study period as well as during his working period within Rural Energy Development Programme of United Nations Development Programme (REDP/UNDP). Several primary data, especially the household surveys were collected by NGOs in different districts where REDP/UNDP programs have been implemented. These NGOs have been supported by REDP/UNDP. Most of the data of Myagdi district in Nepal were collected under the guidance of the author’ work as a district energy advisor. With informal permission from district level NGOs as well as district level offices, these data are analyzed. The data related to the manufacturing sector and consultancies were collected by the author. These data were very rough, because almost no manufacturers are having systematic records of their activities. Most of the data obtained from the manufacturers are generated by interviews in which the figures are told tentatively. Other enumerators were asked to collect data to the same subject to verify the authenticity and reliability. The few qualitative as well as quantitative data were collected during the interviews with community mobilizers of MHP project implementing villages, village representatives and working staff of REDP/UNDP in the districts. The reliability and accuracy of community level data are based on people's perception and experiences because no household has records of how much battery or kerosene has been consumed during the last few months. The data depend upon their memory. Nevertheless, by taking the average of several households any error could have been minimized. Although the data of several villages in Nepal are used on several aspects in the analysis, the main work is based on MHP projects that are being implemented in the Myagdi District of Nepal. Data from other districts are also analyzed to interlink the findings and generalize the results.

### 1.5.3 Analysis of data and reasons for generalization

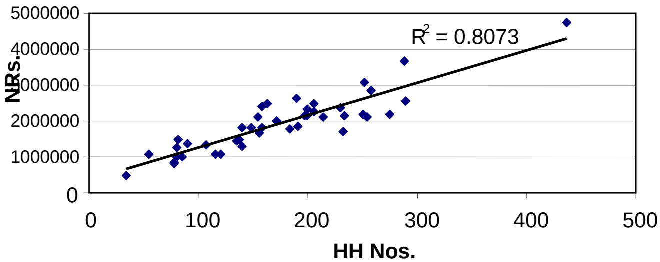
Primary as well as secondary data are calculated and analyzed, wherever needed using MS Excel XP and SPSS 10.0. To draw any types of conclusions usually the average of existing data was taken. The MHP plants existing in the ten districts of Nepal (see **Annex 1.1**) in different regions are taken in the analysis. The characteristics of the community owned plants are almost the same. The following figures are showing that there is a strong relationship among 43 community owned MHP plants situated in the different parts of the country. Their basic features like cost per household, costs per kW and households per kW are similar (see **Annex 1.2** also). The tariff rate is also not so much different (as shown in Chapter Six). From that perspective, if few MHP plants are analyzed in depth they could represent the other MHP plants as well, in general. However, particular community's willingness to pay and the social cohesiveness that enhances the participations can differ in different sites. The community's income and economic activities may also vary. However, the average expense of the communities in lighting and dry cell battery, before the installation of MHP, is also in the closer range (see ***Annex 1.3***). Therefore, while analyzing the sustainability issues, few sites could be selected for valid data.

**Figure 1.1 Relation between Beneficiary HH and capacity of plant**



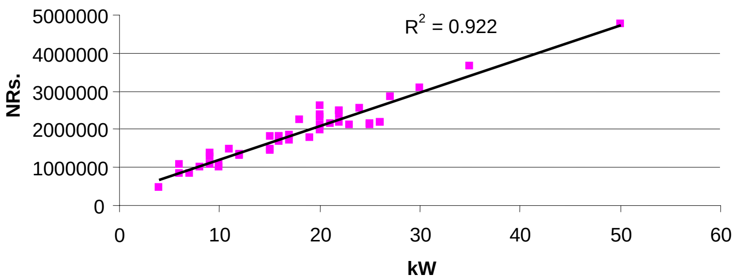

Source: compiled from REDP (2000a, 2000b, 2001) and Author's own collections

**Figure 1.2 Relation between Investment and beneficiary HH**




Source: data compiled from REDP (2000a, 2000b,2001) and Author's own collections

**Figure 1.3 Investment cost and capacity of plant**




Source: data compiled from REDP (2000a, 2000b,2001) and Author's own collections

The figures from 1.1 to 1.3 are showing a close relation among the financial parameters and households per kW of the MHP systems. Analysis of few MHP could justify the results and the outcome could be generalized for the MHP plants installed in the hilly and mountain regions of Nepal. However, the analysis of data could be made still narrower by selecting a site in Myagdi District as five community owned MHP of the district (out of 40 such MHP projects in the several parts of Nepal) are having almost similar characteristics as shown table 1.1 and fig 1.4, i.e. revenue collection/HH, cost/HH, expenses/HH etc. Therefore, chapter six will analyze sustainability of the MHP projects by taking the case of Dajungkhola MHP in Okharbot VDC of Myagdi District in Nepal. However, other sites in different parts of Nepal will also be included into the analysis whenever needed to justify the case more strongly. Otherwise, it is to state that one MHP site represents the general character of MHP in Nepal. More detailed analysis using **<u>SPSS 10</u>** is given in the **Annex 1.4.**

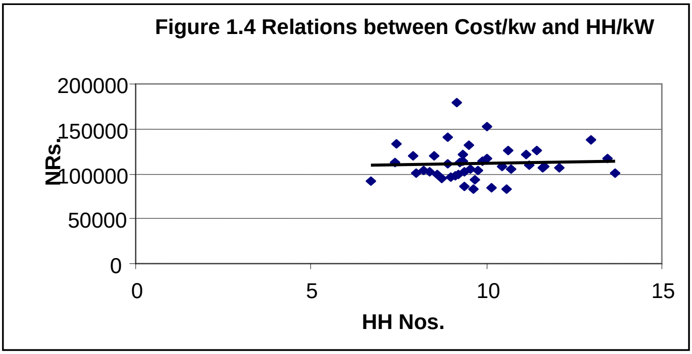


**Figure 1.4 Relations between Cost/kw and HH/kW**

Source: data compiled from REDP (2000a, 2000b, 2001) and Author's own collections

### 1.5.4 Limitations

The data origin from different years, i.e. 1998 to 2002. Therefore, there could be some variations in some figures like the price of kerosene, dry cells and other products. Similarly, the consumption behavior, income of the people, population growth and numbers of households are subject to constant change. The perception of people does change as well, which has an impact on data obtained from people through questionnaires, interviews and discussions. These types of imprecision could not be considered in the analysis.

## 1.6 Structure of dissertation

The structure of this dissertation could be divided into two parts: one theoretical underpinnings and analysis based on reviewed literature, second empirical analysis and discussions based on primary as well as the secondary data. The figure 1.6 illustrates the structure of the dissertation with proportion of theoretical or empirical data.

As shown in the figure 1.5 the structure of the thesis starts with the backgrounds, research questions and methodology in **Chapter One**. The discussion of why sustainability is needed and the reasons for going towards sustainability will be discussed and roots of thoughts or perceptions of sustainability will be listed in **Chapter Two**. The existing definitions that are given diversified views in several issues and sometimes conflicting appraisals are explicating some vagueness because of their too normative criteria or statements. Nevertheless, there are two dominating views of sustainability: strong and weak sustainability that are discussed in Chapter Two. The new dimension of sustainability for the existing milieu of project appraisal and analysis will be defined. This chapter illustrates how sustainability could be defined from the perspective of developmental activities, programs and projects.

**Chapter Three** critically analyses the existing decision-making tools and project analysis as well as appraisal methods in energy and MHP sectors. Exposing the weaknesses of existing methods, new or modified approaches will be suggested by including equity, ecological constraint, climate change and uncertainty issues in appraisal methods. The sustainability criteria for a sustainable energy system for rural Nepal will be formulated in this chapter. **Chapter Four** tries to illustrate the links between sustainability and energy. It discusses global as well as Nepalese energy issues like unsustainable resource exploitation, equity and accessibilities, climate changes, air pollution, energy poverty and society's need. Narrowing in the Nepalese context, the Nepalese energy development efforts, existing resources and technologies as well as economic issues are discussed.

In the context of rural energy use in Nepal, the quantification of the externalities present in the sectors and comparing them to MHP is the main task of **Chapter Five**. Few externalities have been quantified and monetized. **Chapter Six** details facts on micro hydropower (MHP) in Nepal based on primary as well as secondary information. In this chapter manufacturing capacity, investment, employment, costs, tariff and all macro as well as micro economic conditions are also illustrated as the major benefits of MHP for Nepal. This chapter also analyses the MHP projects of Myagdi district in Nepal. The Dajungkhola MHP of a village in the district serves as a reference and the previously developed conceptual framework is applied to the analysis. The sustainability analysis tries to show that all sustainability dimensions or components have to be enhanced after a project has been implemented to claim as a sustainability-enhancing project.

**Chapter Seven** shows the future perspective of MHP in Nepal analyzing different scenarios in employment, investment, population benefiting from MHP and enterprise development. A possible approach of mobilizing the financial resources has also been discussed, especial focus is given to internalizing externalities and carbon trading through clean development Mechanism. MHP is also compared with other energy resources used in rural Nepal. The mechanisms to provide equitable incentives are also suggested.

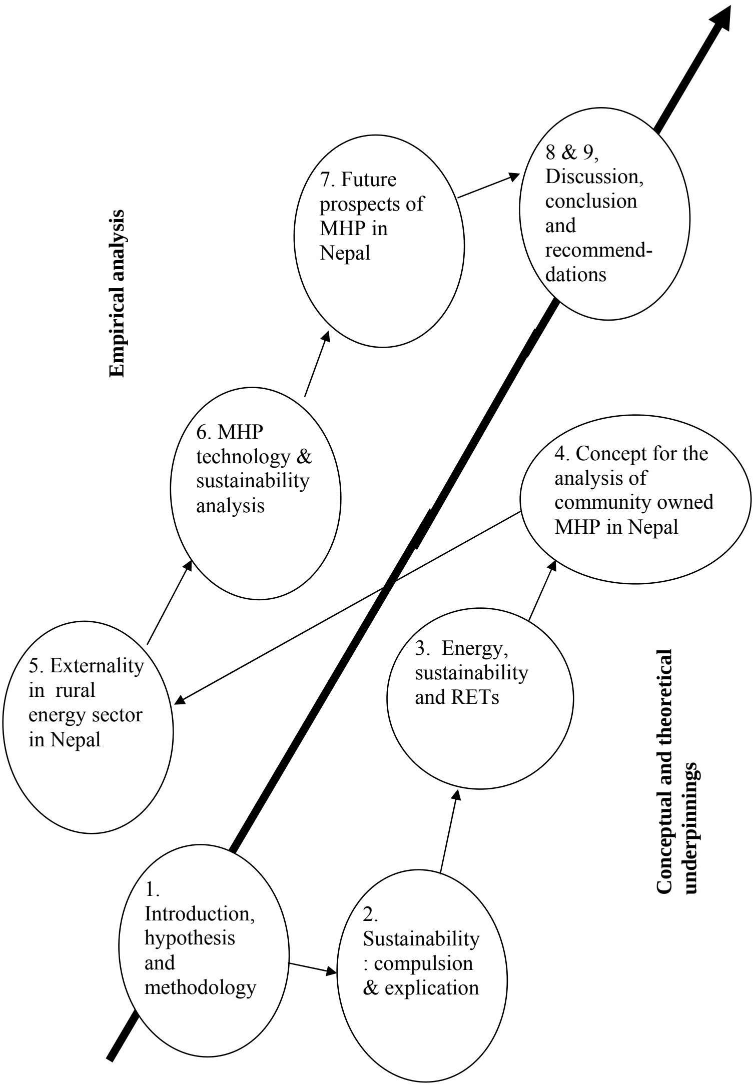



***Figure 1.5 Structure of dissertation***

**Chapter eight** discusses the findings and set hypotheses; and justifies that the hypotheses are satisfied in a larger scale. This chapter also briefly outlines how the principal of sustainability has been incorporated by implementing the MHP projects. **Chapter nine** concludes that the MHP, in its decentralized form and community-based approach promotes the sustainability. Few challenges and issues that have to be dealt with to extend the MHP development works further and farther in Nepal, have been listed.

# Chapter Two

# Sustainability: Compulsion and Explication

## 2.1 Sustainability or sustainable development: A compulsion?

As stated by Amarty Sen, "A person starves either because he does not have the ability to command enough food or because he does not use his ability to avoid starvation" although "ownership of food is one of the most primitive rights" (Sen 1999: 45). When a person starves of either reason, people say it is because of poverty, although the scale and the nature of poverty differ in different regions and societies. It has also been cited several times, that poverty has an impact on the environment because "poverty is a major cause and effect of global environmental problem" (WCED 1987: 3, and also compare Lele 1991: 614). According to Sen's first part of the sentence, the starving individual is helpless because he does not have the ability to search for the means of his/ her survival. There could be various reasons for lacking this ability. When it is considered that the whole human beings, not only as an individual, do they have the ability to search for the means of their survival? Definitely yes because for some millions of years they did it partially or completely and are still surviving in similar or different ways. What will happen in the future? Will they be not starving and surviving on similar, better or different ways? "Humanity's inability to fit its doings into a pattern of clouds, oceans, greenery and soils is changing the planetary system, fundamentally, and some of the changes are accompanied by life threatening hazards" (WCED 1987: 1). Is this happening because we do not have the ability to command enough safety to our Earth like a starving individual? Obviously, we are unable to command enough food for over a billion poor, electricity for about 2 billion people[1], save unknown numbers of species in flora and fauna, prevent global warming and man made catastrophes, soil erosion, which are possibly irreversible, life threatening and endangering the existence of the Earth (Reid 1997: 6, Goodland 1999: 717, WCED 1987: 2-5, Pearce et al 1996: 3-37, King 1992: 3-39, Costanza et al 1997: 3,

[1] The statement "Two billion people without electricity" is not new. Lovins (1977) in his book "Soft Energy Paths, Towards a Durable Peace" had mentioned that there were two billion people without electricity and nearly 20 years later the World Bank in its Report in July 1996 (Report No. 15912 GLB), has mentioned that there are still two billion people without electricity. Moreover, the World Energy Council (*http://www.worldenergy.org printed on 18 August 2002*) has mentioned that even in the year 2020, there would be about two billion people without electricity.

Nakićenović et al 1998: 246, Kane 1999:16, WB 2000: 19, Lovins 1977: 27, Clayton et al 1996)

The second part of Sen's quoted sentence highlights not the weakness but the stubbornness of a capable individual for the causes of starvation or endangering his or her existence, because he/she does not use his/her ability to prevent the prognosticated threat. The relation between ownership right of an individual and poverty has also been raised by Sen. An individual starves even if he owns something. It is a similar situation with the entire human species. Humankind owns everything on Earth and even in the universe in his capacity, but is still unable to solve several problems, which are instead accumulating day by day. Now, stubbornness of human beings might be another reason for the deteriorating condition of whole systems on the Earth. The biodiversity is said to be going in the direction of a starving individual despite humankind's entitlements to it. More than a fifth (1.2 billion) of the world population is struggling, for less than one dollar a day, with absolute poverty (WB 2001: 3) and are on the verge of starvation.

There are evidences of irreversible damages to the very basic condition of survival of the Earth and human beings: maximum human biomass appropriation, climate change, ozone shield rupture, land degradation and biodiversity loss (Costanza et al 1997, Goodland 1999 & 1992). The way humankind deals with technology, economic growth, fossil energy, non-renewable consumption and waste disposals are not in the favor of human beings themselves. These issues were raised by E.F. Schumacher in "Small is Beautiful", Club of Rome in 'Limits to Growth', Reports of Enquete Commission of the German Parliament, "Vorsorge zum Schutz der Erdatmoshäre", Rio Summit on Earth and lots of authors, conferences and commissions since 1960s.

Human being considers natural capital entitled to him (Weiss 1997: 126-127). Most of the economic thoughts and discussions (like WCED 1987, Pearce et al 1990, 1993) never entitled natural resources to other than human beings, mostly even exclusively to contemporaries excluding future generations. Owing to human beings' inability or stubbornness, development activities have gone in wrong directions. Irrespective of what it concerns - economic growth and poverty or ecological problems and natural resources or basic needs like sustainable energy supply - "we need a norm to guide our actions so that the environment we enjoy today will be available for generations to come" (Weiss 1997:126). In addition, we are compelled to proceed with the new dimension of future development that "could provide the means to improve the environment" (Reid 1997:37). At the same time, past development activities have to be corrected and new paths of development be followed, as per the Rio Declaration, recognizing the integral and interdependent nature of the Earth.

### 2.2 Roots of the sustainability concept

Although few valid reasons for sustainable development or sustainability have been discussed, it is worth to delve into the origin of the discussions before looking for a definition of sustainability. In the beginning of the 18th century, the forest, then one of the major sources of energy, came into the centre point of 'sustainability' issue, focusing on the scale of consumption as well as on its regenerating rate (e.g. Stockman 1996). In the $20^{th}$ century, the issue has been brought into the discussion more directly by the International Union for Conservation of Nature (IUCN) in the Ottawa conference in 1986 and more boldly by the Brundtland Commission report "Our Common Future". Although, semantically, the issues of sustainability or sustainable development have been raised in different domains since irreversible impacts of the development process have been realized. According to Bell and Morse (1999) there are six roots of sustainability: a) biosphere root, b) resource scarcity root, c) critics of technology root, d) no growth or slow growth oriented root e) environmental root, ecological and carrying capacity root and f) eco-development root.

a) The biosphere root of sustainability considers the earth has limited space of biosphere and all activities, including that of the economics, are subsystems of the biosphere system. Biosphere is materially closed and only solar energy enters into it. All activities have limits and cannot grow forever inside the closed biosphere system; Daly (1977, 1991, 1996, 1999) and Costanza et al (1997) have highlighted this issue of biosphere root.
b) Concern over resource scarcity and its consequence was also realized very early. Even political persons like Gandhi were concerned about resource scarcity when he replied a query on India's development after independence saying, "It took Britain half the resources of the planet to achieve its prosperity; how many planets will a country like India require?” (Goodland 1991: 15). Economic aspects of resource scarcity with narrowed dimensions were already stated earlier with Hicks’ “Income

theory[2]" (1939). Issues of energy scarcity and depletion of fossil resources dominate the discussion in this root with the energy questions in the centre point.

c) The critics to technological root was first brought up by Schumacher in his "Small is Beautiful: Economics as if People Mattered", suggesting technology with human face that promotes human's well-beings instead of gigantic technologies adopted by the West (Schumacher 1973). "Soft Energy Paths: Toward a Durable Peace", by Amory B. Lovins (1977) also focused sustainability issues, e.g. the danger of nuclear technology and the importance of renewable energy technology. This root is also clearly dominated by energy & sustainable technology issues.

d) Non-growth and slow growth root of sustainability came into prominence after the publication of "Limits to growth" by the Club of Rome in 1972, although Keneth Boulding's "cow boys economy and spaceship economy" were there before Limits to Growth (e.g. Daly 1991). There are several versions of growth related theory: "Steady State Growth" by Daly (1977) and "Human Scale Development" by Max-Neef (Reid 1997). The gist of this thought is that sustainable development cannot be achieved by only growth oriented economic development, but distributional, just and quality oriented growth is essential for the sustainable development. Exponential growth cannot be achieved with limited resources available such as fossil resources and energy.

e) Discussion on environmental roots of sustainability has pioneered since the 1960s. "Silent Spring" of Rachel Carson in 1962 raised the issue of environmental impacts of DDT and instigated the blaze of discussion on sustainability more vividly with solid evidences. Even before that, the first analysis of a possible climate change caused by industrial emissions of radiatively active gases was published in 1896 by a Swedish physical chemist Svante Arrhenius. He calculated that there would be a global warming of 3.2 - 4.0 degree Celsius from a doubling of the Earth' atmospheric CO2 concentration, a level which could be attained sometime in the next century (Arrhenius 1990: 1). The impetus of environmental aspects of sustainability has been mostly driven by UN agencies and IUCN i.e. Brundtland Commission, Rio Summit, Montreal Protocol, Intergovernmental Panel Climate

[2] In his book on "Value and Capital, an Inquiry into some Fundamental Principles of Economic Theory", J. R. Hicks stated "…we ought to define a man's income as the maximum value which he can consumes during a week, and still expect to be as well off at the end of the week as he was at the beginning" (Hicks 1939: 172).

Change (IPCC), World Commission on Dams (WCD) and most recently by the Kyoto Protocol. Resource, ecological and carrying capacity roots of sustainable development are now more or less combined issues when looked upon broadly. The carrying capacity and ecological root of sustainability is focusing mainly on issues like no depletion of non-renewable resources, consumption of renewable resources only within the sustainable yield and waste generation within the assimilative capacity of ecosystem (Costanza 1992, Daly 1991, 1996, 1999, Enquete-Kommission 1994).

f) Several groups and economists like Galtung propagated the eco-development root. He stressed, "Eco-development is the exploration of the interfaces between environment and development. The task…is to identify those processes that enhance the environment and at the same time strengthen development, not merely to explore the constraints which the environment puts on development and the demands development makes on environment" (Simon 1990: 10-11). It is also a politically motivated paradigm especially in Western Europe.

### 2.3 Existing explication of sustainability

In the course of postulating the future path of development, a popular jargon came into discussion: ***Sustainable Development***[3]. In all sectors of society, from politicians to farmers, it is still instigating discussions. The term first came into prominence in the World Conservation Strategy (WCS) published by the International Union for Conservation of Nature (IUCN) in 1980[4], even though the term was assumed to be invented earlier by Eva Balfour and Wes Jackson (Reid 1997: xiii). Some argue that it had already existed during the forest conservation movements in the eighteenth century (Stockmann 1996). "Sustainable development has indeed become a quintessential example of holism" (Bell

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[3] Sustainability and Sustainable Development are frequently used by several authors (like Goodland et al 1992, Capello et al 1999) interchangeably. Bell and Morse (1999) stated that 'sustainability' is similar to 'sustainable' used mostly as an adjective. Pearce (1993) opinioned that sustainability in economic terms is sustained output and input where as sustainable development broadens the concern embracing social goals other than GNP. Stockmann (1996) has also emphasized the differences between the two: Sustainability and Sustainable Development. In this work, both are used sometimes synonymously. Sustainability indicates more about the state of the art of something individually i.e. social sustainability, economic sustainability and environmental sustainability (e.g. Harou et al 1994) etc where as sustainable development encompasses several such sustainability components and output of such sustainability collectively would be sustainable development. However, for Daly, "…it is not useful to include all good things in the definition of sustainable development" (Daly 1996: 9).

[4] Lovins (1977) is his book "Soft Energy Paths, Towards a Durable Peace" has mentioned already "… sustainability is more important than the momentary advantage of any generation or group" (page 13)

and Morse 1999: 5) and "everyone agrees that sustainability is a good thing" (Bell and Morse 1999: 3).

The demand for an exact definition of sustainable development or sustainability arose. When development is discussed, it may not only be in materialistic terms but "the qualitative improvement in the structure, design, and composition of the physical stocks of wealth that results from greater knowledge, both of techniques and purposes" (Daly 1999: 6). "People differ in the environmental, social, and economic condition within which they have to live, and having a single definition that one attempts to apply across this diversity could be both impractical and dangerous" (Bell and Morse 1999: 5). Therefore, it is necessary to define a useful term of sustainability or sustainable development, which is appropriate and considers its several facets. Even now "the absence of semantic and conceptual clarity is hampering a fruitful debate over what this form should actually be" (Lele 1991:607 and also Pezzey 1992) although there already are developed indicators and strategies on operationalization of sustainability. This dissertation, however, in introductory part, will present an overview of existing definitions and their roots, as well as simultaneously commenting on them, because they have a strong influence on all further discussions about sustainability and causes contradictions and preciseness. Considering different factors, an appropriate definition will be formulated in the context of developmental project like MHP in Nepal.

The Brundtland Commission Report stating, "it meets the needs of the present without compromising the ability of future generations to meet their own needs"(WCED 1987: 8) gives a first popular definition for sustainable development stirring up discussion. This famous definition lays emphasis on the equity aspect of development because it considers needs of the present as well as the future generations. It has incorporated both intra- and inter-generational aspects focusing present needs and future needs of human beings, which is not possible without untiring efforts. It was stated that the WCED definition has strongly influenced the discussion but was also criticized for being an "anthropocentric" because even this most famous definition failed to entitle natural resources impartially other than to human beings. Nevertheless, there are also prevailing views stating, "sustainability is fundamentally a human construct" (Heck et al 1997: 53). Heck et al further added that any discussion on sustainability must be conditioned by human values. The WCED definition, which is also conditioned by human values, was also criticized for being full of "vagueness and ambiguity" (Reid 1997: xv) and “still dangerously vague” (Daly 1996: 1). Lele (1991) and Pezzey (1992) also criticized the common use (misuse!) of ‘sustainable development’ ubiquitously, reasoning that it is unable to develop a set of concepts, criteria, and policies that are coherent or consistent.

There are other views regarding sustainable development itself, which are to be considered while looking for an appropriate or at least provisional definition of sustainable development in this dissertation. "The term sustainable development is for us inherently a normative concept" (Robinson 1998: 22), "is an indispensable concept" (Daly 1999: 56) and "a multifaceted concept" (Heck and et all 1997: 47) but "an empty concept lacking firm substance" (Bell 2000: 3) and a “motherhood and apple pie concept” (Pezzey 1992:1) because it must "embody an ultimate practicality since it is literally meaningless unless we can do it" (Bell 2000: 5). Even though the WCED definition was considered too general, it covered, albeit ambiguously, many aspects, which were later, focused on deeply by several authors in individual aspects.

Sustainable development definition given by Daly is “development without growth – without growth in throughput beyond environmental regenerative and absorptive capacities” (Daly 1996: 69 & 1999:18-19). That is the “process of qualitative improvement without quantitative increase beyond environmental capacity" (Daly 1999: 19). Daly’s definition of qualitative growth is mainly hinged upon two types of capital: natural and man-made capital, which are, according to Daly (1996, 1999), complementary and only marginally substitutes. The man-made capital is obtained through processing of natural capital - natural resources (renewable and non-renewable). Substituting in the other way round, i.e. man-made into natural is inefficient and not always possible (e.g. Douthwaite 1999). For sustainable development activities, both capitals are needed because they are complementary. Daly (1991, 1996, 1999) also underlined two rules to design development projects as the criteria of sustainability. According to his output rule, "waste outputs are within the natural absorptive capacities of the environment i.e. non-depletion of the sink services of natural capital". In his input rule, for renewable inputs, harvest rates should not exceed regeneration rates and, for non-renewable, depletion should equal the rate at which renewable substitute can be developed, and for the case that renewable stock is exploited non-renewably, the rule for non-renewable should apply (see Enquete-Kommission 1994 also). Daly’s definition of sustainability encompasses trade offs in using natural resources as per suggested rules because for Daly, the idea of "non renewable resources should never be extracted", is simply "fatuous" (Daly 1999:41). This trade off may have been proposed by Daly because both capitals are partly complementary and partly substitutive to the economic system (e.g. Ayres et al 2001, Daly 1996 & 1999). Daly's proposed trade off could be because of two arguments: firstly, without economic activities (Daly opined economic activities are possible without economic growth) there is no sustainable development. Secondly, non-renewable are to be used for economic activities because "there are also cases where the environment has suffered while the economy stagnated" (Simonis 1990: 14).

On one hand, Daly (1991) emphasizes on the division of receipts from exploitation of non-renewable resources into an income and a capital component thus investing later into renewable substitutes. On the other hand, he maintains that the scale of our developmental activities should be ethically just distributive within the optimum carrying capacity. The idea of dividing receipts, in economic sense, is a revised version of Hicks' income theory of consuming interest only for economic sustainability of a person. However, there is no carrying capacity issue in the Hicks theory. "The ethically just distributive" issue is the basics of WCED definition.

Daly also believes that the technological development can contribute partially to increase "ecological economic efficiency[5]" (Daly 1996: 84). "Service efficiency" and "maintenance efficiency"[6] depend partially on technical design of the production and durability of the products, as per Daly's definition. The development of renewable energy to replace fossil fuels is a sustainable activity, which is also a part of technological development. The "growth efficiency"[7] defined by Daly will be increased if a kerosene using community is provided electricity from a renewable energy technology. That is electricity, as a throughput, to the human activities is better than kerosene; and 'growth efficiency' will be

[5] Ecological economic efficiency is defined by Daly (1996) as the ratio of man-made capital services gained to natural capital services sacrificed; and he divides the ecological economic efficiency into four different efficiencies.
[6] Service efficiency is the ratio of man-made service gained to man-made capital stock; and maintenance efficiency is man-made capital stock to throughput.
[7] It is the ration of throughput to the natural capital stock; similarly, the ecosystem service efficiency is the ration of natural capital stock to the natural capital services scarified, as per Daly (1996).

more through electricity from micro hydropower as a throughput of energy[8]. Efficiency increases without damaging natural capital stock significantly. That means ecological economic efficiency can be increased to some extent technically. Three out of four efficiencies defined by Daly in connection with the sustainability's ecological efficiency can be influenced through the technology development. Therefore, the technology, for Daly, promotes sustainability in the milieu of defined scale and carrying capacity.

Daly (1996) advocates "the investments" that could be used for reducing the throughput to maintain a given level of welfare, i.e. reducing the throughput of non-renewable resources but simultaneously maintaining welfare. The investment "is in increasing the efficiency of throughput use. More generally, this means increasing the efficiency with which capital, both natural and man-made, is used to provide life-support and life-enhancing services" (Daly 1996: 83). Investing in renewable energy technology like MHP would be considered an indirect investment to increase natural capital because electricity from MHP reduces the consumption of fossil fuel. This is an endeavor of ecological economics to increase the efficiency to provide life-support and life-enhancing system (e.g. Daly 1996).

On the policy side (on environmental macroeconomics), for Daly (1991, 1996), optimum scale within carrying capacity and just distribution are the macro economic goals of sustainable development. Optimal allocation is done when decisions on optimum scale of any activity within the carrying capacity of the earth and ethically just distribution are accomplished, opined Daly. Interestingly, Daly (1996) mentioned that both the scale and just distribution are social decisions and not market decisions; because, as per Daly (1991), market solves only the micro allocation problems. In the context of operationalization of sustainability, for example implementing a renewable energy project for rural electrification, first the maximum ecological impacts that would be done and/ or be allowed be defined and fixed. Second, modalities and assurance of ethically just distribution of the output (i.e. electricity) be finalized. Then only the allocation of investment and other activities be carried out. That means to implement a renewable energy project like MHP, first the ecological impact be identified and second, modalities of making electricity accessible to all (to justify ethically just distribution) community

[8] As per Daly, the "growth efficiency" is the ratio of throughput to the natural capital stock. Previously, community was using kerosene as a throughput to daily activity from fossil fuel. The throughput to daily life is more from electricity than kerosene. Assuming, natural capital stock remains the same the efficiency is more in case of electricity.

members be designed. Then only the economic analysis of investment and resource mobilization is made.

In addition to that, Daly (1991, 1996) goes far beyond the sustainability issue itself saying, sustainability is not a sufficient condition for an optimum scale. This thought makes sustainability issue complicated, philosophical and normative for operationalization. If devising optimal scale at the macro level, by maintaining carrying capacity and just distribution goal intact, is not the goal of sustainability, then what exactly does sustainability or sustainable development mean? Daly mentions that the WCED "definition was sufficiently vague" (1996: 2). However, he boasted that the optimal scale is not specified by the definition of sustainable development. Daly himself defines sustainable development as a development without growth within the carrying capacity. How can a carrying capacity be defined without a scale? How can the authorities in a country define the optimum carrying capacity of a river ecology without mentioning that only X kW of hydropower can be built there or only specified amount of activities (scale of activities) are allowed? A scale reference has to be given. One can easily calculate how much petroleum can be consumed by cars and be allowed to consume if a country is allowed to emit Y amount of $CO_2$ – a reference of the carrying capacity of $CO_2$. The carrying capacity could indicate maximum or optimum scale of any activity that can be performed. So, reformulating Daly's conflicting definition again, sustainability is promoted if an activity performing at its defined optimum scale accomplishes the goal of ethically just distribution of output to enhance the living environment for infinite time horizon and simultaneously maintaining the carrying capacity of earth's ecosystem. Therefore, scale issues should not be put beyond the sustainability as suggested by Daly, but considered as part of sustainability parameters.

Pearce and co-authors laid down the key necessary condition for sustainability as "constancy of the natural capital stock" (Pearce et al 1990: 4). Natural capital stock, as they define is oil, water etc, i.e. is the combination of renewable and non-renewable resources. Pearce et al also adopted same rule as Daly stating, "a depleted resource, say oil, would be compensated for by other investments generating the same income" (Pearce et al 1990: 10). However, what is the same income? Is it in monetary value? They have also raised the question of valuing natural capital. The rule of 'constancy of the natural capital stock' is ambiguous as it is not clear whether it is in physical stocks or in monetary terms.

If it were in monetary value, then the rule would be problematic as no natural resource could be valuated perfectly because they have, as Pearce et al themselves mentioned, multifunction. Any valuation can represent value of only one or few functions. If the rule of constant capital is monetary value, then it is also consistent with Hicks (1939)'s constant income rule.

Pearce et al have mentioned that sustainability means making sure that substitute resources are made available as non-renewable resources become physically scarce. It means, "ensuring that the environmental impacts of using those resources are kept within the Earth's carrying capacity to assimilate those impacts" (Pearce et al 1993: 4). They further added that sustainability is concerned with "sustaining of overall stock of natural resources so that they are available for the future; as well as for the present". This is an extended version of the WCED definition, because without equity on resources, needs of both present and future cannot be met. Pearce et al also generalized saying, "sustainable development is about ensuring that some measures of human well-being is sustained over time" (Pearce et al 1993:15). However, Pearce et al's definition is more dominated with economic perspective. For them "sustainable development is economic development that lasts" (Pearce et al 1993:7). Nevertheless, contrary to such a statement, there are also few normative definitions as, "sustainable development involves devising a social and economic system, which ensures that the *enhanced livelihood* goals are sustained" (Pearce et al 1989: 1). In Pearce et al's definition, the resources both natural and man-made, dominated the issues as in Daly's; and operationalization of sustainability was also suggested accordingly. The social dimension of sustainability was included only normatively and taken as inconsequential issue.

There are also views boasting economic growth and technological change will only bring sustainability (e.g. Beckerman 1995 & 1974). The WCED, discussing reviving growth, mentioned that rise in per capita income is a necessary condition for the elimination of absolute poverty and for that, "a certain minimum [growth] is needed to have any impact on absolute poverty" (WCED 1987:50). In addition to that, "aiming at a zero rate of growth, therefore, appears to be socially and politically unfeasible at the national level and particularly in the North-South context" (Simon 1990: 13). As per the WCED, the objective of eliminating absolute poverty in developing countries can be accomplished with a minimum of 3% per capita income growth. Nevertheless, the WCED states, "Sustainable development involves more than *[just]* growth" and "the process of economic development must be more soundly based upon the realities of the stock of capital that sustain". It further added, "Economic development is unsustainable if it increases vulnerability to crises … but vulnerability can be reduced by using technologies that lower production risks". That is why "producing more with less" of the WCED is mainly meant for economic growth (qualitatively and quantitatively) with improved efficiency that would be achieved through developed technology. This view is mostly acceptable by neo-classical as well as non-economist politicians, as these views of sustainability with economic growth and technical efficiency are in consistent with the traditional economic thought like 'growth against poverty, technology against resource scarcity'.

All in all, definitions of sustainable development and sustainability are so broad that no concrete guidelines for operationalization were found until the sustainability indicators were developed by several authors and agencies after the Rio Declaration. Most of the indicators are either of economic or environmental context and focuses only on resource use, environment, etc (e.g. Azar et al 1996). The developed sustainability indicators for particular areas or sectors or sub-sectors were brought into the analysis in practical fields. Such areas or sectors are also complex because not all indicators could be applied completely because of lack of data and information or the developed indicators are not sufficient. So, due to incomplete and insufficient indicators the sustainability issues and definitions were made vague to make the sustainability case non-binding and non-serious (e.g. Daly 1996). There is, as mentioned previously, the danger of vagueness and everything could be claimed as sustainable. Therefore, there should be some ranking (grading!) to avoid any vagueness of what could be achieved in terms of sustainability. A tiny project might be relatively sustainable, 'completely' sustainable or 'sustainable' in one 'determinism'. Stockmann (1996) clearly depicted how sustainability of projects is said to be accomplished, but the achievements of such projects have different impacts for different time horizons with different objectives. Lélé (1991)'s warning resembles the listing of the four different sustainability objectives by Stockmann; and Stockmann's classification of project's objectives justify Lélé's warning that the vague definition of sustainability could be misinterpreted and make sustainability a feeble issue. Therefore, ranking or grading of sustainability, specifically, could avoid the state of confusions. With existing theoretical conflicts over definition and operationalization strategy, sustainability has also been divided, ranked or classified with different names and few such taxonomy are strongly present in the existing discussions (e.g. Neumayer 1999, Daly 1999, Pearce et al 1993, Ayres et al 2001, Douthwaite 1999) which are discussed in the following sections.

### 2.4 Taxonomy of sustainability

As "sustainable development has become pervasive" (Lele 1991: 607), defining sustainable development is not a difficult issue but determining what has to be done to achieve it is more complex (Pearce et al 1993). Therefore, although there are still different opinions about the definition itself, operationalization issues have been burgeoning. Lele (1991) believed that the sustainability concept should be given insights before it is misinterpreted, distorted and even co-opted. There are different opinions in the operationalization, which have mainly been divided into two parts[9]: Weak sustainability and strong sustainability (Goodland 1992, Bell et al 1999, Pearce et al 1990, Pearce et al 1993, Reid 1997, Daly 1999, Noël et al 1998, Ayres et al 2001, Neumayer 1999). Nevertheless, ranking of sustainability into only two aspects would not be sufficient. Several authors on sustainability have also specified sustainability as ecological sustainability, environmental sustainability, economic sustainability, etc. Therefore, it is essential to specify the degree of sustainability (sustainabilityness!) to be achieved because there are several dimensions of development, which are joined by sustainability as adjective, i.e. sustainable agriculture, sustainable trade, sustainable enterprises, sustainable community, etc, etc. If any activity or project cannot achieve 'holistic' aspects of sustainability, (i.e. sustainability in completeness) then it is not liable to be defined as sustainable. Rather adding 'a gradable adjective (ranking!)' to such types of sustainability would be more transparent, for example low, medium, high, complete and so on. Nevertheless, for van Pelt (1993), if sustainability criterion is treated as constraint, binary scale is sufficient (*i.e. either sustainability or unsustainability e.g. yes or no*). Otherwise, the degree of qualitative and quantitative scale is required (if sustainability is interpreted as a goal criterion). That means if a project has a constraint of sustainability then it must satisfy the constraints and the project could be tagged as sustainable. However, if so, then

9 There are also several grading of sustainability; David Pearce mentioned narrow (strong) and broad (weak) sustainability (Reid 1997:102). Ayres et al (2001) also mentioned several types of adjectives for sustainability like "Hicksian sustainability" while referring to weak sustainability, "very strong" referring deep ecological movement who believe in the "right – to- life" of other species. Similarly Commons et al (1992) refer "Holling- Sustainability" which is more than just a strong sustainability and "implies physical and biological indicators" (Ayres et al 2001:166). Serageldin et al (2000) have mentioned that there are three levels of sustainability: Weak, sensible and strong. Sensible sustainability means maintaining capital intact while also considering both substitutability and complementary issues for the development activities.

only a very few projects would be sustainable. Therefore, the degree of 'sustainability-ness' would require to illustrate the level of sustainability so that the projects are evaluated accordingly. Moreover, if done so at the project level, the critics of 'vagueness' and 'normative' could be reduced. Nevertheless, existing classifications that are mainly based on two capital - natural and man-made and their substitutability are just discussed here. Table 2.1 has highlighted some of the issues differentiating the two grading of sustainability.

### 2.4.1 Weak sustainability

"Sustainable development is about ensuring that some measures of human well-beings is sustained over time" (Pearce et al 1990). Pearce et al further put forward that the well-being of human beings depend upon capital, which creates goods and services; and capital comprises man made and natural capital including stock of skills and knowledge. "Weak sustainability requires that the sum of the two [*man made and natural capital*] be maintained intact, since they are presumed to be substitutes" (Daly 1999:56). Here, the stock of knowledge and skills is not mentioned by Daly where it belongs. Weak sustainability equates to a sort of economic sustainability and there is a trade off between environment and socio-economic benefits (Bell et al 1999). Therefore, there is no special weight on ecology because it is a form of capitals; and as per weak sustainability, all types of capitals are substitutable.

Although weak sustainability considers intra-generational and inter-generational equity aspects by proposing an intact stock of total capital, the impacts on ecology are neglected and the possibility of substitutes to the natural capital through technological development is over estimated. Nonetheless, this criterion of sustainability is based on reality of current thought, which was even forwarded by WCED by stating:

> *Sustainable development requires meeting the basic needs of all and extending to all the opportunity to satisfy their aspirations for a better life…Sustainable development clearly requires economic growth in places where such needs are not met. …Economic growth and development obviously involve changes in the physical ecosystem. Every ecosystem everywhere cannot be preserved intact…As for non-renewable resources, like fossil fuels and minerals, their use reduces the stock available for future generations. But this does not mean that such resources should not be used" (WCED, 1987: 44-46).*

Conditions for weak sustainability can be written as

**$X_t + Y_t = C$ for any value of t.** Where Xt and Yt are natural and man made capitals and interchangeable in any time period $t>0$; C is constant.

If Xt is converted into Yt which is possible according to weak sustainability, then all natural resources can be converted in to man made capital i. e. , $X_t + Y_t = C$ or

$2 Y_t = C$ and still we will have fulfilled the sustainability conditions. Xt is the natural capital and part of this is renewable which regenerates the substitutes itself and decaying of old (waste) can be replaced by new i.e. Xt = Xrt (renewable) + Xnrt (non renewable) and Xrt can be renewed.

But if we change part of Xt (Xnrt component) into man made capital Yt, then there is no renewing process to replace decaying non-renewable resources (like depletion of ozone layer, petroleum into $CO_2$ and excess $CO_2$ into the atmosphere is not a capital per se, but a waste which could not be recycled back into petroleum fuels) because "natural capital is subject to irreversibility" (Pearce et al1993: 14). So the condition of weak sustainability cannot be fulfilled because a large fraction of (it can be said that the smaller fraction was used for the value addition like energy used for food processing, raw material processing etc) Xnrt is being reduced from its original stock and there is no substitutes of it i.e. man made capital. As per Ayres et al (2001), a substitution of natural capital for manufacturing or man-made capital may be one way: once it is transformed into man-made capital, there is no way to return to the original situation. In addition to that, in this case, the changed state is not a capital per se like fossil into $CO_2$. Weak sustainability has weak bases because, firstly of the complexity of human and natural interactions; secondly the reaction time period is unknown for impact of human activities on nature; and thirdly the absence of limits on any activities. In the perspective of efficiency too, weak sustainability is a failure: allowing problems to happen and putting them off does not mean they are solved. It is the most inefficient way of doing things (e.g. Douthwaite 1999). From this perspective, substitutability is impossible. So weak sustainability, although based on realities, is not a ‘complete’ sustainability per se because not all non-renewables may be substitutable either by renewables or by man-made capital and vice-versa. The Hicks's approach of sustainable net income is a very good neo-classical example of weak sustainability.

### 2.4.2 Strong sustainability

Strong sustainability comes from the ecological and carrying capacity root of sustainability. The main concern of strong sustainability is not the economic system but the biodiversity, considering economy as a subsystem of the ecological world. Proponents of strong sustainability say that the whole throughput to the economic process is derived from the ecological biodiversity and all wastes of the economic process are also sunk in to it, which is why the economic system is a subsystem of the ecological world.

**Table 2.1 Comparison of weak and strong sustainability**

| Issues concerned | Strong sustainability | Weak sustainability |
|---|---|---|
| Economic growth | Qualitative growth | Quantitative economic growth needed |
| Man made and natural capital | Complimentary & marginally substitutes | Substitutes |
| Natural resources | Stock to be maintained but could be used as per sustainability management rules | Be used with less impact |
| Non-renewable consumption | Only with real substitutes like petroleum by renewable energies within the optimum scale | Any assets with required rate of return, like petroleum with roads |
| Technological factor | Can improve the efficiency, reduce throughput resource, energy and waste | Can change the nature of throughput resource once non-renewable deplete |
| Time horizon | Inter and Intra-generational | Intra and Inter-generational |
| Discounting | Zero or negative rate | Positive rate |
| Deciding force | Market and moral, strict policy | Free market |
| Waste | Should be recycled and produced within the assimilative capacity of Earth | Free market does it |
| Equity | Focused as morally binding | Economic growth does it |
| Scale of economy | Within ecosystem as subsystem | Not limited by scale |
| Externalities | Included in the economic component by policy | Market does it |
| Social aspects | Especially of intertemporal | Economic development does it |

Source: Author (Based on Pearce et al 1990, Bell et al 1999, from the theoretical concepts of Goodland 1991, Famulla et al 1996, Hohmeyer 1997, Costanza et al 1997; O'Connor 1998, Daly 1999, Neumayer 1999, Hussen 2000, Enquete-Kommission 1994 & 1997)

Even the Brundtland commission report stated, "If needs are to be met on sustainable basis, the Earth's natural resource base must be conserved and enhanced" (WCED 1987: 57). Similarly, Daly stressed that the criterion of strong sustainability "is to keep man-made and natural capital intact separately, since they are considered complements" (Daly 1999: 55-56). Daly further added that the future generations have ownership claims to as much natural capital as the present generation, which means that the rule would be to keep natural capital intact. However, there arises two questions: firstly, how 'intact' would be the capital if trade off is allowed as per Daly's input-output rules – that is, investing the income from fossil resources to renewable man-made capital and secondly, how the future generation will have the same natural capital (fossil fuel and other fossil resources are also the natural capital). Daly focused more on the future generation, i.e. inter-generational than intra-generational aspects, even in the strong sustainability issues of 'just distribution'.

Another reason for conserving natural resources or keeping the natural capital intact could be the uncertainty about the workings of the ecological systems, the irreversible nature of some natural resources when they are exploited or consumed. Pearce et al (1993) also laid emphasis on our imperfect understanding of biological functions of the ecological system and the lack of capability to substitute those lost function, which force us to conserve natural resources. In defense against the critics of strong sustainability blaming it as impractical, Daly firmly maintained, "strong sustainability is neither morally reprehensible nor operationally impractical" (Daly 1999: 56). Nevertheless, he accepted saying, it really does limit present welfare maximization.

Goodland opined moderately that sustainability would be achieved only to the extent that quantitative throughput growth stabilizes and is replaced by qualitative development, holding inputs constant (Goodland 1991: 23). But again referring to those who misunderstood strong sustainability, Daly retorted that if someone says no species should ever become extinct or any non-renewable resources ever taken from the ground, then that is an "absurdly strong sustainability" (Daly 1999: 51). Daly accepted, to some extent, a trade off that does not violate the condition of maximum carrying capacity, optimum limits and just distribution. This could be the most accepted version of strong sustainability.

The main logic behind the strong sustainability discussed by Daly (1999), Goodland (1992), Hohmeyer (1997) & Costanza et al (1997) is that the "critical natural resources" (Pearce et al 1990:16) be conserved, waste produced due to human activities be within the assimilative capacity of the ecosystem, economic development be qualitative not quantitative and future generation's ownership on natural resources be ascertained. However, the intra-generational aspect of a just distribution is kept at low profile in strong sustainability discussion as compared to the intergenerational issues and rights of the future generation. Holand (1999) has blamed both weak and strong sustainability theories for being economically dominated and opined that the pursuit of such theories by no means entails the protection of natural capital.

The classification of sustainability into weak and strong is mainly from the perspective of economics and resource use. Mostly economists take resource consumption as an economic aspect and devise definitions of sustainability accordingly, whereas ecologist put weight on ecological issues. In both types of sustainability, the social component hardly gets any weight, although Daly (1999) tries to include a terminology ‘just distribution’ but from inter-generational perspective and macro level only. One can argue that this existing classification of weak and strong sustainability is the product of economics that focuses on the resource use. Both weak and strong sustainability in that sense are not complete sustainability, which encompasses all aspects, components, subsystems and dimensions. Only man-made and natural capital is dominating the definition and other aspects are ignored. When such classifications from the perspective of other sciences (e.g. social science) would also become known, there would be more labeling of sustainability rather than just weak and strong. Such labeling would, to a certain extent, make operationalization issues easier to promote sustainability and make the objective transparent. However, a complete sustainability would not be achievable, because labeling represents only a degree of “sustainabilityness”. Therefore, for the project level, especially in developing countries, weak and strong sustainability issue alone would not be sufficient. There are several aspects and interconnected elements other than man-made and natural capital in the developmental projects which are to be given due attentions.

### 2.5 Interconnected elements of sustainability

Previous paragraphs provide overviews of sustainable development and relayed different aspects and issues. Based upon the previously consulted and referred literature, I believe that sustainable development encompasses different ingredients, which are important to define and need clear explanations. Nevertheless, in the definitions of regional and local level, sustainable development may cover different or additional ingredients including the discussed below. To promote sustainable development the underlining factors (in Table 2.2 in following pages) are to be dealt with in depth with appropriatley-developed indicators, whenever and wherever they are subjected to concern. Promoting activities, which are guided by these factors and defined by reference parameters, the sustainability case will be enhanced, for example in case of rights of accessibility, if rural poor are to be provided electricity as their counterparts in urban areas by utilizing renewable resources, the case of sustainability is enhanced or promoted. In this dissertation, such issues will also be dealt with in depth.

### 2.5.1 Natural resources consumption and equity

There has been a major concern on natural resources while discussing sustainable development, especially from the economists, because natural resources provide throughput as well as assimilative sink to the human economic activities completely. When the scale of exploitation of natural resources crosses a certain limit, the irreversibility issue arises. With irreversible losses of natural resources or its characteristics, there arises an unbalanced ecosystem, which creates risks as well as catastrophic problems to the biodiversity. Therefore, for the sustainable development for an indefinite time horizon, there should be conservation of natural capital. As some economists suggest, there might be a level of trade offs but the scale should not be crossed. The main question is whether the resource consumption should dominate the definition or it is a part of sustainability. So if society 'develops' itself in a situation where they consume only renewable resources renewably and attain highest level of well being, then the whole idea of resource sustainability will be achieved from the both weak and strong sustainability perspective. Nevertheless, "in order to fulfill human needs for a growing population, the resources and services obtained from nature must be used efficiently within the society. Socially, efficiency means that resources should be used where they are needed most. This also led to the requirement of a just distribution of resources among human societies and human beings" Azar et al (1996:92).

Equity is the basis of WCED definition for sustainable development, meeting the needs of the future as well as the present generation. Equity is a 'core idea' of sustainable development (Jacob 1999). In inhuman economic growth, without the aspects of equity, there is no sustainable development because poverty, whether of this generation or of the future generation, is one of the causes of unsustainability (WCED 1987). This equity aspect is not only limited to the allocation of natural and economic resources but also political one; people everywhere are to be given freedom for their opportunity, their progress and governing themselves. “Equity encompasses both rights and duties towards future as well as present generations and ecosystems” (O’Riordan 1998: 111). “Inequitable societies are prone to social conflicts; they are therefore likely to be socially unsustainable” (Jacobs 1999: 38). Therefore, the definition of sustainability must address the issues of natural resources and equity. Depletion of fossil resources and accessibility of poor to the renewable resources are few examples.

### 2.5.2 Waste generation and population growth

Ozone layer problem, global warming and pollution of the surface as well as ground water are perhaps the indicators of unsustainability. These problems are linked to the population growth problem and waste disposal problems because Earth's ecosystem has limited carrying capacity. Similarly, the rampant consumption of natural resources could cross the limits of carrying capacity of our ecology and biosphere. How much population and the resulting consumption and waste can the Earth carry? This is the concern raised by lots of economist and environmentalist when discussing the context of sustainability (e.g. Hohmeyer 1997, Daly 1996, Famulla et al 1996 and others). So the carrying capacity and the population surviving on that capacity are among the major factors in sustainable development discussions and it determines how much natural resources have to be consumed with even the best technological efficiency, how big an economic system can grow and how equity aspects will be affected. In the case of energy for example, how big could an energy system be to enhance sustainability? These few issues have to be dealt with in the definition of sustainability and sustainability promoting projects.

### 2.5.3 Technical efficiency and resource substitution

WCED (1987) emphasized, on "producing more with less" and Daly (1999) suggested, "efficiency increasing rather than throughput-increasing". Both these statements focus on the technological aspect for sustainable development. There is no doubt that the technological development, which increases the efficiency of processes resulting in less consumption of materials and energy, has been suggested by proponents of both weak and strong sustainability. Although, how far and how much technological progress can create 'sustainability’ differ in their views on complementary and substitutable issue of man made and natural capital for indefinite time horizon. Whatever the discussion may be, the argument of technological development especially increasing the efficiency of production process there-by reducing resources and energy throughput, development of renewable technologies and reduction of waste are the major concerns for sustainable development. Development of technology to replace or substitute the non-renewable and fossil resources with renewable is the backbone of sustainable future. In Azar et al (1996)'s point of view, efficient societal metabolism is needed for a prosperous society and the overall efficiency indicators are a measure of the productivity in the technosphere that indicates the condition of sustainability. On the perspective of poor people, technology, especially that enhances the efficiency of the use of renewable resources, would play a vital role in the reduction of poverty, inequality and the existing 'digital gap' in the society. The definition of sustainability must encompass this aspect.

In the case of energy, technological efficiency could be the major concern to diminish the pressure on both types of energy resources (renewable and fossil) and substitution of fossil energy with renewable one. Nevertheless, it must be reiterated that the technology development alone is not the alchemy of problems causing unsustainability (see Daly 1977: 105-107).

### 2.5.4 Economic activities

Short-term quantitative growth (to eliminate the absolute poverty) oriented economic system ultimately leading to the qualitative growth oriented system is the mostly accepted version of WCED (1987), realizing the realities of the poor society's needs and existing economic disparity. Compromising between more extreme materialistic oriented views and idealistic views of no 'quantitative' growths is the economic development approach suggested by the WCED. The size of the economic system decides the equity aspects and depends upon the scale of such an economic system. It is obvious that "[virgin] natural ecosystems can support only a small human population of hunter-gatherers, where as [sustainably managed] pastures and agricultural system can sustainably support disparity among the poor and rich, and fulfilling the very basic needs of the majority that far more people" (Robinson 1998:23). However, economic growth is different from increased economic activity at the decentralized level, which supports more people equitably than the centralized economic growth. The economic growth is dominating the sustainability issue because the economic growth is causing impacts on resources, energy there-by to ecology.

However, if such impacts are avoided and the decentralized development through environmental friendly activities enhances the income of the poor people and that would be added to the national GDP then such a growth should not subjected to the ‘growth controversy’. Therefore, the sustainability definition even in the project level must clarify this because mostly discussed economic growths are not mentioning micro issues of economic development and economic activities and the distributional aspects through sustainable technologies.

### 2.6 Complete sustainability: A constraint with multifaceted development paradigm

There are several exiting definitions of sustainable development. However, “the main issue in development is how to generate opportunities for participation, for creativity and for simple joy that comes from one's [*society’s, community’s, nation’s*] accomplishments in the short run so that capabilities, thus enhanced, can contribute to sustained development in the long run" (Panday 1999: ix). To generate such output to enhance the capabilities of society and sustained development simultaneously a multifaceted and operationalizable concept is needed. Such concept must be “built on a realization of the need to alleviate the global crisis in a systematic way that integrates human, ecological and economic factors” (Reid 1997: 22). Because now, for the human society, "sustainable becomes both a descriptor of something and a target to achieve" (Bell and Morse 1999). The targets are set with operational definition of sustainability. If targets are narrowed and single faceted, then development would be eccentric already in the conception and implementation would not bring completeness in the output. Therefore, any definition with new facets must bring ideas and concepts in such a way that they are in accordance with the basic parameters of longevity of development on one side and construe the operationalization strategies to avoid overall poverty[10] on the other.

Apart from the focus on the poverty [inability & stubbornness] as the impediment to sustainable development, there are other major dimensions to it. Sustainable development is the reconciliation of three dimensions - ecological, economic and social (compare Simonis 1990: 15-23, WB 1992, Mulder et al 1998: 4, Robinson 1998: 22, Kane 1999: 20, Munasinghe 1993, Peet et al 2000). The ecological dimension to remain within the planetary biophysical carrying capacity; the economic dimension to ensure and maintain

[10] Economic, ecological and social poverty.

optimum scale of material living standards for all people; and the social dimension to provide social structures including systems of governance, just distribution, to equally and effectively propagate and sustain the values that people wish to live by. These three dimensions are to be incorporated simultaneously in the definition. The time horizon or scale over which the above components have to be sustainable is another dimension of sustainability (Bell and Morse 1999, Heck and et all 1997, Pearce et al 1993). This can be mathematically written as:

Sustainable Development (SD) = f (E, M, S, t), where E = Ecological, M = Economic and S = Social and t is time scale or time horizon i.e. sustainable development (SD) is the function of ecological, economic and social imperatives for any time horizon t, and

$\delta SD/\delta t>0, \delta E/\delta t>0, \delta M/\delta t>0, \delta S/\delta t>0$ ….. Eq (I) is the condition.

Nevertheless, there are other views as well regarding the relation between economic system and ecosystem. Some argue, "the economy as a subsystem of a larger ecosystem that is finite, non-growing and materially closed" (Daly 1999: 9, Daly1996: 49, Costanza et al 1997:6-7, Hohmeyer 1997). It may also be summarized as

Ecological system = f ($s_1$, $s_2$,….sn), where, ecological system is said to be the function of various sub-systems: s1, s2, etc. and one of them is economy - the biggest subsystem (it is assumed). For the sustainability of the ecological system, all subsystems have to function in their closed loop in a sustainable manner i.e. without crossing their limits or "optimum scale". This school of thought (let us say ecological determinism because this school of thought takes ecology[11] as a reference and defines sustainability based on the impacts on ecology) also argues that the economy and all other possible components are subsystems of the ecological system.

However, for Clayton et al (1996) and Peet et al (2000), sustainability encompasses total systems[12]. In addition, according to Peet et al, a complete system of human society has three subsystems: *Social subsystem* (human and social), *economic subsystem* (economic system and infrastructure) and *ecological subsystem* (natural subsystem – resources and

[11] The term introduced by E. H. Haeckel between 1870-75 (Random house Webster's unabridged dictionary 1998)

[12] An assemblage or combination of things or parts forming a complex or unitary whole: *a mountain system, energy system, etc.* or a complex unity formed of many often diverse parts subject to a common plan or serving a common purpose *(e.g. Webster's Dictionary).*

environmental system). The version of the three dimensions (let us say holistic determinism because it encompasses broader holistic aspects and defines sustainability according to the impacts on these dimensions), focuses on economic, social and on ecological dimensions. The difference between two definitions is the perspectives and areas of concern: ecological determinism looks into one component of system for sustainability individually, whereas the holistic determinism promotes the development simultaneously in several aspects. However, if economic and social subsystems are part of the ecological system[13] then the condition is more or less similar to the holistic determinism. Because sustainability of ecological system is only possible if economic and social subsystems (probably simultaneously!) are sustainable. In that case, the only difference between two schools of thought could be that in ecological determinism first economic and social subsystems including other subsystems are to be brought into the sustainable stage to achieve ecological sustainability whereas in the holistic approach all subsystems are persuaded simultaneously into the sustainable stage. In this perspective, holistic determinism would be more plausible as all three subsystems are simultaneously focused. Otherwise, focusing subsystems individually and not simultaneously achievement of sustainability will be uncertain as happens normally or happened already in the past by focusing the economic component (economic subsystem) only.

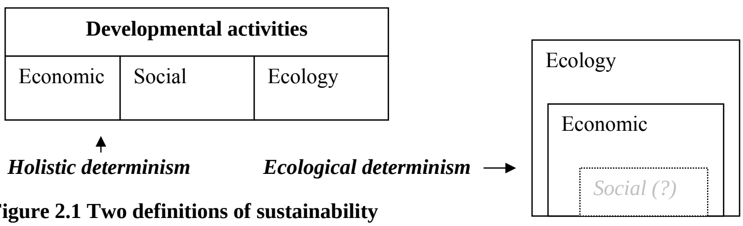



**Figure 2.1 Two definitions of sustainability**

A single-faceted development is an eccentric and could be unsustainable. For example if a MHP project is implemented by a rich man and the whole energy is consumed by himself depriving off other members of the community an access to electricity, then the

[13] Nevertheless, Daly (1991, 1996, 1999) and others have not included (not mentioned!) the social subsystem into the ecological system. If ecological system includes economic subsystem only then ecological system would be sustainable once economic subsystem becomes sustainable. In that case, for example, if a MHP plant is economically sustainable within the carrying capacity, then from the perspective of ecological determinism, ecological sustainability would be achieved. Daly (1991, 1996, 1999) however, mentioned "just distribution" and whether such dimension comes under ecological system or not, is unclear.

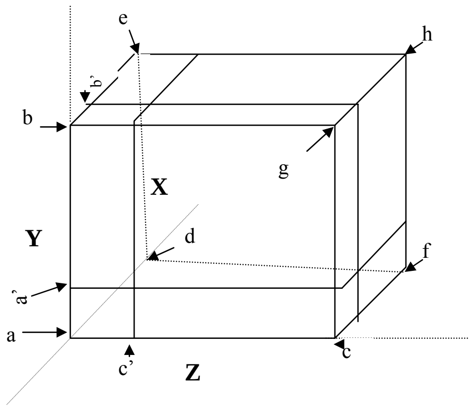
development could be one dimensional (ecological) as renewable resource has been utilized to replace fossil fuel only. Because of possible conflicts with the villagers, there would be social disharmony as best project site could have been occupied by the man leaving more expensive alternative project site to other community members or forcing them to adopt another technology or resources of energy that would not be sustainable. Although one can argue that once MHP is installed, the social issues could be looked upon later. Such argument is similar to common neoclassical embezzlement: "first economic growth and thus accomplished wellbeing takes care of ecology or environment and distribution effects later" (e.g. see Beckerman 1999).

Moreover, complete sustainability cannot be achieved by making only one dimension as a constraint because as per Azar et al "… socio-ecological indicators may give an earlier warning than would environmental quality indicators. … This means that indicators based on the environmental state may give a warning too late, and in many cases only indicate whether past societal activities were sustainable or not" (Azar et al 1996:90). Persuasion of development activities must focus causes of unsustainability early in the causal chain (e.g. Azar et al 1996). The sustainability definition that fixes only environmental limits as a constraint could only achieve targets of the environmental indicators (i.e. in one dimension only) neglecting other indicators. Focusing only on a single component whether it is environment or economy, a complete sustainability is not possible. For example abandoning the use of fossil fuels is not only the solution of climate change, but formulation of policies favoring renewable energy technologies, providing support to and enhancing access of poor communities to shift towards the sustainable renewable resources and maintaining people's economic activities can only make development sustained. More harshly, if socio-ecological issues are not included simultaneously then a nuclear power plant could help to reduce global warming more appropriately. Otherwise, the strategy of reducing GHG will be non-lasting and favoring only the rich who can adapt the new situation because of their access to multiple resources.

The holistic determinism approach that encompasses "… socio-ecological indicators [that] focus on the societal activities and interactions with nature and internal societal resource use" (Azar et al 1996:90) could prevent unsustainable activities early in the causal chain. Because, at last, it is the society that decides the level of compromise, compensation, rights of accessibility and trade off between sacrifices, morals, utilities and welfare. Peet et al opined that the choice of ethical framework is primary and their ethic reads: “all people have their basic needs satisfied, so they can live in dignity and in healthy communities, while ensuring the minimum adverse impact on natural systems, now and in the future” (Peet et al 2000: 225).

In line with holistic determinism, Jacobs (1999) clearly mentioned, it is the domination of the north that has sidelined the equity and social issue in sustainability. If environmental or ecological components only weigh more than the social issues, then the question of sustainability could not have surfaced. Our ancestors and we, knowingly or unknowingly, have exploited the base of our survival not only because of the lack of economic know-how but also because of the lack of the social issues under several imprints. As discussed previously, several unsustainability conditions exist today because of our social problems, not only economic and ecological problems in the past. Only narrow economic and technological domination of development theory brought us to the situation where we now need the sustainability theory to dominate several issues. Despite these facts, the same mistakes are repeated by choosing only one medicine, i.e. a solution dominated by one dimension only (either economic, ecology or social only) as an operationalization strategy for sustainability. Therefore, theories that are meant for solving the problems that occurred due to century long habits, technology and economic development cannot be tackled with only one aspect. For few, it might look like the question of morality and philosophy (e.g. for Beckerman 1999) but without the moral of society towards the nature and their life style, government policy and behaviors of individual, sustainability cannot be achieved. More strongly, if social aspects of development had been quite good with the ecological world in the past, there would not have been the issue of sustainability.

Referring to Daly’s macro economic issues of carrying capacity, scale and just distributions, let us assume that these three are the parameters of sustainable development and can be represented by a function, $S = lx + my + nz$, where l, m and n are constants, which are the weights of x, y and z variables representing ecological, economic and social components of sustainability parameters. The development trajectory will go forward contemporaneously with the three axes, if components are balanced. For example, if a fossil power plant gives more weight on the economic component only and gives less weight on social and ecological components, then the development trajectory will not proceed equally thus causing some inequalities or externalities – thus changes in social and ecological components may be negative causing less “net sustainable development”. This indicates that the developmental activities focus in one component only, therefore growing unbalanced is leading ultimately to unsustainable development.




Sustainability co-ordinate at point a (0,0,0), b(0,m,0) c(0,0,n); d (l,0,0); e(l,m,0); f(l,0,n); g (0,m,n) and h (l,m,n)

Similarly, a’(l,m’,n); b’(l’,m,n) c’(l,m,n’) and l’, m’ and n’ are fraction of l, m and n

**Figure 2.2 Three dimensional development trajectory**

Explaining the figure 2.2, X, Y and Z axis represent the carrying capacity, scale of economic activities and the just distribution parameters of ecological, economic and social dimensions respectively. The point ‘a’ represents zero level of sustainability, ‘b’, ‘c’ and‘d’ represent the one dimensional sustainability in the respective dimensions (as shown by co-ordinates in figure). Similarly ‘e’, ‘f’ and ‘g’ represent the two dimensional development, whereas the point ‘h’ represents the complete sustainability with three dimensions. The point a’, b’ and c’ represent the fraction[14] of sustainability in individual dimensions. From this figure, one can also explain different levels and types of sustainability.

If the values of l, m and n are not negative but greater than or equal to zero and at least one of them is positive then the project promotes sustainability. However, as mentioned in the previous example of hydropower built by a rich man, there should not be any negative impacts in other components. The tagging (or even grading) of sustainability can be done as per their value in each dimensions.

[14] The grade of sustainability or ‘sustainabilityness’.

Therefore, considering the abovementioned discussions existing absolute poverty and deprived off situation, ever-increasing political as well as social crisis and life-threatening environmental concerns, the three dimensions would be more significant and relevant as it focuses all dimensions simultaneously in the development process. In this dissertation, the three dimensional approach is taken as a basis for analysis and evaluation of MHP projects.

### 2.7 Sustainability definition at the project level

As sustainability encompasses the three dimensions, it is important to define project level sustainability in that background. Because project level sustainability definition are to be easily operationalizable. The extended three-capital constancy rule includes social, ecological as well as economic aspects rather than only man-made and natural capital as discussed by the two capital rules of Daly, Pearce et al and others. The matrix in Table 2.2 clarifies how sustainability could be defined or analyzed at the project level or even at the global level in any developmental activities illustrating the level of sustainability. A project could be sustainable if all factors are fulfilled wherever they are applicable. For sustainability analysis or definition of a project, first the time horizon, space and the system quality has to be defined (see details in Chapter Four). Then the sustainability will be analyzed or defined based on three components: social, ecological and economic. These three components again have reference parameters.

On the **economic component** the reference parameters will be the limit, i.e. how big, how large and how far can we go or achieve. Factors are economic activities (e.g. what are the potential activities that would be substituted by electricity from the MHP, is enough revenue generated to sustain the system?), resource substitution (which types of energy use can be replaced by the MHP) and technological efficiency (e.g. how far electricity can be transmitted without loss, how much turbine efficiency can be increased to produce more power, how effectively can the produced electricity be distributed among the community members).

Similarly, for the **ecological component**, carrying capacity could be the reference while analyzing the sustainability. For example, in case of climate change, ecological reference parameters will be the carrying capacity of our earth, i.e. absorption capacity of $CO_2$. For example, how many MHP plants can we build in a stream? This reference parameter has three factors: waste generation, resource consumption and population (units or agents that are consuming resources) growth. In the case of climate change, these are CO2 emission, fossil fuel consumption/depletion and growth of fossil fuel consuming elements (e.g. Automobile and consuming human population, fossil power plants, etc) respectively.

**Table 2.2 Sustainability matrix**

| | | **Components** | **Reference parameters** | **Factors** | |
|---|---|---|---|---|---|
| For defined time horizon and space | Defined system quality based on | Economic | Limit | Economic activities | Level of sustainability (weak, strong to complete, i.e. fulfilling one factor to all) |
| | | | | Resource substitution | |
| | | | | Technological efficiency | |
| | | Ecological | Carrying capacity | Waste generation | |
| | | | | Resource consumption | |
| | | | | Population[15] growth | |
| | | Social | Just distribution (Equity/Justice) | Resource distribution (equity) | |
| | | | | Rights and accessibility (institutional) | |
| | | | | Compensation & compromise (justice) | |

Source: Author

On the **social component** of sustainability, the parameter of reference is just distribution. Factors are resource distribution (e.g. how many people of the community are getting electricity from the MHP), rights and accessibility (e.g. are all women or poor people and all ethnics having rights and access to decision making in tariff fixing, does an representative institution exist to monitor the system as well as to distribute the benefits) and compensation & compromise (e.g. are people getting compensations for land occupation used for the MHP, or are the people of Bangladesh being compensated by Western countries due to climate change related catastrophic events or are the citizens of Western countries compromising by reducing fossil fuel consumption and similarly, are the

[15] Here the term population means number of resource consuming agents or units.

villagers of MHP using community paying adequate tariff of electricity to make the MHP system financially sustainable). The above-mentioned factors and parameters could be used with proper justification to define and analyze sustainability issues at the local, regional or global level project.

An activity or a project may not satisfy all above-mentioned conditions in the reality. Projects or activities that are incorporating these factors without making net negative impacts on other factors would promote sustainability as discussed already. At the project level too, the sustainability definition would encompass several aspects, which are incorporated within three dimensions of holistic determinism. Project sustainability must have indicators in all dimensions and objective of such project must be holistic. A wind energy park to reduce the CO2 from coal power plant cannot be implemented if it is socially unacceptable among the conscious citizens and Wind Park must compensate adequately if people are affected economically. All such considerations include three dimensions at the project level. Otherwise, it is possible that indicators of reducing ecological impacts, e.g. CO2 reduction, could have been sufficient to tag the project as a sustainable one. Therefore, definition of sustainability at project or local level must incorporate three dimensions. (More on project level sustainability of MHP in chapter four)

### 2.8 Promoting sustainability through development activities

Carrying capacity, scale, limits, optimum allocations or resources are normally known parameters whenever one discusses sustainability. Looking towards the strong sustainability criteria, especially people with a strong background of environment, economics and science talk about carrying capacity. A globally discussed topic of climate change, initiations of IPCC and targets of Kyoto-protocol are the good examples of fixing the limits of CO2 emission for not crossing the carrying capacity of the Earth. This aspect of taking references while handling environmental problems is generally the scientifically accepted standard and procedure as well as quantitatively measurable.

However, sustainable development is not only a technically fixed objective as defined by Beckermann (1995). For Beckerman the sustainability concept is basically flawed. “This is because it mixes up together the technical characteristics of a particular development path with a moral injunction to pursue it. And a definition of whether any particular development path is technically sustainable does not, by it self, carry any special moral force" (Beckerman 1995:126). As a staunch proponent of economic growth, a neoclassicist, Beckerman, assumes that technology can be alchemy of existing problems; progress and prosperity will be achieved with the help of technology alone. However, that is not the case because technology is only part of the solution of the existing problems[16]. Technology must be accompanied with ecological as well as human face as Schumacher (1973) suggested.

There are several aspects of sustainability, which are not easily measurable quantitatively. Azar et al (1996) have developed a few social indicators for different principles of sustainability, where intra- and intergenerational justice as well as basic human needs indicators for sustainability have been mentioned at the global level. Such indicators can be developed for projects at local level too. Now the question comes how sustainability can be defined and accomplished at the project level. Is a project itself bringing the whole system into sustainability? Certainly, it cannot. A system can also be defined at different levels, i.e. world, a nation, a region, a village community, a project area, etc. Then how relevant is the definition of sustainability in the context of a project? There are several developmental activities going on in our societies, communities and countries. Some of them are sustainable in one perspective or the other and few are completely sustainable. Those fulfilling the criteria of 'lower' sustainability[17] are contributing trivially to the system and those, which are completely sustainable, promoting sustainability of the system strongly. It has been shown previously in Table 2.2 how an increasing level of sustainability can be achieved. Therefore, at the project level, if a project satisfies the criteria mentioned in eq. (I) previously, the project is sustainable itself and promoting sustainability of the systems.

Figure. 2.2 also shows that there could be several projects that are promoting sustainability of a system from different perspectives in different levels. Some are promoting one dimension of sustainability while others are promoting two or three dimensions of sustainability. Therefore, grading of sustainability is needed because not all projects are completely sustainable and not all projects are promoting sustainability strongly. Few projects are only environmentally sustainable and promoting environmental dimension or

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[16] For the reduction of CO2 nuclear power plants can be installed if social aspects are not considered. Similarly, check dams and barricades can be built against rising sea level if economic as well as other aspects are not considered. Such activities could be mitigative but not sustainable development as such.

[17] Those projects, which are satisfying only few factors as mentioned in table 2.2 making no impacts on other factors, are tagged as lower level of sustainability.

ecological subsystem of sustainability of the systems. Others are economically sustainable and promoting sustainability of economic component. However, those projects, which are partially sustainable or sustainable in one dimension only, should not have any negative impacts on other dimensions. Otherwise, such projects reduce the quality of sustainability (grade of sustainabilityness!). For a system to be sustainable, all activities of the subsystem must fulfill the criteria of sustainability and be completely sustainable.

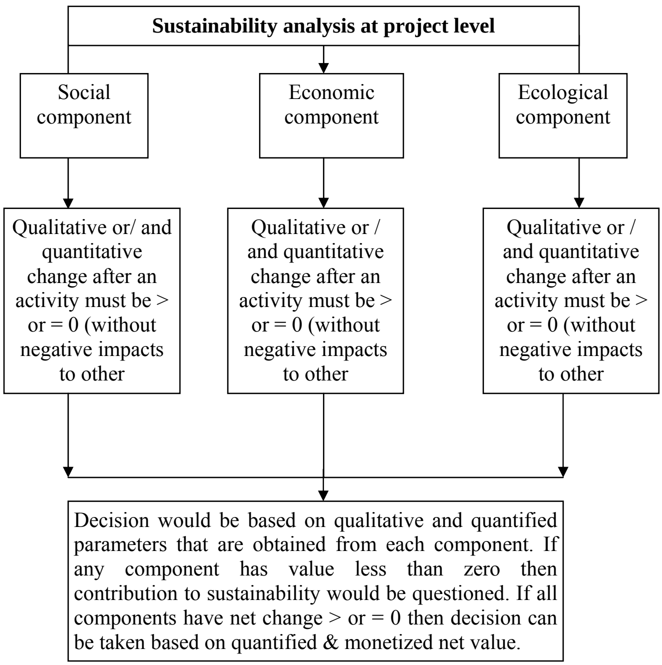



**Figure 2.3 Sustainability analysis for promoting sustainability**

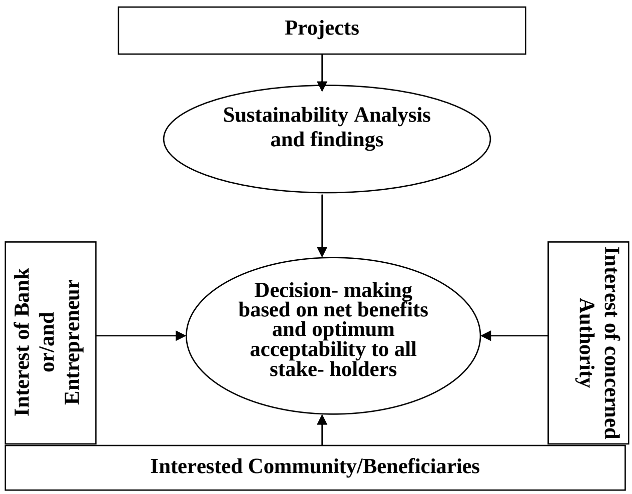
If a project fulfills all criteria of sustainability in all dimensions as shown in figure 2.3, then the project promotes sustainability strongly, otherwise, its contribution to the complete system sustainability is eccentrically achieved or not complete. Therefore, if a project is implemented sustainably and is sustainable itself then it promotes sustainable development in the region, in the country or the world according to its scale. A project can be sustainable itself and induce the sustainability effects in other sectors too. Avoiding the use of kerosene in indoor lighting can contribute to enhancing sustainability of health projects in that community.

Complete sustainability strategy looks at the three components simultaneously but individually as per sustainability rule, i.e. looking whether a project or a development activity satisfies the sustainability rule of constant capital in three dimensions of sustainability separately. The definition of sustainability from the perspective of capital theory came from both the weak and strong sustainability that is focusing only on two capitals. An extended version of this capital theory of "maintain capital constancy" to three dimensions i.e. ecological, social and economic, the sustainability issues can be addressed more appropriately, because there are critics to the existing approaches based on the two capital theory dominated by the issues of resource use only. In operationalization, at project level, one has to look three dimensions and find the potential net benefits either qualitatively or quantitatively or both in each individual dimensions separately. If net benefits in individual dimensions are as mentioned in figure 2.3 then project are to be appraised tagging as sustainability promoting projects. If they are not satisfying the criteria then projects are not promoting sustainability. (More, specifically on MHP, in Chapter Four)

There are also views that sustainability constraint is one among the several constraints. Daly has opined, "It [sustainability] is a necessary, but not sufficient condition for optimal scale" (Daly 1991:41), referring to what would be the level of optimum scale in sustainable development. But, if a development process satisfies sustainability conditions then it must include all such considerations: issues of carrying capacity, issues of optimum scale, issues of just distribution and whatever the questions one can raise from the sustainability perspectives at each level. If it is presumed that there are also criteria beyond sustainability, then the whole discussions and analyses would be purely a mythological tool that is hardly achievable and operationalizable although, there could be a few unknown and complex components remaining in the system, not covered by three dimensions. Therefore, if projects are to be titled sustainable, they need to be "complete sustainable". Otherwise the term "environmental sustainability, economic sustainability, etc. indicate one or other aspect of the projects only.

### 2.9 Decisionmaking process for sustainability promoting projects

In project level, for the decision making an institutional mechanism, which incorporates the participatory principle, is needed because only with an economic model the sustainability objective may not be achieved. A monopoly in decision-making can choose wrong path. Different stakeholders favor different outputs if they decide individually. Combining the interests of different stakeholders may encompass the sustainability issues optimally. The figure 2.4 represents such mechanism at the project level for sustainability promoting projects.




Source: Author

**Figure 2.4 Decisionmaking process and mechanism for sustainability promoting projects**

More on mechanism of implementation of sustainability promoting projects will be discussed in chapter seven. In this chapter, the general sustainability issues have been discussed linking with several factors. In the coming sections, especially the relation between energy and sustainability and importance of renewable energy will be discussed in global and Nepalese context.

# Chapter Three

## Energy, Sustainability and Renewable Energy Technology

### 3.1 Background

Global aspects of sustainability and its facets have been discussed in the previous chapters. Most of the debates on energy sustainability and its linkage with overall sustainability surfaced after the seventies. Whether it is in "Limits to Growth" of Club of Rome or “Our Common Future” of WCED (1987) or in "Agenda 21" of Rio-Summit (1992) or in “Conference on Sustainable Development” of Johansburg in 2002, the questions of sustainability have always been linked to the energy questions and energy was always at the centre point. That is due to our traditional presumption from economic perspective that “energy consumption is complementary to growth in national income” (Ebohon 1996: 452) and “growth in national income is necessary for development” (WCED 1987). That is more in line with the traditional views of sustainability. From the ecological sustainability perspective, the “environmental sustainability is mainly a matter of stability, resilience and biotic diversity” (Ayres 2001: 164). The energy questions came into the centre point of discussion mainly because of resource depletion, just distribution, carrying capacity and the scale of economic activities. A range of environmental and resource problems have emerged so far from the use of energy resources and technology. If one adopts the validity of the second law of physical thermodynamics also for the universe as a closed system[18], where entropy, a measure of disorder, increasing continuously because of the consumption of fossil fuels, then it will consequently develop into a state of maximum value, a uniform chaos (e.g. Thielheim 1982: 16). More and more energy use especially of fossil fuel may aggravate the situation, bringing this chaos sooner than later. Therefore, a sustainable energy system is a more relevant and more important question than the sustainable economy motored by it in the sustainability discussion.

The role energy in the concept of sustainable development comes into the question now. Since energy is the prime mover of all the activities of an individual, an economy and whole biodiversity (see Figure. 3.1 in next page), the development of human activities also has limits; beyond the biodiversity’s capacity, development cannot be expanded as shown

[18] In the previous section, referring to Daly (1999), Constanza et al (1997), Hohmeyer (1997) and Goodland et al (1990), it has been discussed that our ecological world is a materially closed system where only energy can transfer. In case of the universe, where our ecological world is a part, it may be true.

in figure. 3.1. Energy propels these development activities. The bigger *Developmental Block*[19], the more energy and waste are produced and the more unsustainable are the developmental activities. With a more qualitative development block, less energy is used and a lower amount of wastage is thrown. Source of energy resources, exploitation of these resources and technologies, consuming styles and behaviors of energy users will determine the sustainability of energy and economy as well as the ecology. Therefore, energy has an important function in the sustainable development discussions, policies and programs.

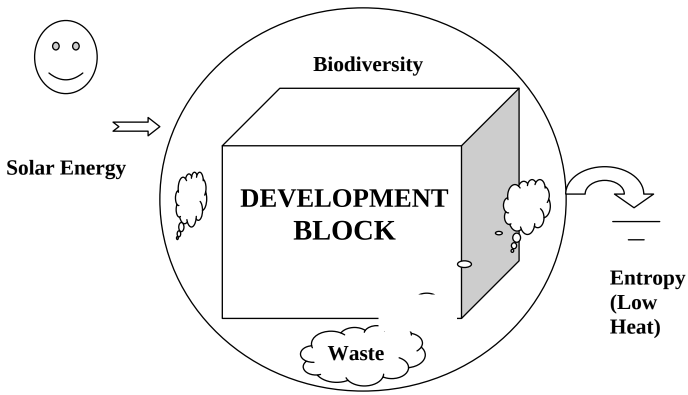



Figure 3.1 Energy and development block in the limited biodiversity

Source: Modified from Daly (1999), Costanza et al (1997), Hohmeyer (1997), Goodland (1992)

In the neoclassical perspective, the utility function has different variables and availability of energy would be among them. So, even in an utilitarian perspective, that is to maintain or 'sustain' the constant or increasing utility, a 'certain' amount of energy input or supply must be 'sustainable’, because “the relationship between energy and economic growth is complementary” (Ebohon 1996: 453 and see figure. 3.3 also). As energy has a strong linkage with economic well-being, human livelihoods and ecological environment needed for human survival (e.g. Goldemburg 1996), the sustainability question of energy itself

[19] The development block has limited space to grow because of limited biodiversity. The quality of the development block can be improved using sustainable activities and efficient use of resources. Such activities can increase the ‘scale’ of the development block, i.e. lower size can represent ‘bigger development’, which is possible through efficient and sustainable use of energy and resources within the biosphere. At the same time, the three-dimensional block represents the three-dimensional development: social, ecological, and economic. Only three-dimensional block can represent the optimum volume of development where as a two-dimensional block illustrates lower developmental size.

arisen from mainly because of two aspects: firstly the major energy supplying resources today are non-renewable and they are being used in such a way that they could vanish in the future[20].

As operationalization of sustainability came into discussion, considerations and planning for implementation strategies are still widely divided e.g. weak and strong sustainability (e.g. Nordhaus's (1990) strategy or Azar and Sterner's (1996) views to reduce the global warming). For the analysis, development of implementation strategies and decision-making processes of the energy sectors, considering existing problems of climate change, biomass appropriation, political conflicts and unbalanced development, the 'complete[21]' sustainability approach has to be adopted. Nevertheless, the methodology and analytical tools, which are popular in the neoclassical economic perspectives could be used with modifications encompassing issues raised from the perspective of 'complete' sustainability.

## 3.2 Global energy issues

### 3.2.1 Energy and society

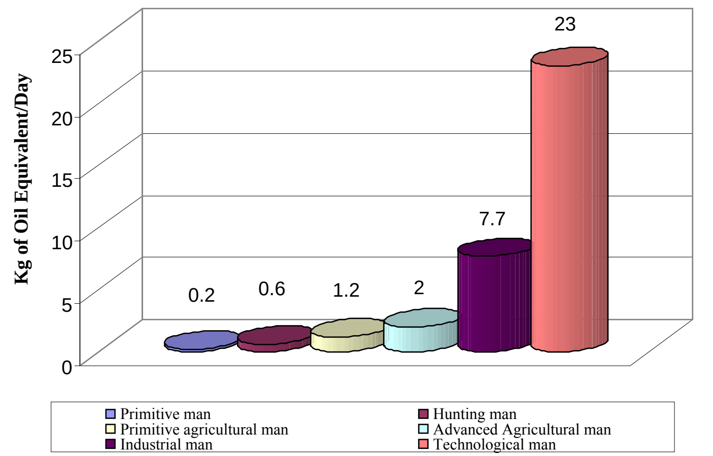
Not knowing the existence of a physical quantity called energy and its properties, people during the seventeenth century could not move Archimedes screw with falling water perpetually i.e. feeding and lifting the same amount of water without losses. The basics of energy and its properties were discovered by Robert Julius Meyer (around 1740) saying that the motion of our muscle consume energy from food and dissipate heat to the surroundings. In 1824, Sadi Carrnot discovered that there is no conversion of heat into mechanical energy without losing a part of heat energy. This became later known as the second law of thermodynamics and plays a central role in energy physics (e.g. Thielheim 1982: 3-5).

Human civilization developed simultaneously with the increasing use of energy. A primitive man about one million years ago used about 0.2 kg of oil equivalent per day energy for his survival whereas a technological man of this century consumes about 23 kg of oil equivalent per day (Goldemberg 1996: 6-7). The primitive man and his subsequent generations were mostly depending on the renewable nature of energy resources but since

[20] However, according to IPCC (2001), fossil fuel scarcity, at least at the global level, is not a significant factor in considering climate change mitigation.
[21] Complete sustainability encompasses a holistic approach as discussed in the previous chapter.

the eighteenth century, the demand of energy has increased drastically leading to intensive search for energy resources with innovative ideas. It has been successful to explore more intensive resources of energy to meet the growing demand although these available resources are for a limited time horizon.

**Figure 3.2 Energy Consumption and Human Civilization**




Source: Modified from Goldemberg 1996:6

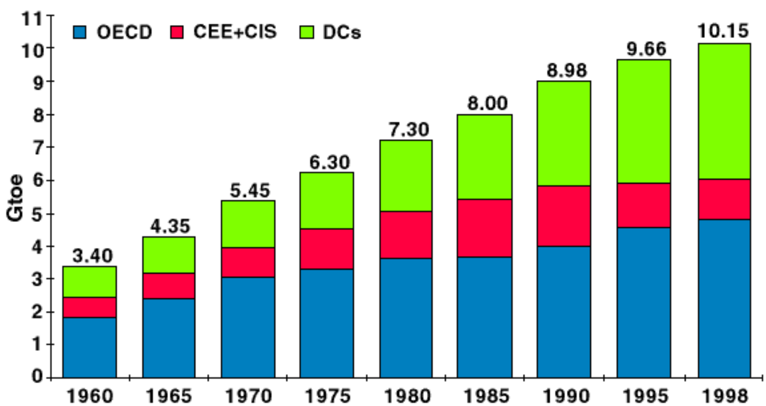



**Figure 3.3 Energy consumption scenario after 1960 (Source IEA (2003))**

The industrial development has consumed fossil resources in ever-increasing trends even until today. The global energy consumption was 9.354 GTOE (391 EJ) in 1990, which was 2% more than in 1989, and the trend was an average annual increment of 2.5- 3.3 percent per year during 1960-1990 (Mulder, 1998: 18, Goldemberg 1996: 71). Similarly, the annual growth in primary energy consumption between 1990 and 1998 was about 1.3% (IPCC 2001: 22). The growing demand was mainly due to urbanization, industrialization and societal affluence with increasing population. (e.g Nakićenović et al 1998: 11 - 13, WCED 1987: 169). The explored energy resources have changed the human civilization as well as the concern for its existence.

### 3.2.2 Energy poverty and economic well-being

Energy is necessary for daily survival (WCED 1987: 168). "Energy is but a means to social ends; it is not an end in itself" (Lovins 1977: 4). One Ton of Oil Equivalent (TOE) per capita year seems the minimum energy needed to guarantee an acceptable level of living as measured by Human Development Index (HDI) of 0.8. The energy cost of satisfying basic human needs ranges between 27,800 to 36,400 kcal per day per capita i.e. between 1.0 to 1.3 TOE (Goldemburg 1999: 20-21). However, most of the people in developing countries are still far from having that much energy. Average per capita energy consumption of the third world is reported to be about 0.6 TOE and this includes traditional sources of energy

***Definition and causes of energy poverty***

***Energy poverty***

- *A state of insufficient energy resources for basic living*
- *A state of primitive use resources- causing several impacts*

***Causes***

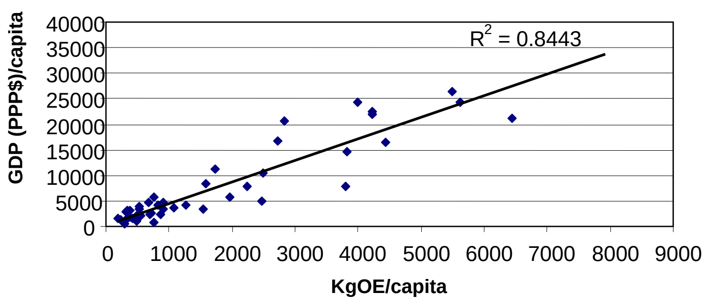
- *Lack of resources/Capital/ Policy*
- *Political as well as social marginalization despite resources*
- *Lack of institutions that support every aspects to accomplish the tasks to meet energy needs*

Source: Author

like fuelwood, crop residue and animal dung. Moreover, according to the Brundtland Commission Report, in the year 2000 around 2.4 billion people had fuelwood scarcity (WCED 1987: 172). Similarly, FAO's estimated deficit of fuelwood for the year 2000 was 960 million cubic meters (Goldemberg 1996: 36). More than seventy percent of the people in developing countries use fuelwood as a source of energy and consume, on the average, 700 kg per capita per year (WCED 1987: 189). Therefore, scarcity will increase as population increases, either the average energy consumption of 0.6 TOE will be reduced or more fossil fuel will be consumed in the absence of fuelwood (if other alternatives are not available for the increased population).

"The rural energy users, while deprived of wired electricity from distant sources, must also cope with a scarcity in nearby biomass resources such as wood" (Lensen 1992: 14). Approximately one-third of the total energy consumption in developing countries derives from bio-fuels, i.e. wood, agriculture residues and animal dung (WB 1996: 20). The condition of "energy poverty" (i.e. extreme fuel shortage) (WB 1996: 10) is compensated with less valuable fuels such as leaves, straw and dung (HEDON 1995: 25, WCED 1987: 190). Such shifting action from fuelwood to crop residue and dung will reduce the nutrients needed for the soil. Therefore, the energy poverty can reduce the number of cooked meals and increase malnourishment and thus overall poverty (e.g. WCED 1987).

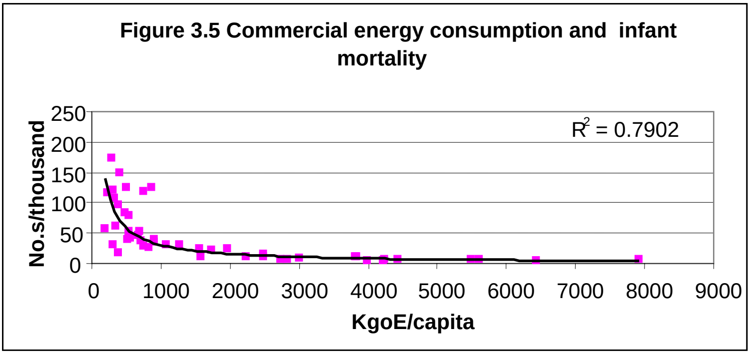
**Figure 3.4 Commercial energy consumption and GDP**



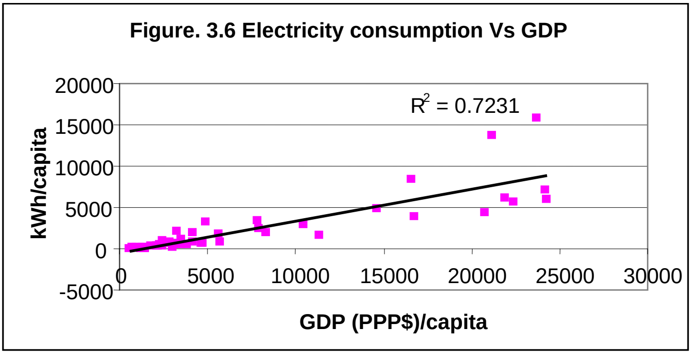

Source: Based on data of 50 countries compiled from WB (2001)

Disparity in the use of primary as well as final energy is also large similar to the existing economic disparity at the global level. As per the data of 1990, the richest 20 % of the world's population use 55% of the final and primary energy while the poorest 20% use only 5%. The disparities are largest with electricity, where the richest 20% use 75% and the poorest 20% use only 3% of the world's electricity (Nakićenović et al 1998: 16). The relations between development indicators and energy consumption (as in the figures 3.4 to

3.6) have shown that there is, to a certain extent, a strong relationship between the people's living standard, energy consumption, energy poverty and overall poverty




Source: Based on data of 50 countries compiled from WB (2001)




Source: Data compiled into graph from WB (2001) and based on the data of 50 rich and poor countries from Asia, Europe, Africa and Latin America.

Energy is an essential ingredient of socio economic development and economic growth (Goldemburg 1996: 18). Energy is vital and basic to the development of economic activities; hence poverty cannot be reduced without the greater use of modern forms of clean energy, as no country has managed to develop much beyond a subsistence economy without ensuring at least minimum access to energy services for a broad section of its population (e.g. WB 2000:19). However, not all economic activities require energy as a prerequisite in the poor third world countries. However, at the present context, the low energy consumption in poor countries can be interpreted as insufficient for minimum need (or consumption of insufficient amount of final energy although a significant amount of primary energy is consumed like fuelwood).

Due to urbanization and industrialization, the demand of energy is increasing and is forcing authorities to implement new energy projects to meet the growing demand. Various countries have implemented mega energy projects with foreign loans to fulfill their increasing demands. This policy has increased the debt of the country because of two aspects: firstly, the big energy projects were not economically viable and secondly the produced energy was not used in the 'productive sector' that would enhance the socio-economic conditions of the people. Apart from that, "the faulty implementation has been strongly advocated by the multilateral lenders and blindly followed by the borrowers" (Bhadra 2002: 2). Therefore, as rising energy use deepened the debt, the debt deepened poverty (Lensen 1992:6). The living standards are then further battered by the strategies used to pay off the debt as energy tariff are being increased regularly and not proportionally, due to the direct and indirect pressure from the loan lenders. The energy intensive industries are also given several incentives, cutting large parts of the budget meant for social services and public welfare projects (e.g. Lensen 1992). Therefore, such policies have further aggravated the situation of overall poverty. The local environmental problems associated with the energy use remain the matter of concern, as it is the poor who suffer the most, because of lack of access to better alternatives and hence forcing them to rely upon the most polluting and inefficient resources (e.g. World Bank 2000).

There is a strong relation between "energy poverty" not only with economic poverty but also with health aspects of poor people. "Some 400 to 700 million people, primarily women and children, suffer from carbon monoxide, particulates and cancer causing chemicals such as benzopyrene emitted by traditional stoves" (Lenseen 1992: 14) and more than 1.5 billion people live in unhealthy air according to WHO estimates in 1990 (Goldemberg 1996: 36). More alarming is the indoor pollution, which is causing the death of 1.6 million people every year from lethal levels of smoke in the home (WBGU 2003, WHO 2002, ITDG n.d.). Despite the great disparity in energy use, less energy resource users are more prone to risk than more energy exploiters. The vicious circle of energy poverty, economic poverty, unhygienic living conditions and exploitation related to the energy systems must be reduced, at least, from sustainable energy systems.

**Table 3.1 Indoor air concentration in some developing countries**

| Typical exposure in some developing countries* | Pollutant | WHO daily exposure guidelines |
|---|---|---|
| 1-20 mg/m3 | Suspended Particulate Matters | 0.12mg/m3 |
| 10-50 mg/m3 | CO | 10 mg/m3 |
| 0.1-0.3 mg/m3 | NO2 | 0.15 mg/m3 |
| 1-20 ug/m3 | Benzo-alpha-pyrene | 0.001 ug/m3** |

* India, Nepal, Nigeria, Kenya, Guatemala, and Papua New Guinea
* Concentration causing a cancer link out of 100,000 people after a life-time exposure

Source: Goldemberg (1996:37) and e.g. WB (1996)

### 3.2.3 Energy and environment

Energy supplied to human beings' activities is derived mainly from two sources: renewable and non-renewable (as shown in figure. 3.7 and figure. 3.8 in next page). Society, with its increasing size in numbers and energy consuming behaviors, is responsible for exploiting more and more energy resources that is leading towards its own limits of survival (e.g. Costanza et al 1997, Goldemberg 1996, King et al 1992 WCED 1987). "The ultimate limits to global development are perhaps determined by the availability of energy resources and by the biosphere's capacity to absorb the by-products of energy use" (WCED 1987: 58). Most of the environmental problems faced by human beings and its biodiversity are from the rampant use of energy resources. Even "the extraction of energy from natural flows may have significant impacts since some of this energy may have performed crucial functions in the local or regional ecosystem" (Elliott 1997:42). Using the energy resources (renewable and non-renewable) beyond certain limits[22] has the following consequences to the ecological world and human society (e.g. WCED 1987: 59):

- depletion of resources irreversibly and its negative consequences and
- damages caused by the waste and emissions coming out from these used resources.

[22] It is very difficult to set limits but scale of such uses has been discussed previously while discussing sustainability. Regarding limits and scales of the use of natural resources, conditions were recommended by Daly (1999), Goodland (1992) and Costanza (1997) suggesting resources should be used within the carrying capacity of our ecology.

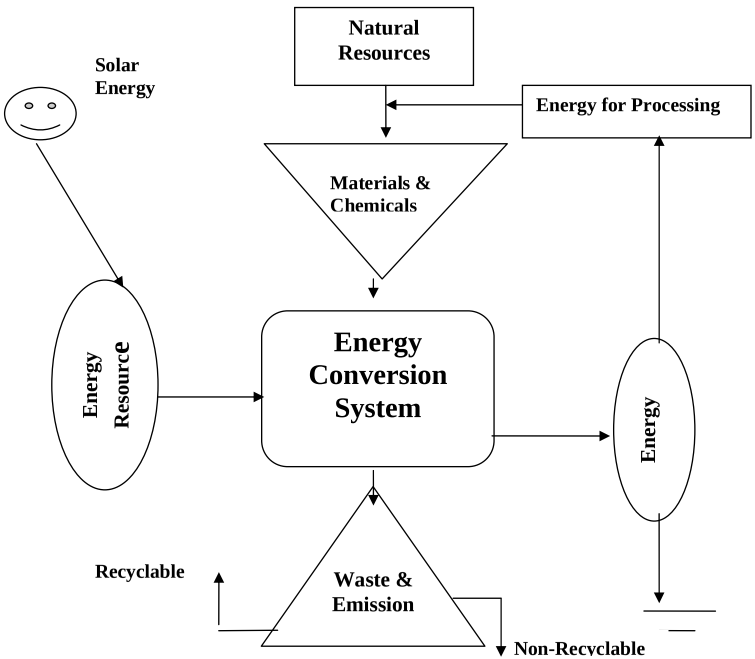



Fig. 3.9 Renewable Energy and Its conversion System (open system)

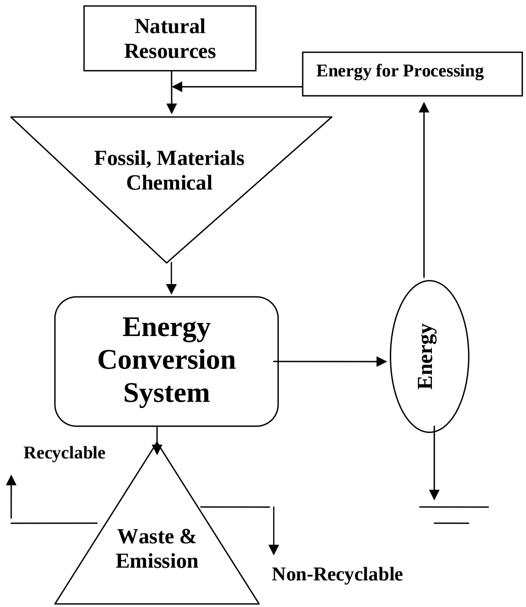



Fig. 3.10 Non- Renewable and Its conversion System (closed loop)

#### 3.2.3.1 Depletion of energy resources

The depletion of non-renewable energy resources has still to have great consequences in the economy and environment when we consider only the depletion rate and physical quantity (not the consequences of their burning). However, depletion of renewable resources like forests beyond its regenerating rate has already shown evidences like land degradation, loss of biodiversity, impact on human life (e.g. Costanza et al 1997:12 - 13, Goldemberg 1996:45, King et al 1992, Goodland 1992, WCED 1987) and reducing the capacity of sink for CO2 (Goldemberg 1996, Elliott 1997, IPCC 2001). Deforestation from the inefficient use of fuelwood for cooking in the poor regions of the world can also cause severe problems. “It is estimated that 1.2 billion people are threatened by desertification” (IEA 2003: 44). Deforestation contributes significantly to the reduction of sink capacity of CO2 and global warming through the emission of CO2, “which accounts 25 percent of CO2 emission due to fossil fuel burning” (Goldemberg 1996: 70). In addition to the above problems, due to the depletion of forest resources like fuelwood, there is a direct consequence to agriculture and ecology as more chemical fertilizers are used because crop residue and dung are serving as a replacement fuel (Lenseen 1992: 14). The scenario of the depletion of fossil fuels has not yet been realized seriously. As per IPCC (2001), between 1860 to1997 about 311 GTOE fossil fuels were burned releasing 290 GtC into the atmosphere; and about 5,000 GtC equivalent of fossil fuel (reserves plus resources) are said to be remaining in the ground. Hence, the depletion scenario may not be worrying people more than the impacts of the use these resources.

#### 3.2.3.2 Waste and emissions of energy resources

The unlimited and rampant uses of energy have created "the world problematique" (King, 1992:112) which has interrelated impacts on resources, biodiversity and living beings. As Goodland (1992) pointed out the world has reached the limits and the evidences have been more visible now. Most of these impacts are due to the unsustainable use of energy resources as throughput to the economic development. Major environmental concerns directly related to energy use are air pollution, acid rain and GHG warming originated due to the burning of fossil fuels or biomass either for cooking, electricity generation or for transportation (Goldemberg 1996:55). The potential impacts are shown in the table 3.2 (in next page).

**Table 3.2 Energy and its relation to main environmental problems**

| Unsustainable problems | Source of problems | Impact |
|---|---|---|
| Urban air pollution | *Energy* (industry and transportation) | Health, Fog, etc |
| Indoor air pollution | *Energy* (cooking) | Health |
| Acid rain | *Energy* (fossil-fuel burning) | Destruction other flora and fauna, decaying of invaluable structures |
| Greenhouse warming and climate change | *Energy* burning | Extreme global climate change, inundation of islands and river deltas and changing biodiversity |
| Availability and quality of fresh water | *Energy*, agriculture, waste disposal | Water borne diseases, water pollution, water shortage |
| Deforestation and desertification | *Energy*, agriculture, population increase | Reducing CO2 sink capacity, land degradation, reduced agriculture production |
| Toxic chemical and hazardous waste | *Energy* (nuclear) and industry | Health impact and extinction of flora & fauna, ecological damage |
| Coastal degradation | *Energy* and transportation | Extinction of fish species |
| Ozone layer depletion | *Energy* (emission of HC) and industry | Health of living beings and damage to agriculture and forests |

***Source: Modified from Goldemberg (1997:30)***

### 3.2.3.3 Global warming and climate change

The problem of global warming is now taken as a major problem of CO2 emission from energy use, although it was raised by Svante Arrhenius of Sweden in 1896 (Goldemberg 1996: 43, Costanza et al 1997: 9, Arrhenius et al 1990: 1). Conventional energy development has increased the threat of global warming as GHG stems largely from the burning of fossil fuels in energy, transportation and industry (Lenseen 1992: 7, French 1990: 7). The overall contribution to the greenhouse effect by energy production and its use is about 57 per cent (Goldemberg 1996: 55) and energy use accounts for more than two thirds of the GHG emissions addressed by the Kyoto-protocol (IPCC 2001: 22). Due to the GHG emission from anthropogenic activities, the Earth's temperature will rise from 1.5 to 4.5 degree Celsius for a doubling of CO2 concentration within the next century, which would lead to a sea level rise of 25 to 140 centimeters (IPCC 2001, WCED 1987: 176, King et al 1992, Arrhenius et al 1990: 2-8). Rising of sea level will "virtually eliminate some groups of islands and greatly erode many important river deltas" (King et al 1992: 30). Importantly, this will also affect at large population, agriculture production and the whole ecosystem.

Global warming due to GHG emission will lead to adverse weather conditions and its effects like cyclones, unexpected rain thus floods, drought, heat waves, which will have direct impact on the community, which in turn are solely relying on natural resources (IPCC 2001, Goldemberg 1996: 40-45, Costanza et al 1997: 9-15, King et al 1992: 30, OECD 1992: 11-16, Lenseen 1992:15, Arrhenius et al 1990: 2-8, WCED 1987: 176, Lovins 1977: 10). Although there are also few conflicting views[23] regarding GHG global warming, the world community has already been experiencing many evidences. Therefore, the main alarming impact of energy use is the global warming. To avoid this tragedy, new renewable and sustainable resources must be developed and used. Figure 3.9 shows the Earth's increasing temperature due to CO2 concentration.

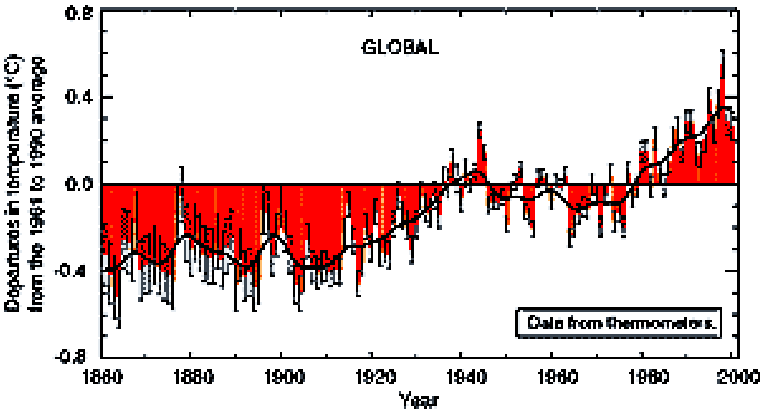



Figure 3.9 Combined annual land-surface air and sea surface temperature anomalies (°C) 1861 to 2000, relative to 1961 to 1990. (Source: www.ipcc.ch)

[23] Prof. Lindzen, a scientist of Massachusetts Institute of Technology opined that clouds warmed by the effects of increased CO2 would produce rain more efficiently than cooler clouds, which would reduce the air's humidity and greenhouse effects (Guterl 2001). Few conflicting reports and hypothesis are also mentioned by Roberts and Lansford (1979) with skepticism in their book on “The Climate Mandate”.

### 3.2.4 Energy resources and technologies

"Man used nuclear energy from the sun long before the physical concept of energy become known" (Thielheim 1982: 1). In the form of electromagnetic radiation, the solar energy travels through interplanetary space; in form of chemical energy; it is stored in organic materials on the surface of the Earth; and later transforms into energy of man and animals through foods. Similarly, in different time horizons, solar energy has been converted into different form of energy like coal, wind, hydro etc.

The world is being run unsustainably now - being fuelled by inherited fossil fuels is the best single example (Goodland 1992: 15). To be sustainable, the world must be fuelled by sustainable resources and renewable energy resources are considered sustainable in the aspect of resource depletion and waste generation. Therefore, when developed with minimum environmental impact, the renewables are sustainable resources for energy, although "all energy technologies have some environmental impacts" (Elliott 1997: 35).

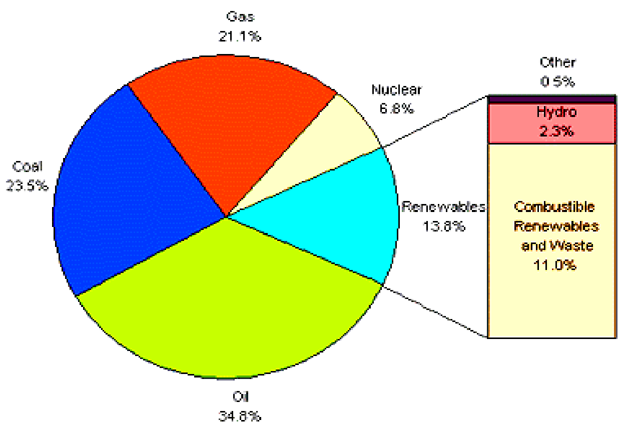



Figure 3.10 - Global total primary energy supply in the year 2000 (source: IEA 2003)

Fossil fuel accounts for more than 80% of the present world energy consumption (see figure 3.10). The current consumption of energy globally is about 8.6 GTOE (100,000 TWh) p. a. and maximum limit of energy supply that can be achieved from solar and biomass in the Earth is about 17.2 GTOE (200,000 TWh) p.a. (Elliott 1997: 44)[24] . That means there is also a limit to the supply of renewable energy in the Earth. So, development of renewable technologies only may not solve the problems but the social dimension, which could enhance the conservation activities, compromise on welfare by rich people and other saving aspects of energy, has to be focused equally.

The question is how energy can be supplied sustainably. The main question is attitude and grasping reality by decision makers and planners. "The most important, difficult and neglected questions of energy strategy are not mainly technical or economic but rather social and ethical" (Lovins 1977: 58). Therefore, energy sustainability issue is also linked to all components of sustainability and a solution should be found through the holistic determinism approach as discussed in previous chapter.

## 3.3 Nepal: Energy at a glimpse

### 3.3.1 Energy poverty

Nepal, mainly dependent on traditional sources of energy that is supplied by the country's fragile and waning forests, is among the least per capita energy consuming countries in the world (Baskota et al 1999: 106). Nevertheless, Nepal's total energy consumption has increased by 54% in the last fifteen years (between 1985-2000). The average final energy consumption of a Nepali is about 0.340 TOE (14.2 GJ) (HMG/N 2001). The energy problem in Nepal arises not only from the excessive reliance on non-renewable energy resources, but rather from the fact that one form of energy resources (fuelwood) is being consumed at an unsustainable rate, while the vast potential of other forms of renewable energy is virtually unused. There is already a significant deficit in biomass supply and there are no substitutes available for the rural masses for the immediate future.

Necessary for daily survival, energy itself is of little interest but is an essential ingredient or means of achieving socio-economic development and economic activities in present society. The amount of energy consumption also indicates the level of human development and living standards of people to a certain extent (e.g. Goldemberg 1996: 20). In this context, Nepalese people are not only economically poor, there also exists a state of energy

[24] As per RIGES (Renewable Intensive Global Energy Scenario) for the year 2025, total energy consumption is 11.21 GTOE with 45 percent RET, whereas of World Energy Council (WEC) in its scenario C (ecologically driven-economic growth of the world is 3.3) has estimated about 11.3 GTOE for the year 2020 with 30 percent RET (Goldemberg 1996:73-74, Nakićenović et al 1998). In the year 1998, the global primary energy consumption was 400EJ (9.385 GTOE) (IPCC 2001).

insufficiency, because on the average a Nepali consumes (or has access to) only about 340 kg of oil equivalent per year. A major part of that comes from traditional sources like fuelwood, which is used in the most primitive way. According to Goldemberg (1996), energy consumption for a normal living standard for a person, on the average, is about 1000 - 1300 Kg of oil equivalent. This situation of energy poverty in Nepal is hindering not only economic activities but also overall development of living standard physically, socially and ecologically.

The reason is that Nepal could not progress economically and politically thus the living standard of the people and the policy of the government has hardly improved hence fast switching over to new energy technologies or resources (renewable and non-renewable) was not possible. Also the modern form of energy, facilities or resources are not free of costs economically and politically. The consequences are that the sole energy resource - fuelwood from forests - is being unsustainably used as it is still "free of cash[25]" and causing irreversible effects (e.g. Baskota et al 1999: 107). Pearce et al quoting "the Sunday Times of U.K. of 11 Sept 1988" has mentioned "at the present rate of cutting, the Himalayas will be bald in 25 years; topsoil will have disappeared, and the climatic effects threaten to turn the fertile plain into a new Sahel" (Pearce et al 1990: 174). A gloomy picture of Nepal was also illustrated long ago by Eckholm (1976) in his "Losing Ground. Environmental Stress and World Food Prospects". His words reflect how complex the relation is among economic poverty, environmental poverty and energy poverty in Nepal some 25 years ago and unfortunately, such pathetic situation continues even after 25 years.

*"There is no better place to begin an examination of deteriorating mountain environments than Nepal. In probably no other mountain countries are the forces of ecological degrading building so rapidly and visibly. This kingdom… forms the nucleus of one of the world's strategic ecological nerve centers. …in this land of unexcelled natural beauty live some of the world's most desperately poor. Nepal could face what could be the world's most acute national soil erosion problem… The façade of romance and beauty remains intact, but behind it are the making of a great tragedy….Villagers must roam farther and farther from their homes to gather fodder and firewood. Thus surrounding most villages with a widening circle of denuded hillsides…The decades of the 1960s was a period of*

[25] It is not free of cost, as people have to devote their time and labor although due to high level of underemployment and unemployment, the opportunity cost of fuelwood collection is almost negligible. Nevertheless, fuelwood is free of cash, i.e. the majority of rural people in Nepal do not have to pay cash for fuelwood although it has cost.

*record economic growth for most of the world's poor countries. But for …Nepalese…'is deteriorating economy'…. Top soil washing down into India and Bangladesh is now Nepal's most precious export, but one for which receives no compensation. …farmers faced with an unduly long trek to gather firewood for cooking and warmth have seen no alternative to the self-defeating practice of burning dong- sorely needed for fertilizer- for fuel" (Eckholm 1976: 76-78.*

Although there are again reports of increment of forest covers in few areas, especially in the hilly regions after the initiations of community forestry programs and other conservation activities through governmental as well as non-governmental initiatives[26]. In reality, deforestation is still a major problem of environmental poverty leading to overall poverty. As urbanization and modernization goes on, consumption of petroleum product also grows. Within the last 15 years, there was a 449% increase in the consumption of solely imported fossil fuel, which could lead towards economical and ecological unsustainability.


*Energy is the nucleus of poverty, especially in the rural areas of Nepal. Energy poverty, lack of clean energy leads to ecological poverty, i.e. deforestation, primitive art of excessive use of primary energy, etc. Ecological poverty leads to economic poverty causing lower agriculture production, economic impacts due to climatic catastrophes, etc. Then, economic poverty leads to overall poverty making pathetic human living standard: illiteracy, poor health system, poor infrastructure like schools, hospitals etc.*

Figure 3.11: Linkages between energy poverty and overall poverty in the Nepalese context. (Source: Author)

Nepal's energy consumption pattern is also dominated by domestic sectors such as cooking, heating and lighting. But within the last fifteen years (1985-2000), the overall consumption increased by 326% but per capita energy consumption more or less remained

[26] As per Acharya (1993), change in forest area between 1964 and 1978 in the hills and middle mountains was positive (1.8%) whereas in Siwalik and Terai was negative (-15.5% and -24.4% respectively).

the same because of population growth[27]. The scenario of the last fifteen years shows that the electricity consumption ratio is growing in industrial and domestic sectors. At least the statistics show that there is a great demand of electricity in the country for the industrial activities and domestic lighting.

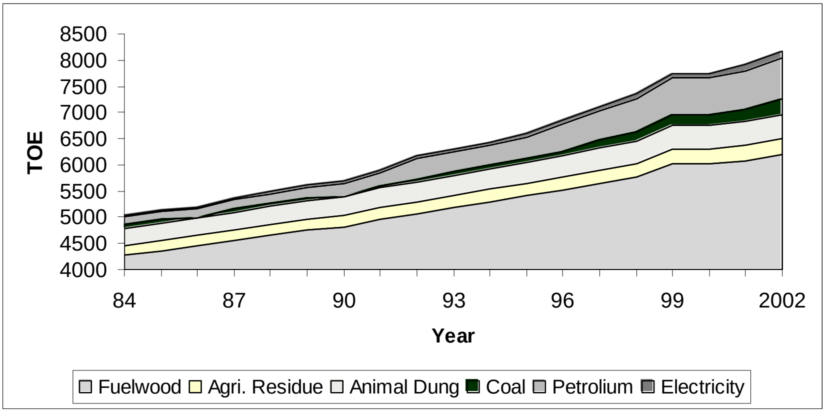



Figure 3.12 Energy consumption scenario of Nepal
Source: compiled from HMG/N (2001), CBS (2002a)

The above-mentioned energy scenarios and its consequences are hindering the sustainability path of the country in all fronts. Economically, the above-mentioned path will lead towards ruin, ecologically, a catastrophic future and socially, more conflicts because of lack of the poor community's access to resources and inequality in energy distribution. Without dealing with this vicious cycle, no sustainable path is possible. There are alternatives if plausible policies and strategies are adopted, especially in utilizing decentralized forms of energy resources and technologies that are locally operated, managed and extended.

### 3.3.2 Energy and development plans and policies in Nepal

The Table 3.3 (next page) summarizes energy planning endeavors in Nepal that has started since 1956.

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[27] Another reason for the increment in total amount of consumption could be the extension of grid in rural areas thus increasing the number of customers rather than increment of the specific consumption.

**Table 3.3 Development plans and energy in Nepal**

| Plan | Main objectives or principles | Remarks |
|---|---|---|
| First five year plan (1956-60) | Emphasis given to decentralized and community owned plants to reduce the drudgery and kerosene consumption and large hydropower were said to be unfeasible because of transportation, lack of investment, industrialization and purchasing power of the people | No mentioned objectives were realized |
| Second three year plan (1962-65) | Stressed to fulfill the need of electricity for agriculture and other end-uses, establish a public sector to look after the matter of electricity and to meet the growing demand of electricity a concept to implement of thermal power plant is forwarded | hydropower potential in Nepal was mentioned as 80 GW |
| Third five year plan (1965-1970) | Emphasized the need of electricity in transportation | Continuity of second plan |
| Fourth five year plan (1970-1975) | Buying electricity from India and installing few thermal power plant in Terai region | |
| Fifth five year plan (1975-1980) | Adopted integrated approach of utilizing water resources and shifting people from fossil to energy from hydropower, extension alternative energy like of biogas, solar thermal were stated in the plan | First time *energy* instead of electricity is mentioned |
| Sixth five year plan (1980-1985) | Developing hydropower plants to export electricity, replace fossil fuel in transport, widening the use of electricity to save forest and involving private as well as co-operatives in the hydropower development and developing alternative energy was the main objectives | A special focus on biogas was given in this plan |
| Seventh five year plan (1985-1990) | Reducing the consumption of fossil fuel in the transport sector and extension of improve cook stoves were proposed to save fuelwood burning | |
| Eighth five year plan (1992-1997) | Involvement of internal as well as foreign investors in hydropower development thus developing industry, a community forestry concept was initiated after developing forestry master plan, , proposed to include social cost of energy in pricing, and to develop 30,000 family biogas plants | About 30,494 biogas plants and 20 kW wind generator were installed, more than target |
| Ninth five year plan (1997-2002) | Renewable energy technologies were targeted with specific objectives and proper budget allocation separately, establishment of alternative energy promotion center (AEPC) is envisaged with regular embellishment of previous plans | AEPC is established as an autonomous center |

Source: Compiled from NPC ( 1956, 1962, 1966, 1971, 1982, 1985, 1992, 1997)

In the beginning, the energy planning was meant as electricity planning. All policies were the usual embellishment of the previous plans. Although the development results were not as they were supposed to be according to the formulated policies, achievements were better after the passage of the ninth development plan. If the formulated policies would have been translated into action appropriately, the development of energy sector could have been a lot better in spite of incomplete or inadequate policies. Other legislations, related to the energy sector development issued after the 1990s, are the Hydropower Development Policy, The Electricity Act, Electricity Regulations, Water Resource Regulations, The Industrial Enterprises Act and The Foreign Investment and Technology Transfer Act.

Energy planning investments have, for the most part, been biased in favor of large schemes and emphasis has always been placed on the expansion of supply rather than on the potential energy demand management (Rijal 1998:19). In almost four decades of planning, a concrete policy and transparent implementation activities were hardly carried out especially in renewable energy developmental activities including hydro of different scales. Even after the passage of almost 45 years of the development plans, the government could not provide more than 70 percent of its people with a minimum access to electricity. From this outcome, the efficacy of development plans can be ascertained. Nevertheless, biogas is one of the successful programs in Nepal in the renewable energy sector - with the support as well as direct involvement of the donor agency. The main weaknesses of the past energy development endeavors are mainly centralized decision-making and non-participatory implementation including others.

### 3.3.3 Existing macro/micro policy on energy (MHP) development in Nepal

The Nepalese government has started to subsidize MHP since 1985[28], as a means to encourage the rural and remote area electrification; it was 50 - 75% on electrical components only, depending upon the remoteness of the sites (CES 2000, deLucia et al 1997, ITDG 1997a, ICIMOD 1993, REDP 2000a). Currently the AEPC/ESAP under the

[28] There are also conflicting reports: REDP (2000a) has mentioned that the subsidy programme has started in FY 1981/82 whereas ICIMOD (1993), Adhikari (1994) have also mentioned, without mentioning the terminology 'subsidy', that ADB/N introduced financial assistance programme in the same FY. ICIMOD (1993), deLucia et al (1997), ITDG (1997) and AEPC (2002) have mentioned that the subsidy has been started in FY 1985/86. DeLucia et al (1997) has reported that the subsidy has been started in 1985 and discontinued in 1986 and reinstated in 1988 and stable for a year and then discontinued. In 1993 subsidy has been started again. Before the year 2000, there was 50% subsidy on electrical components of MHP and for remote districts as classified by HMG/N it was 75% of the total electrical costs.

Ministry of Science and Technology has formulated a subsidy policy[29] to support MHP and improved ghatta for rural electrification (AEPC 2002). Hydropower Development Policy 2001 has also mentioned that the government shall provide grants to small-scale hydropower to be implemented in the remote mountains, where grid will not be extended.

Except for providing ad hoc subsidy with the support from donor agencies and vague 'should be/shall be done' pronouncements, there is still no concrete policy specially designed to promote MHP even without external support in Nepal. Hydropower policy designed for MW projects are dominating the formal policies and some times replicated or understood as MHP policy. There is still no clear-cut policy of regional isolated grid and legality of such grid if private investors invest on such projects. Ad-hoc subsidy policy is termed as MHP policy in several fronts. However, the Hydropower Development Policy – 2001 included some provisions plausible to the MHP sectors.

As per Hydropower Development Policy of Nepal 1992 and 2001, no license, no royalty and no corporate income tax is required for running water mills or water grinders as a cottage industry and for small hydropower plants less than 1000 kW. This policy says that the water resources are state property; water resource can be developed directly by the government or through user's group. There is also a mandatory power purchasing provision by government owned utility – NEA from private companies based on mutually agreed conditions; and private companies can use NEA's transmission system for the power wheeling.

The policy also purposes that the financial institutions shall make concession-loan available for the entrepreneurs of MHP under the social sector investment criteria. However, the collaterals needed for the bank's loans are hindering the poor communities to receive the loans from the private banks easily. As per government policy, "commercial banks are required to allocate 40% and 12% of their total loans to the productive sector and priority sector respectively" (Acharya 2000: 63). The priority sectors are agriculture, small-scale cottage industry and small–scale services in social development sectors. Moreover, the Hydropower Development Policy has also included MHP in the prioritized

[29] Rs. 55,000 per kW for new MHP which are up to three kW, Rs. 70,000 per kW for new MHP above three kW, Rs. 35,000 per kW or 50% of the cost of rehabilitation of MHP projects; and from Rs. 8750 to Rs. 21,000 per kW as a transport subsidy; Rs. 27,000 for add-on electricity generation from improved Ghatta, and an investment ceiling per kW of Rs 150,000 are some of the provisions of subsidy policy related to MHP.

loan sector (HDP 2001). Due to the high operational costs, the private and commercial banks are said to be rather paying penalties than investing the money in such sectors. However, the partially good policy does not function if it is not linked with other strategies, especially the implementing strategies that is often found to be conflicting with macro-policies in the developing countries like Nepal.

Moreover, the HDP- 2001 policy has categorically mentioned, "Electricity shall be supplied from small hydropower projects in the mountainous rural areas falling outside the access of the national power system. Provision shall be made to hand over the responsibility of operation and maintenance of such small hydropower projects to the local co-operative groups and these groups shall also be involved in the course of formulation and implementation of plans" (HDP 2001: 13). Similarly, the government's policy regarding the function, duties and power of the local bodies is encouraging to utilize local resources for the development of small-scale energy projects. According to the Local Self Governance Act- 1999, in the provision relating to village development, the Article 28 clearly states, "to generate and distribute electricity and to cause to be generated and distribute the same" are the duties and powers of the Village Development Committee (VDC) (HMG/N 1999: 25). Similarly, under Article 189, while stating the functions and duties of the District Development Committee (DDC) relating to hydropower, it has been stated, "to formulate, implement, operate, distribute, maintain and repair projects on mini and micro hydropower and other energy, and cause to be done the same" (HMG/N 1999: 143) is the responsibility and function of the DDC. This clearly indicates that the government policy in principle, is promoting the decentralized form of hydropower. There are 3,912 VDCs and 75 districts in Nepal (See the figure in **Annex 3.1**). If a VDC plans an energy project, based on its resources, it cannot opt for bigger and unsustainable system. While formulating the plans, according to the Article 43 Clause 3 of Local Self Governance (LSG) Act 1999, VDC shall give priority to the projects raising living standards, income, employment and direct benefits to the rural people.

Similarly, it has been stated that the projects are to be operated through local means, resources and skills providing direct benefits to the women as well as the backward classes and children. Regarding the proper selection of projects by local authority at VDC level, the LSG Act under its Article 46 also states that the selection shall have to be so as to protect and promote the environment, and shall have utmost participation and labor of the local inhabitants. Therefore, from the perspective of the Local Self-Governance Act-1999, there are ample opportunities and encouragement for the MHP projects, at least theoretically, for the benefits of the local people of different class and gender.

Water Resource Strategy of Nepal (WECS 2002) has underlined three national objectives: social development, economic development and environmental sustainability. The policy underlines the principles of utilizing appropriate technology, utilizing water resources for poverty alleviation and employment generation as well as integration of sustainability considerations at every level of the development process from policy setting, implementation to operation. The strategy also targeted to provide 60% of households with electricity by 2027. However, strategy itself cautions that "the business as usual" approach is not sustainable and targets are not realizable. The most important policy statement is the recognition of the importance of the community participation and involvement in planning, implementation and management of mini and micro hydropower. The strategy categorically mentioned that " rural communities and private entrepreneurs will be encouraged to invest in hydropower, taking into account the associated intangible benefits of access to electric light and power that enhance quality of life and make environmental conservation possible" (WECS 2002:102).

There must be a different approach and policy for MHP because MHPs are not comparable and compatible with MW hydro policy in several aspects: environmental impact, resource investment, decentralized systems and local financial and technical affordability. Till now, the policy only meant for MHP is the frequently changing ad-hoc subsidy policy. Being of ad hoc, the question is being raised on subsidy policy such as how such subsidy has been provided, and who is receiving such subsidy. There are also critics saying that subsidy has not reached the poor but affluent society or to groups that have been benefited (compare WB 1996, Nepal 2001). Nevertheless, in the case of community owned MHP, such subsidy, even though ad hoc, has better distributional effects than privately owned MHP because of the accessibility of all community households to the system. Manipulation and misuse of such subsidy, in the case of the community owned MHP system, have fewer chances because of transparency. Therefore, the emphasis should be given to design such subsidy or incentive providing policies in an appropriate manner considering types of recipients, sites, purposes, implementation approaches, transparency, social as well as ecological issues. The distribution factor, basic needs factor, human development index, externalities, etc. discussed in the chapter four and five could be the reference factors to design subsidy and other policies for MHP.

The macro level policies as well as local level policies are slowly making at least plausible environment for the MHP promotion. However, sustainable implementation modalities, financing modalities and ownership modalities are still not being concretized. Existing mechanism are not clear in the government policy. For example, as per HDP (2001)[30], if a private owner of bigger hydropower or public utilities brings grid to the community where a well functioning MHP is being used for electrification, then such MHP will be replaced paying only financial compensation as per traditional evaluation; no clear policy of power purchase has been mentioned. Such policy will undermine the decentralization practices in the energy sector. Policy statements are too vague and broad even though they are underlining the importance of MHP. There are several conflicting laws, by-laws within and among the different Ministries regarding the utilization of local resources like water, forest, etc, ownership of such resources and proper decentralization of the political power of decision-making itself. Implementation strategies are still unclear. Nevertheless, because of the on-going activities on MHP demonstration programmes and feedbacks from stakeholders about the macro as well as micro level policies on MHP, a discourse is prevailing among the planners, implementers and policy makers.

### 3.3.4 Energy resources and technologies and their potential in Nepal

Table 3.4 (next page) shows the major renewable and non-renewable energy resources used in rural Nepal. The table also shows the generally used services that are consuming energy. Nepal has no significant known fossil reserves and resources and those known are said to be of low quality and economically not viable. The major renewable energy resources available abundantly in Nepal are hydro, solar, wind and some low temperature geothermal sites. Economically biomasses, solar and hydro are seen to be attractive until today. Biomass is used as traditional resources like fuelwood and biogas from the animal dung. Biomass is providing energy services to cooking and space heating for more than 90 percent of the people and to the small-scale rural industries. Hydro is mainly exploited for electricity generation and solar energy is being used mainly for water heating and decentralized electricity production for rural lighting.

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[30] Para 6.12.11 and sub clause 4 of HDP (2001).

**Table 3.4 Energy and technologies in the rural domestic sector in Nepal**[31]

| End-uses | Non Renewable | | | Renewable | | | | |
|---|---|---|---|---|---|---|---|---|
| | Kerosene | Diesel | Gas | Biomass | Biogas | H/MMH@ | Solar Thermal# | Solar PV |
| Cooking | ✸ | | ✸ | ✸ | ✸ | ✸ | ✸ | |
| Lighting | ✸ | ✸ | | | ✸ | ✸ | | ✸ |
| Agroprocessing plus small scale industrial use | | ✸ | | | | ✸ | ✸ | |

@ Hydro and Mini Micro Hydro # Still in preliminary phase for cooking but used for water heating ***Source: Author***

**Table 3.5 The potential of renewable energy resources/technology**[32]

| **Resources** | **Potential** | **Currently used** | **Remarks** |
|---|---|---|---|
| Fuelwood million ton | 5.448 | 10.972 | Is in deficit |
| Briquettes ton | 95000 | 4000 | Potential of Terai |
| Biogas (Nos.) | 1.3 Million | 95000 | Till the end of 2002 |
| Solar PV (MW) | 26000 MW | 1500 kW | |
| Solar thermal nos. of solar water heaters | -NA | 17265 | |
| Hydro power (MW) | 83000 MW | 500 MW | |
| MHP (MW) | 1000 MW | 6 MW[33] | As of July 2001 |
| Wind | NA | None | |
| Geo Thermal (Sites) | 33 | None | |

Source: Compiled from CES (2000), ICIMOD (1998), WECS (1995), NPC (1995), Pokharel (2003)

Among these renewable and alternative technologies, micro and mini hydropower are being considered better with respect to technology, social conditions and nature of supply. Solar PV is economically still expensive in Nepalese context. Biogas is not suitable for motive power at household level and has limitations because of the cold climate in the hilly and mountainous regions, although it is very popular in the lower hills and the plains of

[31] There are some demonstrative programs with solar cookers and PV agro processing mills. These are not taken into account here as a widely used technology.
[32] Gasifiers, liquid fuel, co-generations are still not used except in experimental demonstrations; regarding traditional/improved ghattas (existing nos. are about 16-25 thousand), there is no reliable data available for improved cook stoves, solar cookers, and solar dryers.
[33] Only electrical energy producing system mentioned

Nepal. Biomass is not sufficient in the perspective of sustainable yield. Wind energy technologies are still to be developed. Nepal is said to be having adequate technical and economical potential for MHP. Hence, among the renewable energy technologies, this dissertation will focus mainly on the issues of hydropower especially the micro hydropower sector in Nepal, which could uplift a significant number of the rural and remote Nepalese households located in the mountains and hills from the pathetic energy situation.

### 3.3.5 Economic, social and ecological aspect of energy use in Nepal

The traditional energy resources are mostly not traded in Nepal and do not pass through the cash economy. There is no (or no significant) opportunity cost of fuelwood collection as unemployment and underemployment is widespread in the rural areas. Long-term economic consequences due to the unsustainable use of traditional fuel are, amidst poverty, simply ignored and the fact that the energy poverty is causing economic poverty is simply not comprehended. The sustainable annual yield of fuelwood in Nepal is theoretically 5.448 million ton whereas about 10.972 million ton is the estimated consumption per year (WECS 1996). This shows that the per capita accessible sustainable fuelwood is less than 237 kg per year, which is less than 0.092 ton of oil equivalent (TOE). Analysis carried out for the year 2010 show that fuelwood deficits are likely to become more serious under all scenarios and there is less room for improvements (Pearce 1990: 187). Annual deforestation was about 1.3 percent during 1978/79 – 1990/91 but about 0.12 percent recovered through reforestations (WECS 1995b and Banskota et al 1999: 107). The existing energy economics has to be changed for sustainable energy future. Therefore, the use of traditional resources cannot be replaced by clean and sustainable energy systems unless and until the economic aspects of energy, their affordability and economic activities are focused integrally.

Economically, energy needed for cooking and space heating for the majority of rural people cannot be substituted with modern forms of energy like electricity, as the existing living standard of people is not capable to pay the current price of electricity from the grid and other commercial energy. The electricity produced from renewable resources can be used to replace imported fossil fuels as kerosene and diesel used for lighting and agroprocessing, initially. If sustainability issues are made a constraint for the development of the country with long-term vision, clean energy could be cheaper than now because of positive social cost of clean energy. Simultaneously, the cheaper clean electricity could generate new economic activities leading to its applications to replace traditional forms of energy once the economic ability to pay is raised.

The mountains of Nepal provide some of the most spectacular scenery in the world, which attracts large numbers of tourists for trekking and mountaineering each year. The economic condition of the country demands that tourism be developed and increased as much as possible. This has direct impact on natural resources and one of them is fuel wood. The derived demand of energy due to tourists is high (Baskota et al 1997). However, there is hardly any electricity or clean forms of energy available. The market centers and trekking routes are rugged and bringing the national grid there is uneconomical and difficult (Pearce et al 1990: 178, Baskota et al 1997: 1). So, without alternative vision of supplying energy in these areas, tourism cannot be promoted sustainably.

The followings are the some of the issues in energy sector at the macro as well as micro level in Nepal (compare e.g. deLicia 1997, Rijal 1998, Rijal 1999, Baskota et al 1999, Christensen 1997, Bandopadhyaya et al 1994, ICIMOD 1998, Pearce et al 1990), which could be addressed once sustainable energy technologies are developed:

- fossil fuels are being solely imported, draining huge percentage of foreign earnings (more in chapter five),
- political scenario especially with neighbor countries has great impact on these fuels as the country has already been almost ruined twice due to the Indian trade embargo that had also affected the import of fossil fuels,
- very limited direct employment opportunity has been generated by fossil energy sector,
- urban areas are already experiencing a high level of air pollution due to the burning of fossil fuel,
- due to poor infrastructure and difficulties in the transportation, fossil fuel has several secondary impacts like great variation in fuel price within a small country like Nepal and it is mostly the poor who live in remote areas are paying more despite subsidies,
- facing a situation where the market cannot always provide the basic human needs, alleviate poverty, reduce gender or ethnic oppression and protect the environment in the case of energy development sector too,

- ignorance of the biophysical aspects of the hilly and mountain areas, thus replicating the approaches and strategies suitable to plain areas or developed regions of the country and especially, renewable rural energy system is still in small scale, niche, and site specific,
- wrong choice of technology and negligence of indigenous one, even in the RETs,
- traditional energy use is heavily integrated with other systems dealing with often non-monetized "market" in fodder, fuelwood, dung and crop residues,
- non standardized systems and components in the RETs,
- renewable like micro and mini hydro have to compete with directly or indirectly subsidized fossil fuels or big hydro and this makes most of the projects financially not viable (details in chapter five),
- subsidies are also being provided to RET systems with ad-hoc policies giving the impression of privileged technologies,
- no significant technological innovations to challenge the imported quality that have occurred as choices are made on an ad hoc basis.

### 3.4 Sustainable energy systems

Due to several reasons, the poor people of developing countries follow the same path as developed nations and for which they need more economic resources that are lacking. However, because of already available new technologies in the west, it is possible for the developing countries to leapfrog over the dirty and inefficient intermediate stages of industrialization, what developed countries have gone through (e.g. Elliott, 1997:195-201). This leapfrog is achieved through directly adopting advantageous environmental friendly appropriate technologies that enhance and assimilate with the local indigenous skills, techniques and knowledge. Nevertheless, the choice of appropriate technologies available in the west will be a critical factor for the developing countries, because not all technologies available are suitable, affordable, or environmentally and socially acceptable in the third world.

Now the question arises, when energy is indispensable for human beings' survival as clearly mentioned by Goldemberg (1996) and others, how can increased demand of energy be supplied sustainably. On the other hand, the previously discussed problems related to energy use have to be reduced or solved for the survival of human beings and the ecosystem. Therefore, a sustainable energy supply system is indispensable in the global as well as Nepalese context. As figures 3.7 and 3.8 (in page 58) have clearly indicated, there are two types of sources and two types of wastes. There are a few problems with renewable resources and recyclable waste but to a certain limit. If we do not cross the limits of carrying capacity of our ecology, then there would be no issues of unsustainability because recycling process of ecology takes care of itself. Non-renewables or depletable resources and non-recyclable wastes of within a specified time horizon are causing problems to our ecology, and energy is the main culprit as shown in Table 3.2 (page 60). Being a materially closed system, our ecology cannot supply non-renewable resources forever (e.g. Medow et al 1972, Daly 1977, Daly 1996). So sustainable supply of energy has to be ascertained because energy is driving our societies.

Sustainability has numerous facets and when it comes to energy systems, it is also very difficult to categorize, what is sustainable or not, even for renewable energy resources. Fuelwood is sustainable when it is consumed within its sustainable yields and similarly hydropower, etc. The specific definition of a sustainable energy system varies in each continent, region or even in individual countries. Any discussion on sustainable aspects and technological endeavor that tries to resolve the energy problems must first be cleared of the following questions: Who is going to require the energy and how much? What kind of energy? For what purpose? For how long? (Lovin 1977: 5). For Cassedy (2000), the criteria of sustainable energy resources are inexhaustibility (superabundance as solar energy), renewability (as hydropower) and recyclability (as bio-waste and forest, which recycles the carbon dioxide emission of energy conversions to a certain scale). The sustainability criteria mentioned by Cassedy indicates the types of energy to be used, but could not mentioned about other issues raised by Lovin. “Who is going to get and how much?” is a social issue, which generally lacks in sustainability definition of energy resources. Cassedy’s definition of sustainable energy covers only ecological issues. Therefore, sustainable energy system’s definition can be formulated as a system that is inexhaustible, recyclable, renewable, viable, manageable by and accessible to the needy people to sustain livelihoods for infinite time horizon.

From the perspective of energy resources depletion and non-recyclable waste, the suitable definition for a sustainable energy system would be "sustainable energy resources are those resources, which can substitute fossil fuels in masses used for ever-increasing economic activities without threatening our environment and climate” (e.g. Cassedy 2000: 6). Describing further in detail, the World Commission on Environment and Development

(WCED) has outlined four elements for energy sustainability: sufficient growth of energy to meet human needs, energy efficiency and conservation measures to minimize consumption of primary resources, concern over health and risks aspects of energy, and biosphere and pollution aspects (WCED 1987: 169). In short, these elements can be summarized into two aspects: development of renewable energy to meet the current and future energy demand equitably with no negative impacts and not to deplete non-renewable beyond the carrying capacity of the Earth.

Strategies of sustainable energy technology will be choosing, developing and deploying new energy technologies and thus avoiding the use of fossil fuels. Goldemburg (1996) emphasizes that the conventional energy strategies fail to help meet the basic human needs for the majority of the poor in the developing countries. From the perspective of intra-generational equity too, small-scale renewable decentralized systems seem favorable for the poor masses to have access to better energy that are economically feasible, ecologically plausible and socially acceptable. If such parameters are fulfilled such systems could be defined as sustainable.

### 3.4.1 Micro hydro power in Nepal

MHP, which could be consistent with the definition of sustainable energy system discussed in the previous sections, will be the sustainable energy technology for the people of the hilly and mountainous region of Nepal compared to other alternatives. Before going through sustainability issues of MHP, the following section will illustrates the state of the art and background of MHP technology in Nepal.

### 3.4.2 Historical background of MHP in Nepal

Since centuries the traditional wooden water wheels, popularly known as g*hatta* or *Panighatta*, are being widely used for grinding and milling throughout the country and it is estimated and frequently quoted that there are about 16,000 - 30,000 *ghattas* in Nepal (Pandey 1998, Rijal 1997a). Some even say tens of thousand of these *ghattas* are being used for grinding grain into flour for centuries (e.g. deLucia 1997). As the majority of the Nepalese (73 % in 2001) are said to be subsistence farmers and about 42 percent people are below the absolute poverty, most of the installed micro-hydro[34] powers are being used for

[34] As per Nepalese Government's classification hydropower below 100 kW are known as micro and below 1 MW known as mini hydro.

agro processing like oil expelling, grinding, milling and husking thereby reducing the human drudgery especially of women. There are different types of applications and definitions[35] of these micro technologies in Nepal ranging from few watts to 100 kW for simple mechanical grain grinding to rural electrification. The impetus behind all modern types of micro hydropower development were certainly traditional types of wooden water wheels solely developed, installed and operated by the local Nepalese people. The water wheels have been helping to reduce the drudgery of women and children in the agroprocessing, i.e. grinding and milling millets, wheat and maize in several areas.

The fist-five years programme (1955-1960) of Nepal has stated, "we shall need to follow a policy of generating power in relatively small scale installation when and where required rather than attempt 'grid system' involving high initial investment including wide power line distribution" (NPC 1955:50). In its basic principle the sixth development plan has also envisaged micro hydro projects through people's participation and local resources (NPC/HMG 1978:43). "A 'pre-existing' ideological sin, 'economy of scale' is an unquestioned "good" of both engineering and economics. Technological 'gigantism' is a fashionable measure and expression of "progress" for politicians and common folks as well as engineers and moneyman" (Christiansen, et al 1997:28). This is what is exactly true in the case of Nepal. Although a 500 kW small turbine was installed in 1911 in Nepal, and there were already existing thousands of wooden-runners, but, because of the dream of "gigantism", Nepal could not develop hydropower for five decades. Only after almost 50 years, in 1962 a Japanese made micro turbine of 5 kW for electricity generation was installed by a local manufacturing company at Godavari fishpond in the premise of Kathmandu valley to promote small-scale technology (e.g. REDP 2000a). Even though, gigantism was a dream of then decision-makers but in reality neither such gigantism nor small-scale technology could came into existence during those 50 years. Pandey rightly mentioned, "A short sighted belief on the part of planners that 'hydropower development in the country is simply an increase of the MW's on the grid' has stymied growth of local capability to develop hydropower" (Padey 1994:181).

[35] ***Ghatta***: Traditional wooden water mill for grinding grain into flour, ***Improved ghatta***: upgraded ghatta with metal runner and shaft, ***MPPU***: Multipurpose Power Unit, a turgo-type turbine developed by a Nepalese to replace ghatta with higher capacity grinder and other power off takes, ***Peltric Set***: A pelton turbine directly coupled to an induction motor for electricity generation from few watt to 5 kW, ***Stand-alone***: Micro-hydro plant for electricity generation not attached to agro-processing mill or plant directly to the turbine used only for electricity generation, ***Add-on:*** electricity generation attached to agro-processing mill. (compare deLucia 1997, AEPC 2002)

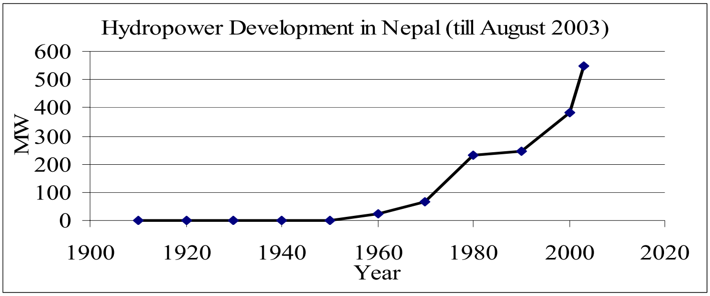


Figure. 3.13 Hydropower development in Nepal

Source:Data compiled from Pandey (1999), NEA (2001,2003), NHA (2001), CBS (2002)

Few interventions of micro hydro plants were also there during this period but as an isolated case. Unfortunately, 'a long silent period' until 1960s after the installation of first mini-hydropower in 1911 could have hindered the development of the country in all aspects. The reasons could be several but dream for gigantism must be one that has oppressed the Nepalese dream of prosperity.

Development of MHP came faster when Nepalese government has decided to provide loan and technical assistance to MHP in FY 1981/82 (ICIMOD 1993) and after fiscal year 1985/86 electrical components of MHP were provided with subsidy when add-on electrical system of mechanical power producing turbines are not financially attractive. By the end of F.Y. 1986/87 there were 534 water turbines installed (ADB/N 1987) and increased by more than 800 turbines by 1992 (Pandey 1994:185) and most of them are in the range of 5 to 20 kW and are used for agro-processing and small fraction of them for community electrification. The average size of plant was around 8 kW for mainly agroprocessing mechanical mills (ADB/N 1987). Up to the end of 1993 about 121 MHP were installed only for rural electrification and producing a capacity of 1.348 MW (ICIMOD 1993, Pandey 1994). When a rural energy development programme (REDP) supported by UNDP has been implemented in 1996, by the end of September 2003 about 123 with the capacity of 1.607 MW additional MHP for rural electrification were commissioned and management was looked by user's committee (REDP 2003). On the other side about 49 nos. of MHP were also installed and handed over to the users committee by Remote Area Development Committee (RADC) since 1993, which is the government agency to look after remote areas of Nepal (Baskota et al 2000). Since 2000, an Energy Sector Assistant Programme supported by DANIDA is also providing subsidy to the private or community owned MHP. As per Energy Sector Assistance Programme under Alternative Energy Promotion Center (ESAP/AEPC) report 2002, the MHP development scenario is rather positive than pessimistic at least in numbers, if the present subsidy continues.

MHP development strategy in Nepal could be said is still in the trial and error phase because of frequently changing ad-hoc approaches and policies based on several donors, funding agencies, and implementing organization's programmes with their own interests. Limited external support that is being available time to time through bilateral or multilateral co-operations is being utilized in providing subsidy. These types of subsidies have been provided based on ad-hoc policies and decisions, sometimes as per donor’s recommendations or strategies because the amount of subsidies were different in respective supporting agencies till the year 2000 (see **Annex 3.2** for the details). Although HMG/N has brought the policy for providing subsidy to various RETs including MHP, the sustainability of the policy is in question because it is formulated in the background of ESAP/DANIDA financial support on ad-hoc basis. This policy could promote the installation until subsidy continues. Once subsidy policy changes or discontinues, there would be no installation of MHP. Therefore, there is a fear that wrong policies that are based on ad-hoc decisions without looking important aspects in details, could make whole efforts fruitless because experiences showed that such effort doomed to be a failure (e.g. ICIMOD/ITDG 1998). This will again breed the critics from the opponents of MHP and putting MHP in the same question of “unsustainabililty and expensive”. A genuine sector of development needed to the rural and remote people could be thwarted despites its importance to the country. That is why incentives providing policies should be rationale and transparent. Any subsidy policy should incorporate the resource mobilization possibilities and potentials at the local as well as national level in its mechanism so that in the absence of subsidy the development efforts continue.

### 3.4.3 Potential of MHP in Nepal

The river systems in Nepal can be divided into three groups:

a) the major rivers like originated from trans-Himalayan region,

b) the medium rivers originating in the Mahabharat range or middle mountain region and

c) the small rivers mostly originating from Silwalik and seasonal.

According to Rijal (1999), over eighty percent of the country's land is drained by the rivers of all types. There are more than 6000 rivers and innumerable rivulets criss-crossing the country (WECS 1995) often with rapid rates of fall showing a great potential (figure 3.14 ) for hydropower of different ranges. More than 80 percent of Nepal's area is a hilly and all small river and rivulets are flowing towards plain in south. A sizeable potential of MHP, which exists in almost all the region of Hindu Kush-Himalyas (ICIMOD 1998:14). Moreover, hilly districts of Nepal, which come under this region, are known to have sufficient and feasible potential for MHP.

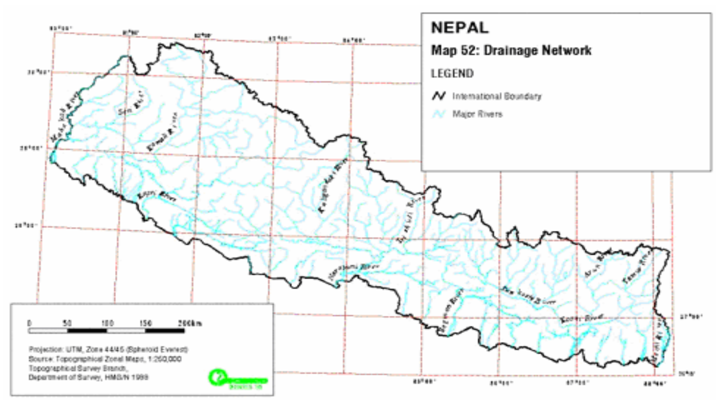


**Figure 3.14 Rivers and Rivulets criss-crossing the Nepal**

As Nepal's well-known data of 83,000 MW hydro potential was calculated by Dr. H. M. Shrestha in his dissertation in 1966 considering only those rivers which have more than 300 sq. km. of catchments area, minimum specific discharge of 5 liters per second per sq. km - thus the corresponding minimum discharge is about 1.5 cu. m. per second and this consideration covers only about 500 large and small rivers whereas there are more than 6,000 rivers which are more than 2 km in length (CES 2000). The estimate of 83000 MW based on above-mentioned criteria does not include potential of micro hydropower, which are mainly from small rivers of the remaining 5500. Therefore, the total MHP potential may exceed 1,000 MW (Joshi, 2000).

A pilot study project carried out in a hilly district of Nepal (Sindhupalchowk district, east of Kathmandu) in summer of 1996 has found that only in 22 VDCs (out of 79) there are 32 potential or existing MHP sites (deLucia et al 1997) and the number will be more if the whole district will be covered. Similarly another study carried out by CRT (1996), indicates that the total potential of MHP in the above mentioned area (only in the catchments area of Melamchi and Indrawati river of Sindhupalchowk district, excluding existing ***Ghattas*** and existing irrigation canal) is about 1000 kW. This excludes bigger hydro of MW capacities. This is, normally, the lower range of potential available for MHP in a hilly district of Nepal. Similarly, a study carried out by the WECS envisages about 20 MHP sites in each hilly district (CES, 2000). There are 55 hilly districts in Nepal, so roughly there will be at least 1100 potential sites minimum. However, this is far less compared to estimates of Joshi (2000). Even if we consider all having a capacity of 100 kW (max capacity of MHP), there will be only 110 MW, where as Joshi mentioned the potential of about 1,000 MW.

In addition to that, deLucia et al (1997) mentioned that there are more than 1100 turbines already installed. Similarly, AEPC (2002) has also listed the 1956 installation that includes peltric sets, stand-alone, add-on and mechanical power producing systems. That means the development of MHP is already in saturation - if we believe these data, which is not the case. Because, the existing studies and reports are giving still conflicting data but in reality, there are still so many virgin areas for MHP in the hilly districts of Nepal. Based on authors own field experiences, available inventory profile of 15 district's energy situation reports of REDP/UNDP, feasibility surveys carried out in different districts with the support of ESAP/AEPC by different consultancies, there has hardly 25% of potential MHP sites of the country been utilized. The traditional as well as modern irrigation canals in the hills and mountains could also be utilized to generate power simultaneously. Therefore, it can be stated that a huge potential (i.e. probably more than 1,000 MW) of MHP is available in Nepal and Joshi (2000) may have rightly mentioned the potential at the lower range.

Pandey (1994) has mentioned that 80 MW of MHP would be sufficient to provide electricity to one third of hilly population by 2008. By considering that assumption, only 240 MW of MHP is enough to provide all hilly and mountain people electricity by 2008 if local as well as feasible regional transmission network is developed. Therefore, in this aspect estimated potential of MHP will be more than sufficient for rural electrification in Nepal. In addition, even if there will be an increase in demand of electricity, MHP can supply to some extend. Looking current trends of rural economy, such drastic industrialization in rural areas in hilly region is far from reality. To increase the demand of electricity in rural areas, productivity or value addition of rural economy and income of rural people must be increased. To have such results there are several internal as well as external factors to be considered.

### 3.4.4 Micro hydro technology development in Nepal

The micro hydro technology is an indigenous technology in Nepal. The first installed MHP of Nepal in 1962 was a propeller turbine but after 1970s locally made and designed cross-flow turbine got popularity and enhanced reliability. In 1977 the first four cross-flow turbine was installed in the hilly districts of Nepal mainly for mechanical power needed for agroprocessing mills like: grinding, husking and oil expelling and a first MHP for electrification was installed only in 1981 (ICIMOD 1993). Almost all installed turbines of even modern micro hydropower were manufactured in Nepal (deLucia 1997, Pandey 1994). After 1980s, Pelton and MPPU (Multi-Purpose Power Unit) were also manufactured by local entrepreneurs. As per ITDG/ICIMOD (1998), it has been found that the majority of these turbines that are made locally are working well and small fraction of them working with regular repair maintenance and another small fraction is not working. This indicates that the turbine manufacturing capacity of local entrepreneurs for MHP is reliable to some extent. The production capacity of Nepali turbine manufacturer is about 200 turbines per year (Rijal 1999:117) but it depends upon the size of the turbines. Summing up the data given by the manufacturers during author’s field study, in total about 3000 kW MHP projects and more than 300 Peltric sets (ranging from few watts to 3 kW) can be manufactured and installed yearly in Nepal. Altogether, till mid of 2001, 1956 different types of MHPs were installed with the installed capacity of 13.064 MW and this includes 347 MHP producing electricity, 799 MHP running agroprocessing mechanical mills only and 810 peltric sets (AEPC 2002) (see **Annex 3.3** for the MHP development chronology in Nepal).

Despite the existing potential of manufacturing skills and technology, there has been status quo regarding the quality improvements and efficiency of the turbines. Manufacturers use their intuitiveness and ad-hoc design because of lack of standardizations. Despite several donor driven initiatives[36] in implementation, training of plant operators, case studies, very little or no incentives or support has been given in advanced training of manufacturers. A push is needed through government or concerned agencies to improve the quality and performance of turbines and other components. Increased implementation pace can increase the competition among the manufacturing companies and promotes the quality on the one side. On the other side, better quality demand could also induce the import of turbines and accessories from the foreign countries. To catch pace of fast developing technology and innovations, the manufacturers need advance trainings[37]. Therefore, concerned authority must help, support or at least sensitize the manufacturer to improve the quality and standard of the products. Otherwise, the benefits that are in consistent with sustainability perspective will be reduced.

### 3.4.5 Micro hydropower systems and sustainability criteria in Nepal

There are many potentialities of renewable energies in Nepal. About 26 GW of solar energy could be produced if whole of Nepal is covered with solar panels. Potential of wind energy is still unknown but a preliminary study has shown some potential (CES 2000). Biomass used by more than 90 percent of the inhabitants is now in deficit. The largest known renewable resource is hydropower. Sustainable development of energy systems in Nepal may be different when we take only the national boundary. As Nepal does not have known resources of fossil fuels i.e. petroleum, natural gas, the sustainability may reject the import of fossil fuels needed to the sector where country's own resources could be utilized. From international perspective in the regional as well as global level, sustainability issues may impose the restriction into the use of excessive fuelwood and other resources that emit CO2 beyond the sink capacity. Therefore, sustainability issues may encompass different issues at different levels from different perspectives and definition of such system may differ with levels and technology. However, this thesis is focusing only on the utilization of hydro resources in small-scale for sustainable energy to promote sustainable development in Nepal.

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[36] It is worth to mention that there was always assistance or support to Nepalese MHP sector from outside. Swiss co-operation mission, SDC, united mission to Nepal, GTZ, ITDG, DED, USAID, FAKT, and SKAT are the international organizations actively involved in the promotion of MHPs in Nepal. Recently UNDP, DANIDA, GTZ and SNV are also helping in providing co-operation in improving manufacturing capabilities as well as providing subsidy of different nature. Institutions like ICIMOD are also supporting different governmental as well as other non-governmental organizations.

[37] This was also comprehended by the author during the interaction with the local manufacturers during the field study.

Ayers (2001) mentioned that the practical expression of the sustainability concept is likely to be in terms of preservation of certain species, safe minimum standards for the impact on environmental quality (or within the carrying capacity) and the sustainable use of renewable natural resources. In this aspect, Nepal can give more emphasis on the last aspect as it still has not crossed the safe minimum standards, although the conditions of its forests is approaching the red signal, i.e. a huge deficit in fuelwood supply and soil erosion. Sustainable use of renewable resources in the sector of energy can have several spin-off effects. There are several options available to Nepal.

Moreover, the economic theory and development paradigm dominated only by 'economism' may not function in societies, which are still far from theoretical conjecture of 'economism'- i.e. 'only market based decisions are fair, transparent, and sustainable'. Because "markets work only in carefully defined and constrained context" (Ayres et al 2001:168). However, there are two important contemplations: firstly, the part of society living in the rural and remote areas is still not functioning as neo-classical wisdom assumes because there are several hurdles like the market based on money hardly exists and people are living meagerly at subsistence level. Secondly, paradoxically, despite these hurdles the society is already in the path of "modernization" and "consumerism" without basic infrastructures like roads, electricity, hospitals, education etc. Hence, due to these characteristics of the rural areas of Nepal, *government intervention or support is often needed and justified in order to ensure more rapid and broad based energization that is sustainable: equitable, efficient and environmentally sound* (e.g. deLucia et al 1997). Therefore, based on the above milieu, defining the criteria of sustainable energy systems in the context of Nepal, a complete sustainability path, as discussed in previous chapter, is more appropriate and easier to follow because people are having complex problems that are interrelated with the energy sector because energy problems cannot be separated with other social trajectories. Based on these broad criteria, analyzing methods will be discussed and formulated in next chapter.

## Chapter Four

# Concept for the Analysis of Community Owned MHP Projects

### 4.1 Background

In the conservative tradition, various development theories have given the economic realm a clear primacy over the social, political and cultural domain and the dominance of economism still represents one of the most crucial features of the tradition of development thinking (Haque 1999). Upholding the legacy of such thinking, the definition of development has mostly been confined in the anthropogenic and hedonistic aspects of satisfaction or utility. That is why, in most of the developmental programmes, plans and policies, dominance of the economism has impelled to perform economic analysis of all the development projects to weigh economic benefits of any resource utilization or even exploitation. Even for the sustainability discussion, economism is the main reference point because of belief, “an economic interpretation of sustainable development is possible and focuses on the traditional concerns of economic efficiency and equitable distribution of income” (Babier et al 1998:55). In the absence of clear alternative methods, “it may be fair to say that discounted utilitarianism dominates our approach more of lack of convincing alternatives than because of the conviction that it inspires” (Heal 2001:220) because “…a rigorous exploration of a new methodology has yet to be attempted” (Babier 1998:6). In the context of such reality, because of the realization of importance of other domains, in addition to the economism, a few modifications have been incorporated within the existing system of project analysis to have at least a considerable output in the other domains too. Even then, such efforts are still confined within the economism, because economic efficiency still dominates and other domains are still secondary constraints in most of the decision-making process.

Pursuit of an economic or developmental objective requires societal (man-made and natural) resources. The use of resources has always some trade-off even though Pareto's "actual improvement" theory says that undertaking a project (in certain conditions) no members of the society may become worse off and at least one becomes better off[38] (Hussen 2000, Brent 1998). Pursuit of a development activity "allows society to move

[38] Better off mentioned here could be only in economic sense, and can be compared as riding a luxurious motorbike with pollution mask, i.e. economically better off but living condition is poor in the areas.

from the status quo [old state] to a new position [new state]" (Hussen 2000: 316). But as per Squire et al "in many cases the situation without the project is not simply a continuation of the status quo, but some increase in outputs and costs are often expected to occur anyway" (Squire et al 1975:19). Squire et al's statement indicates that even in the condition of non-implementation of a project, costs or benefits to the society can change. If rural Nepalese who are depending on fossil energy for lighting are not being provided clean form of energy, then the costs to the country will not remain the same but increase due to the external costs from the use of fossil fuel for lighting. In that sense, trade off is always there whether a project is implemented or not. Economically, to avoid such 'trade off', the projects are implemented if outcomes of the project are more than the foregone trade off benefits. The Nepalese government will only implement the rural energy projects if the foregone trade-off benefits are lesser than the project outcomes. That is, from the government's traditional perspective, the benefits of implementing MHP should be more than the benefits of using kerosene for lighting and at least few communities must be happy without making any type of negative impacts on other communities. The question is how such impacts or arising costs and benefits and projects itself are analyzed.

The existing theoretical analyses that are based on the ideal perfect conditions could not enunciate true results if the reality is different from the ideal efficient conditions. In that context, available resources could not be utilized efficiently only through the century old utilitarian, free-market and individual entrepreneur approach. This approach has neglected the negative aspect (or burden on ecosystem or biodiversity! like climate change etc.) of an inexorably rising living standards through 'narrow' market capitalism or other hedonistic development process. Moreover, the perspective from which project is being analyzed differ the conclusive outcomes and decisions based on such outcomes (e.g. Curry & Weiss 2000). If the fundamentals of analyzing theory were different from the reality then the decisions based on such analysis would not be matching with reality. It could be the case with the hilly and mountainous regions of Nepal. The reality is that no "rational capitalist" would come to invest in the energy sector because there exist no markets that could bring the acceptable profit to the rational capitalist. Even being rich in the natural resources, people are deprived of facilities that could have been generated locally. The traditional approach of investment could not serve the people. That is why, based on niche character and social setup of the hilly and mountainous regions of Nepal, a modified approach is needed based on community perspectives. The theory would be more relevant to assume that the communities, which are the owner as well as the users of resources, could act as an entrepreneur jointly, rather than assuming whether a global capitalist entrepreneur‘s investment for the community in unknown future is profitable or not. Because “global capital, too, seeks quick returns, not bottom-up initiatives necessary for self reliant change” (Ahmed et al 1999:115). Moreover, by providing resources rights and ownerships to the poor community, better environment for sustainability is achieved (e.g. Pezzey et al 1992).

Additionally, there is no free market in the hydro sector of Nepal as the resource belongs to the communities or the government. According to the hydropower development policy of 1992 and 2002 of HMG/Nepal, the local resources belong to the government or community. A private firm can lease for specified period but it has to deal with all impacts of different natures. In my analysis, whereas, community as a whole is taken as entrepreneur, ownership of water resources goes to the community, which could be working as an entrepreneur for their maximum social benefits. Community as a whole cannot be oriented towards only narrow profit because their life style is interconnecting with lots of other local socio-economic and environmental factors that are dependent on local resources and living styles (e.g. Daly et al 1994, Douthwaite 1999). Now, the question is how to utilize water resources for MHP encompassing social, economic and ecological issues so that these projects will contribute to the promotion of sustainable energy future in Nepal and how can such projects be analyzed.

### 4.2 Factors affecting the project analysis

There are several analyses like environment impacts assessment (EIA), multi- criteria objective analysis (MCA), cost effectiveness analysis (CEA), cost benefit analysis (CBA); and these are discussed by several authors deeply from different perspectives (e.g. Van Pelt 1993, Pearce et al 1990, Ward et al 1991, Pearce 1983, Babier et al 1998, Brent 1998, Mishan 1988, Hanley et al 1993). However, most of their basic assumptions are within the neo-classical social welfare theory, i.e. improving allocative efficiency for the utilization of scarce resources, or “economic efficiency first”. Nevertheless, some of them like MCA discussed by van Pelt (1993) could include several non-quantitative factors to sharpen the decisionmaking criteria. EIA and many other methods are being modified to include several pertaining issues of environmental, social and economic problems that are lacking in traditional analysis. Certainly, a development activity could not cover the whole issues, and its analysis has certain limits. Therefore, all perceived benefits, costs and issues are to be acquired by considering three factors: Time horizon, system quality, and space (compare Bell et al 1999). These three factors are prime considerations before any project analysis or evaluation begins. After specifying these conditions, a project could be analyzed with appropriate criteria.

### 4.2.1 Time horizon

A project in the pursuit of an objective can bring short-term benefits but in the long term may create huge costs to the society, e.g. clearing forest for the production of more fuelwood solves the immediate energy problem but later induces negative impacts like soil erosion, etc. Such environmental impacts aggravate the problems – making it much more complex. An activity defines its objectives taking certain time horizon and assigns the values of costs and benefits according to the predefined time horizon. So, in the calculation of costs and benefits of a project or activity, appropriate time horizon has to be defined, otherwise, which costs/benefits occur when, is an uncertain question. From Figure 4.1, for time horizon $T_1$,

Cumulative impacts = $\sum_{i=1}^{i=t_1} (B_i - C_i)\, A > 0$ , where A is discount, risks factor, etc

Where, B is the benefit of all types and C is all types of cost of project i.

For time horizon $T_2$, cumulative impacts = $\sum_{i=1}^{i=t_2} (B_i - C_i)\, A = 0$

For time horizon $T_3$, cumulative impacts = $\sum_{i=1}^{i=t_3} (B_i - C_i)\, A < 0$

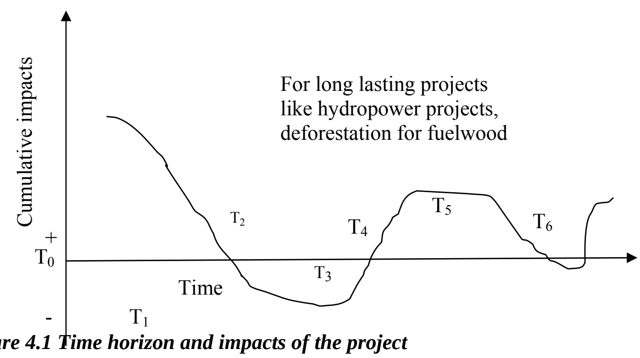


***Figure 4.1 Time horizon and impacts of the project***

This clearly shows that the consideration of time horizon makes difference in the analyses of projects, their impacts, and costs and benefits - thus decision-making and sustainability issues. In Nepal, for big hydropower 40 to 50 years and for mini and micro hydro about 20 years of project life is being considered (e.g. Pandey 1994). The project life is just the physical life of the installed system and the impacts may not be recovered just after project life. Except irreversible impacts, which are irrecoverable, other damages will also take some years to recover. There are no such data or information available for that because it depends on type of impacts and perception of time-scales and the methodology of impact assessments. "To economists, twenty years is a long time; to biologists and ecologists, half a century is relatively short time and economic and ecological consequences unfold over different time - frames" (Heal 2001:221). In any project analysis that considers the sustainability criteria, it must define the time horizon. On the other side, the defined time horizon must also be consistent with types of projects and its impacts. A nuclear power plant must take its time horizon longer because its by-products or wastes are known to have very long radiation impacts. Similarly, for MHP, its time horizon can be taken at least 20 years life of plant although most of its impacts if any would not be recoverable within 20 years (destroyed vegetation during canal construction etc.). Defining a project Qi with $t_i$ time horizon is not simple but such considerations in a project level may not be impossible and appropriate considerations are needed.

### 4.2.2 System quality

System quality is the state of the system (as shown in Figure 4.2 page 92 and Table 4.1 in page 93). An initial state or old state of a system has certain quality and by pursuing activities for better objectives or more satisfaction or to solve existing problems, the quality of a system is changed from previous state to new state. The quality of an output can be assigned positive or negative value depending upon expected out comes and previous baselines. Mostly, accomplished output is always considered to be in the better state than before within defined a boundary of indicators if activities are persuaded as planned. However, the main problem is the valuation of the state of the system quality and measuring indicators. Quality, which is always considered a relative term and benefit or costs, cannot be easily derived monetarily from a condition that is relative. It is always a perception of an individual or organization that defines the system quality qualitatively. Therefore, the output of a project has certain system quality and traditionally designated a certain amount of benefits and costs, however, there could be large number of unaccounted costs and benefits and unceasing uncertain impacts. These designated benefits and costs are being used in traditional economics to define the sustainability of a system and according to that a project or activity is commissioned.

Especially impacts of the projects have certain quality and that state has been given certain numerical values and generally monetized. However, it is always difficult to justify that, e.g. losses of fishes due to the diversion of a river cannot be given simply a value. The state of quality required has to be defined in all project analysis like considering losses of 50% of fishes as an impact quality and giving monetary value for analysis may be easier. However, if 100% fishes will be disappearing because of the project, what will be the value of fishes? Do we tag same value arithmetically multiplying the numbers? Certainly not. Because losing 50% has a different system quality than losing 100 %, and so are the values. Therefore, definition of the required system quality makes difference.

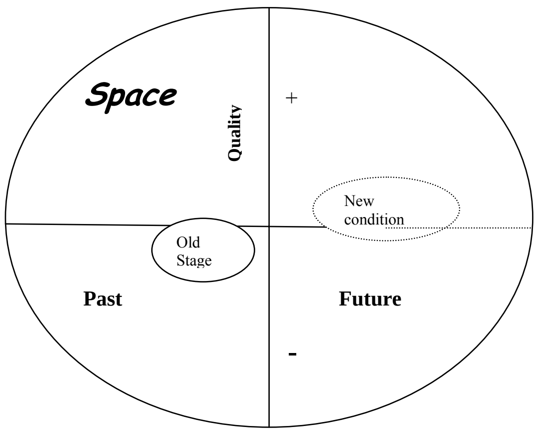


**Figure 4.2 limits of a project definition**

Moreover, in the case of MHP, the expected quality will be that MHP provides sufficient electricity for lighting, agroprocessing, replacing fossil fuel consumption and replaces or reduces manual labor for agroprocessing works, and additionally, enhances economic activities by providing opportunity to run small-scale industrial and commercial activities without any ecological damages. These are the expected system quality of MHP in the hilly and mountainous regions in Nepal.

### 4.2.3 Space or system boundary

Space or system boundary plays a bigger role in the determination of project impacts. The impacts or externalities exist even after a careful planning of project activities because of several reasons and one of them is an improper definition of a system boundary. Whenever the term sustainability appears, it explores the defined boundary of a project that has certain objectives. When an example of big dam or reservoir hydropower project is taken, old system quality is non-electrified village and new system is electrified village, if one looks at only the village boundary. Whereas in the case of river and its surroundings, the old system quality is naturally following river and the new system quality is diverted or obstructed river.

From the matrix in Table 4.1, the idea of system quality and boundary has been clearly illustrated. Assuming the example of non-electrified village in remote Nepal, the life may be hard as no electricity is available. When village is electrified, the new system quality is different or better within the village boundary (physical, social life and environment). New system quality is considered better than old. When this boundary is taken in the analysis of sustainability, the result will be positive.

**Table 4.1 System boundary and system quality**

| System boundary | | System quality –I (Old) | System quality - II (New) | Expected/ perceived impacts |
|---|---|---|---|---|
| a | Village | Non-electrified village | Electrified village | + ve |
| b | Downstream of diverted river | Naturally following river | Diverted or obstructed river | - ve |

Source: Author

If the boundary of old and new system is the river from where electricity has been generated by building dam or diverting river, then the new system quality of the down stream would be worse than before because of affected irrigation, fisheries etc. If this river system is taken only as a boundary then the analysis of sustainability shows negative. So system quality definition and its consequences are bounded by boundary. More importantly, the system boundary should not be limited to narrow space, otherwise; the analyses will bring different outcomes than the real one. Nevertheless, it is again very difficult to fix an optimal boundary in impact analysis of a project. In this works, it has been divided into two aspects of impacts, i.e. micro and macro level and within these two levels boundary has been considered- as far as possible whole system, and its direct linking components.

For the global level, the space limit is our world and time horizon is the future generations of infinite limit. On a project level, the space could be the surrounding environment; boundaries would be up to where the project can cause impacts; and time horizon would be the project running life plus the duration until its negative impacts will be diminished and original state recovered. Then system quality has to be defined, i.e. which types of system do we need. For project level sustainability, it could be projected qualitative and quantitative out-put after each project activities persuaded and accomplished.

### 4.3 Analysis and investment decisionmaking criteria in the Nepalese MHP sector

As per Squire et al (1975), the financial analysis of a project identifies the money profit accruing to the project-operating entity. It uses market or financial costs to estimate the financial viability and profits of the business firm or project enterprise. Inasmuch as Nepal is desperately inviting investors, especially in the big hydropower sectors[39], the private investors generally evaluate the project only on financial criteria, i.e. financial returns on their investment only. For the private entrepreneurs, unless restricted with rules and regulations, pure financial profit is a deciding factor. Decisions based on only financial analysis could undermine several externalities and in the extreme case, even people in vicinity[40] of the project sites and in hinterland will not have energy (electricity) supplied because of insufficient financial returns from the perspective of a private investor. Financial analysis considers only the project as a system and narrow down the boundary of impacts. It places the impacts outside the system, i.e. prioritize the hydropower project's

[39] Hydropower Development Policy of HMG/N (1992, 2001) has formulated the lucrative conditions suitable to the national as well as multination investors.

[40] There are several cases that the people in the vicinity of the hydro project site either did not get their area electrified or have waited at least decades even after agitation, mass demonstrations and protests. In Nepal also, there are numerous examples of this kind. According to Bandyopadhyay et al (1994), in Nuwakot district of Nepal, villagers in the vicinity of Hydropower plant waited about 2 decades to have electricity connected to the houses.

financial income and expenditure only and not the issues of decentralization, service to hinterland, environmental and social aspects in details. Moreover, several ecological as well as social issues linked to the people, are difficult to include in financial analysis. If such financial policy will dominate national policy and decisionmaking as well as appraising process, then the remote people of Nepal will have to wait some decades for clean form of energy – electricity. Electricity is also a basic need for the improvement of drudgery-dominated livelihoods, until other forms of energy resources abandoned due to scarcity or other economic reasons and making a way for RETs

Economic analysis is an accepted method for public projects and generally applied among the valuation methods. In traditional welfare economics, prognosticated economic value in terms of money is taken to choose optimum or best project. The economic analysis seeks to capture economic effects on overall economy, using shadow prices that reflect opportunity costs (Munasinghe 1993). External costs are also to some extent being added if they are easy to tag values by existing methods. The financial values equal economic values when there is a perfectly functioning market, which has none of the aspects of market failure (Ward et al 1995:26). However, traditional economic analysis is anthropogenic because the analysis is done only from the perspective of human welfare. Nevertheless, the economic analysis has been modified drastically by adding more issues, especially of environment. It has now also been encompassing values of traded and non-traded goods through different methods of monetizing their 'expected market' values.

The main weaknesses of traditional economic analysis are neglecting issues like intra- and intergenerational equity, issues of the carrying capacity of ecology and uncertainties that are not tied in economic returns. Traditionalists only consider uncertainty in economic rate of return but not other issues such as ecological irreversibility, climate change etc (Little & Mirrlees 1994). Nevertheless, because of sustainability constraint, such negligence are being minimized and few factors are being considered even in economic analysis (e.g. Azar et al 1996). As terminology itself indicates, financial and economical analysis consider only one aspect of project, i.e. economic components based on monetary value and only monetized part of other components. However, not all values, i.e. social and ecological values, can be converted into economic terms. There should be other components or terms including economic component in the analysis of developmental projects because economic analysis alone could not include the social and ecological analysis of the projects. That is why a holistic approach of project analysis, which encompasses these issues, is to be developed. Such methods or tools are to be applied to evaluate or analyze the sustainability promoting projects including that of Nepalese MHP sector. However, currently the MHP projects' investment are being analyzed, evaluated and appraised as per three criteria of traditional financial and economic analyzing theory that are based on discounted cost and benefits: Internal Rate of Return (IRR), Net Present Value (NPV) and Benefit Cost Ratio. The shortcomings of these methods are being discussed in following paragraphs, which could help to formulate new approach taking pertaining issues.

### 4.3.1 Internal rate of return

IRR is a purely financial decision to compare returns on investments. It allows the project's net value compared to the opportunity costs of the capital that has to be invested (e.g. Edwards-Jones et al 2000). For IRR, one needs not to be aware of even currency because this is just a rate of return on investment. IRR is interesting mainly for an investor who has certain amount to invest for a long time and he just wanted to be sure that an optimum return is assured from his invested capital. There is no multiple issues left in IRR and it does not care about other things except market interest rate because IRR must be more than bank interest rate for capital market private investors.

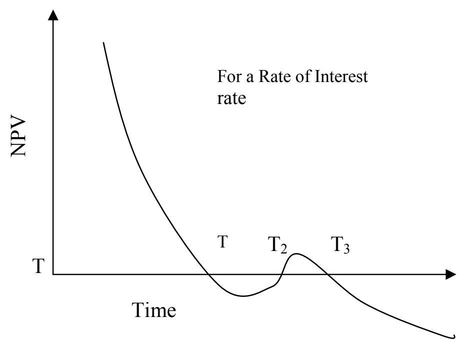


**Figure 4.3 Changing value of NPV for an interest (discount) rate r**

For Mishan (1988) there could be several IRR and some even negative because of polynomial nature of IRR equation[41]. It does not indicate the quantity of benefits or costs; there is no difference whether the investment is huge or tiny. In case of social projects like community owned energy system, the rate of return is only interesting if they have borrowed loan for investment. Because of discounted future benefits that are in monetary units, IRR cannot indicate the yield rate of investment to the society in other domains than the monetary benefits. In the case of mutually exclusive projects, i.e. diesel generator and MHP, the IRR will be defective measure of relative merits. "The economic rate of return thus may be misleading in comparing economic merits of alternative projects and should not be used for this essential function of project analysis" (Squire et al 1975). So in the case of choosing MHP projects while comparing with other alternatives, IRR is not a suitable criterion.

### 4.3.2 Net present value

The net present value criterion is generally used by private sector to know what the current discounted net benefit is over lifetime of the project. The basics of NPV is consistent with potential Pareto improvement, according to which a project is worthy of consideration provided the net benefit from the project is positive. NPV criterion does not cover the benefit distribution, basic needs or other non-monetary issues. The word 'present value' itself encompasses the attribute of discount factor which is a controversial issue in sustainability discussion (e.g. Daly 1996 & 1999, Pearce et al 1990, Azar & Sterner 1996 and Hussen 2000, Heal 2001). Take an example of hydropower project, which diverts the water from a river and make the downstream relatively dry. The flora, fauna, and other ecological function depending upon river flow will disappear slowly. People depending upon fish for their additional nutrition will be deprived of and especially children will have negative consequences on their health (e.g. Author's master thesis 1997). The immunity to fight against diseases will be decreased and later they will have to pay more for health problems but net present value method calculates the cost with discounting (if it really does) and net present value will be negligible but the expenses on health will be higher and hidden to the present calculation.

[41] For IRR $\{B_0/(1+IRR)^0\}+\{B_1/(1+IRR)^1\}+\{B_2/(1+IRR)^2\}+\{B_3/(1+IRR)^3\}+\ldots\{B_n/(1+IRR)^n\}=0$, where $B_0$, $B_1$, …, $B_n$ are the benefit streams.

Although the social benefits of a planned project have to be more than NPV, but "high net present value may reflect an inadequate search for alternative projects rather than a potentially valuable project" (Squire et al 1975 : 39). The allocated resources even in the traditional perspective, is not efficient without looking for efficient alternative project. Inasmuch as resources are allocated inefficiently, the decision based on NPV could not be said optimal even in the neo-classical aspect of efficient resource allocation for maximum welfare. According to Mishan (1988), the optimal investment period that yields highest returns of a project is also different for NPV and IRR criteria, later is shorter. This indicates that the selection of investment scheme in a project also depends on criteria used and no criterion is an optimum to other criterion. Squire et al (1975) have also given three reasons why NPV criteria is not optimum: first, the net present value does not necessarily measure the total output of the project in comparisons with the rejected alternatives; second, the definition of what would happen without the project is not altogether unambiguous; third, the size of NPV may be greatly affected by estimation of costs of primary factors. Moreover, in the case of selection of the rural energy projects, NPV criteria could favor unsustainable resources because of its limited scope of covering several positive and negative externalities. Therefore, NPV criteria would not be the optimum in the selection of MHP projects.

### 4.3.3 Cost benefit analysis

Based on a very simple concept of rationality, cost-benefit analysis (CBA) is one of the basic economic techniques or "an economists' tool" (Lekakis 2002:154) used for project appraisal, "making a value judgement" (Hussen 200:317). For few CBA, "embodies intuitive rationality" (Pearce & Markande et al 1994: 57) and is a "highest form of strategic planning model" (Ward et al 1995:145) because it "offeres only reasoned technique" and " also has a fundamental attraction of reducing a complex problem to something less complex and more manageable" (Pearce 1983:21). It is "a methodology which aims to select projects and policies which are efficient in terms of resource use" (Edwards-Jones et al 2000:122) and fulfils the criteria of utilitarian ethic because "…its methodological foundations in discounted utilitarianism" (Heal 2001:218). "CBA is about efficiency not equity" (Common 1995:169) and "…the cost benefit criterion is useful in identifying potential welfare improvements, but is not in itself a measure of 'social welfare'" (Howarth 2003).

CBA, which founded on a directly utilitarian approach to decision making, was first practiced in USA after 1936 when the Flood Control Act was implemented (Pearce 1983:14, Hanley et al 1993:5, Tisdell 1993:95, Lumley 2002: 95). The basic logic behind it was if the benefits incurred are in excess of the estimated costs of the flood control, project has to be carried out. CBA is itself intended to help decision-makers to identify projects that have more net social benefits after reducing costs i.e. projects with potential Pareto's gains. Regarding CBA and its impacts, Heal (2001) has given most sincere and vivid critics and suggestions stating,

> "Economic decisions are driving phenomena such as global warming and biodiversity loss. The decision to use fossil rather than solar energy is economic, likewise the decision to use more rather than less energy. And the changes in habitat, which lead to extinction, are also economically driven; it appears more profitable to chop down rainforests and plant coffee or cash crops than maintain them intact. So behind many of the offending dimensions of human activity are economic choices and calculations. We will not improve significantly the unsustainability of human activity unless we can develop an economic environment within which such choices are no longer attractive. In other words, we need to change 'the rule of the economic game' so that it becomes economically rational to pursue alternatives, which are sustainable. Cost benefit analysis is one of the most relevant rules of the game" (Heal 2001:217).

The main controversial issue of CBA is that its common unit is the money or in another words, money is all that matters (Hanley etc al 1993:11). Not all resources, outputs, results, impacts and goods are easily quantifiable in terms of money. Feelings, sentiments, and happiness are not easily quantifiable although several methods are being applied for the valuation of impact and non-market goods. However, it depends mainly on where it is used and how attributes are formulated and designated their values. Because of the following aspects, the judgments given with the help of CBA are subjected to discussions (e.g. Squire et al 1975, Ward et al 1995, Pearce & Markande et al 1994, Boardman et al 1996, Edwards-Jones et al 2000, Hussen 2000, Ward et al 1991, Munasighe 1993, Pearce 1983, Hanley et al 1993, Tisdell 1993, Lumley 2002)

a) *Lack of inclusion of total costs and benefits:* all relevant costs and benefits associated with the projects including externalities with *accuracy and acceptability* of valuation especially non-market and public resources,

b) *Operating functions:* inefficient allocation of resources considering faire distribution of costs and benefits and such objectives, etc.,

c) *Discount Factor:* Use of discount factor considering intra- and intergenerational equity and resource aspects

*d) Lack of inclusion of irreversibility, risks and uncertainty*: Factors that includes not only economic risks but also ecological irreversibility, climate change, etc.

#### 4.3.3.1 Inclusion of total costs and benefits

Most of the analysis of costs and benefits which even encompasses the aspects of risks of human life (in extreme case death) put an economic value for the sake of favorable decisions and interestingly most of the time, intention of putting price tag is said to be sympathetic to human life in the broader aspect to hinder anthropogenic misdeeds. Does it make sense that human beings value other human being's life and other non-market goods in monetary terms and lives of future generations too, that are still to exist? However, until an alternative exists, such value tagging could bring the economic decisions in favor of sustainability although such values are mostly designated from the economic perspectives. For Howarth (2003) where costs and/or benefits are unquantifiable, the cost benefit criterion will prove inoperational under certain conditions, necessitating the search for alternative decision-making tool.

Some intangible goods might have greater social value and market cannot value them. Therefore, it is just difficult to justify our valuations. A widespread market failure, which requires extensive use of shadow prices to replace true market price or total value, is a common constraint (e.g. Tisdell 1993, Squire et al 1975). There are different methods developed to quantify non market goods and shadow prices of market goods but they all depend on the perception of human's values, i.e. represent not real costs and benefits because human beings value as per his own interest. “This anthropomorphic set of values will not necessarily reflect the contribution made by a given species to the maintenance of the global ecology” (Clayton and Radcliffe 1996:113). But there are also versions justifying our valuation of nature as Neumayer mentioned that "nature has value only if human value nature" (Neumayer 1999:9). Question can be raised again why human being is ready to pay. Certainly, not 100% altruistically. Another factor may be due to the increasing environmental awareness, and the value of willingness to pay determined previously will be changed even without any change in income in case of public goods (or bads). The values of various goods and services from a long-run perspective also vary with different causes.

Inclusion of total costs and benefits depend on the type of values we take. As there are different types of values attached to goods, i.e. use value, non-use value and option value, and within the non-use value, there are also existence value, bequest values and option values (Garrod et al 1999, Hussen 2000, Hanley et al 1993, Munasinghe 1993). For market goods, market price is considered to reflect total value (Hussen 2000, Pearce 1983) but for non-market public goods (or bads) it's very hard to tag correct value although economists are trying to come up with anthropocentric value of non-market goods and bads (see Hohmeyer 1988, Pace 1992, EU 1994). However, for Clayton and Radcliffe, "any valuation procedure based on anthropocentric values will provide information about current fashions in human likes and dislikes, but may not necessarily provide useful information about sustainability" (Clayton and Radcliffe 1996:113). Notwithstanding the critics, the valuation of socio-ecological goods and amenities, even though anthropocentrically, will not hinder the way towards sustainability but promotes such endeavors. Nevertheless, such valuations are not perfect one, even economically.

When the energy projects are considered, things are not different from already discussed issues. Impacts are of either nature (i.e positive or negative). The values of such impacts are of different levels. The project analysis must take into account such condition while valuing costs and benefits.

#### 4.3.3.2 Discount factor

Discount factor is the mostly discussed, controversial and criticized topic while considering the sustainability aspects of resources utilization by discounting the future. The reason behind is that the future generations should not be discriminated and be given equal weight for any unit of gains and losses (Pearce & Markende 1994: 23). This is also mentioned in the well-known definition of Brundtland Report "…without compromising the ability of future generations to meet their needs"(WCED 1987:8). Discounting the future also speed up the process of resource consumption because the same resource in future is valued less than today because of human being's 'impatient' behaviors or ' social time preference' and 'expectation of being rich in the future' (e.g. Azar et al 1996, Pearce 1983). Individual's perceptions are that the present capital is productive and brings surplus in future and future is uncertain (Pearce & Markende 1994: 23, Hussen 200:319-320).

Giving logic of uncertainty for discounting the future can also be taken in the other way round. The future costs (estimated today) because of using the resources or pursuing unsustainable activities today can be several times more in future (actual cost in future) so discounting may add more the costs for the future generation. Preservation costs of our environment today are valued more than its benefits in the future because of discounting - making preservation task expensive (Heal 2001). It means, when opportunity costs of not implementing big hydropower dam project is more than discounted future benefits of keeping river valley 'not inundated', then the project has to be implemented. As Page (1977) questioned, when decisions are only based on the discounted benefits and costs criterion, it is possible to justify decisions that would lead to the virtual extinction of the future generations provided that such decisions generated higher discounted net benefits. This tendency is there because "…cost estimates [at present] are often relatively certain, while benefits estimates [occurring in future] are frequently quite uncertain" (Heal 2001:219). It can also be said in the other way round for the current environmental resource exploiting projects, the future recovery costs will be more than discounted costs, for example

| | |
|---|---|
| Non-discounted value of future cost (certain costs) today | P |
| Discounted value of future costs today | P/d |
| Extra cost for future generation because of uncertainty (presently could not be estimated by present costs forecasting) | C |
| Additional value (plus the value what present generation presumes) that could be given to resources by future generation because of increased awareness | W |

That means future generation could have the real costs of P + C + W, whereas present generation presumes the cost to them only P/d, which is not fair[42].

[42] For example, considering a hypothetical case, the future cost of diverting a river to implement a big project that makes down stream dry in summer season is about 100 million (reduced rice production, fish production/catch impacts, recreations etc after 15 years). The discounted cost now is 18.27 Million at 12% discount rate. Suppose, because of dry summer and malnutrition due to lack of fish in food the uncertain cost after 15 years is about 10%, that is 10 million – a possibility that has not been considered in present calculations. These types of costs increase with the passage of time. The future generation after 15 years will be aware of environment and give higher value to ecological matters – they value their ecology, say, by 15% higher than now, which is simple to assume as it is generally said that people give higher priority when they become aware of consequences. So in total future generation will have a cost of 125 (100+10+15) million where as present generation assumes only 18.27 million. The people of downstream do not have any concern regarding the business of the project. They cannot earn money in future from the project, or they are not becoming rich because of the project, in general. Therefore, such discounting is not making justice to the people.

These reasons for discounting are from the perspective of individual. From the community perspective, it is, as per Daly and Cobb (1994), different. Community's pure time preference is different from individuals. The community's discounting i.e. social rate of time preference varies with respect to the magnitudes of inter-temporal exchange of goods and to the length of time involved even though it has been assumed invariant (e.g. Mishan 1988:227). Sometimes community may prefer something to be available in the future than in present. Therefore, assumptions behind the 'discounting' are purely from financial and individual perspectives.

In developing countries like Nepal, the discount rate is high, but high rates of discount[43] in LDCs mean that future impacts of projects including environmental ones are to be given little weight in decision-making (e.g. Tisdell 1993:97). For Azar et al (1996) the discount factor should be negative i.e. present values of future costs of environmental and other damages are more or equal. Taking the issues of big hydropower or fossil fuel plant and its ecological damages and their irreversibility issues, discount factor must be less or negative while calculating future damage cost. Because abatement, mitigation as well as recovery costs will be expensive in the future. In addition to that, future generation being aware of environmental and health issues may put more value to ecology than the current generation presumes. More importantly, from the intergenerational fairness perspective discounting is to be, as stressed by Heal (2001), neglected for sustainability. The development projects that are not oriented only for the financial profit but also socio-ecological objectives must neglect discounting or minimize it drastically. The projects meant for socio-ecological developments are for the reduction of current as well as future bads (costs to the society) and generally focus on intra-generational issues as well. Such projects would reduce the future costs to the society, which could be increasing in the passage of time, for example, using MHP electricity to replace kerosene wick lamps – thus reducing the chances as well as impacts of the future global warming. Therefore, projects that are promoting sustainability could neglect the discounting. However, the country's average inflation rate has been considered while analyzing the MHP projects financially.

#### 4.3.3.3 Operating functions

The operating functions like economic efficiency, distribution of benefits, etc are also the deciding factors in the resource allocation in project activities. However, cost benefit analysis has only one objective - economic efficiency - and uses a form of economic efficiency numeraire to focus on static efficiency and ignores distributional efficiency (Ward et al 1995:5). If economic efficiency, which is generally the case, is given higher priority than other social goals, then the judgement of CBA may not be covering other socio-ecological issues. "We must also recognize that economic efficiency is not the only objective of society" (Ward et al 1995:9).

“A 'good' project is one where efficiency and distribution are furthered and one should choose a project where this good is 'greatest'" (Brent 1998:22.). Efficiency might not be limited to financial or economics only. Distribution of benefits wherever needed would bring higher social efficiency. If a rural electrification project has achieved its objective of providing electricity to targeted people without damaging other factors of sustainability, then it is generally considered that the project has achieved higher efficiency. However, it depends upon the goal of operating function. Daly (1996) maintained that ecological efficiency encompasses all other major efficiencies. That means to achieve higher ecological efficiency, all other efficiencies are to be at higher level. However, Azar et al (1996) gave the social efficiency, i.e. distributive efficiency a separate identity. Therefore, it depends on the objective of projects that presume and prioritize the type of efficiency to be achieved. Nevertheless, the ecological efficiency, social efficiency and economic efficiency thus overall efficiency are to be achieved at higher level for the sustainability of a project. These efficiencies depend on the factors discussed in Chapter Two. The operating function of project analysis, especially in developing countries, where environmental problems are arising simultaneously with poverty, (exactly opposite to developed country where poverty has been alleviated by exploiting previously existing environmental conditions) has to encompass all the efficiencies together and be different from developed country’s perceptions of ecological efficiency alone.

### 4.4 Analyzing and evaluating MHP projects in Nepal: Alternative approach

Inasmuch as financial and economical analysis cannot cover the whole issues related to the project and sustainability, a new approach - the sustainability analysis approach should be brought into the discussions. Because "based on economical analyses that isolate a few threads from the whole cloth of natural environment and human activity, foreign aid projects and indigenous development programs alike too often fail to discern and eradicate

[43] In Nepal, the discount rate is generally taken as 12% for MHP projects (e.g. ITDG 1997b).

the ecological roots of impoverishment" (Ekholm 1976: 185). Even though, there were several modifications in the decision-making criteria and several of them have been modified and changed to incorporate ideas and issues raised, controversy still exists (e.g. Heal 2001). Environmental impacts assessment methods are incorporating, to some extent, the aspects of environmental as well as some social objectives. An approach beyond such assessments is needed to incorporate socio-ecological perspectives into the development-planning and appraising process from its inception. Such planning and appraising exercise, with the socio-ecological capacity to serve human needs as its reference point, would generate a different mix of priorities and programs that are better than present system of planning and implementing the projects (e.g. Ekholm 1976).

Several methods are being used to evaluate the prognosticated outcomes of the projects in terms of monetary value to judge whether the project is worth taking or not, mostly by the decision makers, loan lenders and supporting agencies. The standard project analysis methods (e.g. statistical methods, dynamic methods, annuity methods, and return on investment methods, etc) are being used to decide any capital investment (e.g. Munasinghe 1993). The fact is that the standard methods are purely based on neo-classical welfare theory, which use theoretical milieu based on purely ideal condition of market that aims to maximize the benefits without considering other factors like distribution of benefits and environmental consequences. That (ideal condition) is not the case in reality in developing countries (Brent 1998, Square et al 1975, Bandyopadhyay et al 1994) like Nepal, especially in the hilly and mountainous areas. Many externalities exist in the energy sectors of Nepal. Not only the externalities but also overall living standard of the targeted people (*as Chapter Three illustrated*) does not support the traditional approach of project analysis and investment decisions. That is because firstly, market hardly exists because of isolation from mainstream markets, etc. and secondly, people are subsistence farmers and use their own production to survive. Market activities are very limited in these remote and isolated areas. In this context, the existing standard methods that are being applied into investment criteria by several authorities in Nepal (e.g. AEPC 2000, ITDG 1997) for the community as well as privately owned MHP projects are not directly applicable. Therefore, the objective of promoting sustainability cannot be achieved without modification or development of better approach that includes the issues raised and ground realities as discussed in previous sections and chapters.

### 4.4.1 Sustainability approach of project analysis

Environmental economics and ecological economics have changed the style of appraisal methods. Nevertheless, controversies and issues of completeness are still there and economic issues are deciding factors even in modified approach. Whether it is Schumacher (1973), Lovins (1977) or Daly (1999), the weaknesses on decision-making based only on economic aspect of an activity or a project has been criticized several times. Therefore, a sustainability approach should at least encompass sustainability issues and indicators for the analysis of development projects.

<table>
<tr><th>Analysis<br>Projects</th><th>Financial</th><th rowspan="2">Economic</th><th rowspan="3">Sustainable</th></tr>
<tr><td>Diesel generator lighting</td><td>Net benefit XX Euro</td></tr>
<tr><td>Big hydropower</td><td colspan="2">Net financial benefits XX Euro, YY people employed, ZZ liter fossil fuel saved.</td></tr>
<tr><td>Micro hydropower</td><td colspan="3">Net financial benefit XX Euro, YY people employed, ZZ fossil fuel saved, EE Environmental benefits of reducing CO2 and other pollutants, SS social benefits of distributing project income, empowerment through decentralized system and its development process, fulfillment of a basic needs of lighting, X% of people have access to electricity and tariff fixing process, YY% of employee are women, etc.</td></tr>
</table>

**Figure 4.4 Conceptual example of project analysis aspects & coverage of issues**

Source: Author

Considering an energy project in Nepal- the different analysis could be illustrated with the help of a matrix as shown in Figure 4.4. If the objective of an energy project is to provide electricity to a community then there are several possibilities. If a diesel generator is to be installed by a private entrepreneur, the financial analysis shows viability of the project. Because of consumption of imported fossil fuels, its environmental impacts and regular burden of managing fuels, community based diesel power plant hardly exist[44]. A privately owned system also rarely encompasses social issues. However, the case would be different

[44] Resource intensive system, i.e. based on imported resources that are consumed daily and regular maintenance work based on a complicated technology, diesel generator for electrification cannot be feasible as community owned system and such examples are seldom available. Whereas MHP based on appropriate technology and indigenous skills can be operated under a community management system, there are hundreds of examples not only in Nepal but also in other parts of the world.

with different technologies and types of ownerships. If a decision on energy projects has to be taken, the possibility of covering issues by different type's energy projects in Nepal is being illustrated in Figure 4.4.

In the case of Nepalese MHP sector, whether for the project planning, appraisal, decision-making, or evaluation, the sustainability dimensions are to be analyzed considering (as shown in Table 2.2) the following issues:

- resource burden, i.e. import burden, economic sovereignty,
- decision-making dependency, empowerment, micro and macro level economic activities, etc.,
- ecological perspective,
- environmental and economic impact to the society, drudgery reduction, health impacts,
- types and quality of services provided in each aspects to the society to fulfill their needs and,
- factors that are helping to enhance sustainability in micro as well as macro level.

The approach of sustainability analysis must encompass the issues raised in other analysis in one side, and on the other side, must be feasible, operationalizable and acceptable. The following statement provides guidelines while formulating such approach.

> *"In order to fulfill human needs for a growing population, the resources and services obtained from nature must be used efficiently within the society. Socially, efficiency means that resources should be used where they are needed most. This also led to the requirement of a just distribution of resources among human societies and human beings" Azar et al (1996: 92).*

### 4.4.2 Framework of sustainability analysis of MHP projects

Availability of resources indicates the potential of a country for sustainable development although most of the countries are having limited resources to be used sustainably. However, the availability of resources abundantly alone is also not leading the country towards the sustainable development. "The basic economic problem facing all countries is that of allocating inherently limited resources to a variety of different uses in such a way that the net benefit to society is as large as possible" (Squire et al 1975:4) without having any negative impacts. Although, "the central goal of neo-classical economics, efficient resource allocation, is only the fourth goal of economic policy in a hierarchy of different objectives" (Hohmeyer 1997:66) in the sustainability aspects. For Hohmeyer, scale, inter- and intra-generational equity and internalization of externalities hierarchically come before the efficient allocation of resources[45]. The limited resources are allocated only after devising the sustainability constraints to each sustainability dimensions. The scale, distribution and carrying capacity would be incorporated under these dimensions as discussed in Chapter Two. The projects' aim would be the rational use of resources (not only economic but also natural as well as social resources) according to constraints devised and simultaneously, accomplishing the final aim for the pursuit of fundamental objectives like alleviation of poverty, reduction of inequality, betterment of living environment and maintaining nature's life support system.

The physical as well as economic resources are also scarce. Therefore, the task of any analysis, which encompasses the rational use of resources for diverse social objectives, is to assist decision making in prioritizing the objectives to allocate the scarce resources in most effective way. In this regards, analyses and appraisal of the projects are very critical because of their diverse objectives and social responsibilities. If resources are allocated to unsustainable activities then its impacts are multifold for poor countries because used resources bring negative results in one side, while on the other side, other needy sectors will be deprived of resources and deteriorate further[46]. Considering the examples of large-scale water resources in Nepal, which are limited (if one looks feasible sites that can be utilized in sustainable way), sustainability rules for water resource consumption may apply. Because once a hydro plant is built, which is not sustainable and may have impacts on other sustainable - feasible sites too - making them non-feasible for the future use. "Resources or assimilative capacity we overuse or damage today will not be available for future generations" (Hohmeyer 1997:66). A good example will be the case of Jhimruk Hydroelectric Plant (12 MW) in Nepal, which has been diverting a river making water shortage for fertile agriculture fields in the down stream, where a possible site with minimum impacts, would have been developed about 25 km down from the current site (Author's master's thesis, 1997). The possibility of another plant at that site has been reduced. The unsustainable uses of water resources (or other resources) may have impacts

[45] For Daly (1991) the optimum allocation comes third in hierarchy after optimum scale, just distribution from the sustainability perspective.

on other (or alternative) projects, which could have been relatively better and meet certain criteria of sustainability. Therefore, it is necessary to device sustainability approach for the project before allocating scarce resources.

In real world, a project is carried out choosing best alternative when there are net benefits. But "the nature of choice itself is in flaw because it is based on 'preference maps' and not on reasons, beliefs, hopes, habits, character traits, principles, promises and values" (Lekakis 2001: 151). The main issue is how to make a choice, analysis, decisions or evaluation with the following constraint that will promote sustainability.

- equity oriented but economically sustainable,
- ecologically enriching but availability of 'acceptable' or 'adequate' level of consumption of facilities and services, and
- conservation of critical resources but improved accessibility of the 'community'[47] in decision-making for the future courses of actions and choices.

Using renewable resources has also to be consistent with sustainability constraints. There are few such 'normative' criterion or approaches, for example, Heal (2001)'s 'green golden rule', or Chichilnisky's 'non- dictatorship path' or Enquote-Commission (1997)'s 'management rules'. For the project level such criteria are vague and very difficult to set and are complex to generalize. However, there are also views that the sustainability constraint should not hinder the project implementation. They argue, if projects are rejected based on such reasons, "the world would be a very primitive place" (Little and Mirrlees 1994:213). Little & Mirrlees opined that whether a project is sustainable has nothing to do with whether it is desirable. Nevertheless, if any projects are unsustainable then why such projects are desirable? Pursuing a project means bringing net benefits but if it is unsustainable then there will be more social costs than the individual benefits. In broader sense, this clearly illustrates the misunderstanding of sustainability aspects of any project analysis. If a project is sustainable, then it brings net benefits based on the sustainability criteria and promotes sustainability.

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[46] For example providing resources to subsidise kerosene is misallocation of resources as kerosene, in case of Nepal is an unsustainable resource and has several socio-ecological burdens. On the other side, because of misallocated resource (fund), the country would not be able to finance MHP which could be a sustainable system for the rural and remote people and have positive effects like development of better health facilities etc and absence of such activities, livelihood would be deteriorated.

[47] Community has been defined by Daly and Cobb (1994) and Warburton (ed.) (1998), with several examples, group of people living or working together, etc.

Taking examples of Nepal, water resources are renewable resources (if we do not take climate change and its impacts on Nepal's water resources into account although IPCC (2001) TAR has indicated such possibilities in the region). Except physical system and components of the MHP plant itself, which consume depletable resources, energy-generating resources are renewable. Analysis of such projects at the local level or the community level has certain sustainability constraints. Nevertheless, analysis of such development process has also certain limitations because of the scale of the projects. A tiny project could be demanding huge analysis if constraints and criteria are too broad and vague. A big hydropower with a dam and a MHP must have different scales of analysis otherwise decentralized and labor-intensive technologies will not have equal weighting because of analysis costs[48]. So sustainability analysis and its constraint should be designed according to scale of projects, their spatial impact potential, etc.

The multi-criteria analysis discussed by van Pelt (1993) and AMOEBA approach by Clayton et al (1996) as well as Bell et al (1999) incorporates some issues of the sustainability analysis at the project level. Nevertheless, the economic component was still the major decision-making factor and sustainability was only one of the constraints in these processes[49]. On the other side, it was not mentioned clearly, how a decisionmaking process would follow the rule in operationalization and implementation. In this dissertation, the sustainability analysis approach that includes the three dimensions of sustainability is discussed with the empirical data based on the MHP projects in Nepal.

The sustainability analysis is not a reductionism approach of narrow scientific methods because "sustainability is not a single thing" and "sustainability is not an absolute quantity to be measured" (Bell et al 1999:100). Nevertheless, a controversy can surface once the analytical results from such holistic approach are vague because of immeasurable and multi meaning nature. It is said that systematic approach covers the 'whole'. Within the 'whole', a reductionism approach could be applied to analyze its components individually and illustrate the combined results of such components to analyze sustainability. Holism could cover all aspects but could be branched to go in depth so as to reduce or avoid the critics of vagueness. Nevertheless, analysis of components like economic, social and

[48] However, developed sustainability analysis method for MHP encompassing major issues would be applicable to other MHP projects, thereby reducing such costs.
[49] Van Pelt (1993) does not include *equity* criteria within the sustainability constraint. From his perspective, sustainability would be something that has to do with economics and ecology only.

ecological might not cover the whole system because, as per Clayton et al (1996), a system has several facets and other unknown and complex components or behaviors as shown in Figure 4.5. However, analysis of three components (or dimensions) could cover largely the issues of sustainability of a system or a project as other system components are unknown, complex or may be non-existent.

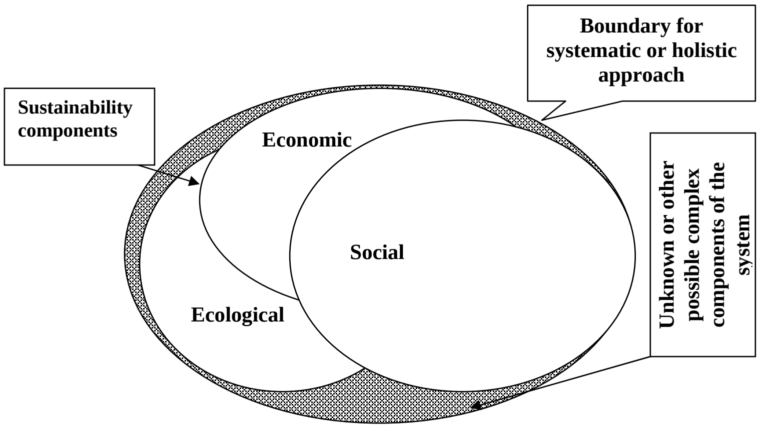


**Figure 4.5 Sustainability components and system**

Whatever the theoretical and conceptual discussion on sustainability means, without operational definitions, it is hollow and vague. Operational definition needs criteria to proceed, analysis for appraisal and indicators to target the achievements of the objectives. Sustainability issues are sometimes confined with economic as well as environmental issues only. Daly (1991, 1996, 1999) and others have emphasized sustainability mainly from the perspective of two capital: natural and man-made at the project level. Pearce et al (1989) and Barbier et al (1998) have tried to establish a weak and strong sustainability constraint by including environmental costs and benefits only through 'compensating projects' that neutralizes the environmental costs at the programme level. From their perspective, sustainability conditions can be incorporated in the traditional analysis of projects – CBA and tried to prove that incorporating sustainability constraint is possible if environmental costs and benefits are valuated properly. However, this is not a complete sustainability constraint because of absence of social aspects on one side, while on the other side, monetization of environmental values are difficult, as Pearce et al (1989) themselves discussed, due to the several reasons. Even if valuation is done through participation of the present generation, it is still not a consensus of the society because the future generations are not there (e.g. Clayton et al 1996).

However, at the project level, individual dimensions could be analyzed even without monetized value but comparing old and new state of the project periphery. Nevertheless, if social issues as well as ecological issues were incorporated into "the compensating project" rule, at the project level, the sustainability constraint in project appraisal or analysis would be consistent with sustainability definition. As per Pearce et al (1989) and Babier et al (1998), for the strong sustainability criteria with 'compensating' or 'shadow' projects (j=1, …, m) in addition to portfolio of the projects (i=1, …, n)

$({}_i\Sigma Eit - {}_j\Sigma Ajt) \leq 0$, for all value of t.

Where Eit is the Environmental costs of the projects and Ait is the benefits of compensating projects. The condition should be that the projects must maximize returns such that

${}_i\Sigma(Bit-Cit-Eit) \geq 0$, that is ${}_i\Sigma(Bit-Cit) \geq Eit$

Where B is benefit and C is the cost. Let us assume that the net benefit, which is benefits less costs, is the quantitative indication of development (D), then

$Dit \geq Eit$

That is, when there is excess economic development, which is accomplished after compensating environmental costs then the project could be implemented. This is certainly a condition in line with Pareto optimal criterion that has been questioned several times (e.g. Rawls 1971). The compensating project approach discussed by Pearce et al (1989) and Babier et al (1998) does not cover the equity aspects. If a diesel power plant is installed near a residential area of the plain area of Nepal, as per compensating principle, a MHP of the same capacity can be installed in a hamlet of the Himalayan valley. If $CO_2$ emissions from diesel engine in residential areas are compensated by the MHP, then as per Pearce et al (1989) and Babier et al (1998) sustainability is achieved. The above-mentioned condition considers only macro environmental issues, a major constraint for sustainability. However, in real sense, the macro level environmental aspect would be only a facet of sustainability. Pearce et al's condition for sustainability in the analysis could be modified as

$_i\Sigma[B(Enc+ Ecc+ Soc)\ t-C(Enc+ Ecc+ Soc)\ t] \geqslant 0$

Where Ecc, Enc and Soc are the ecological, economic and social capitals; i=1, 2, 3…n projects and t=1, 2, 3…nth time horizon of the projects. However, the individual project[50] should also fulfill the above-mentioned condition based on the defined system quality. Going to the individual project level to satisfy the sustainability constraint means totally changing the idea of compensating project. So compensating approach will be meaningless if it is considered only at the macro level[51] in that sense. Therefore, sustainability analysis would be

$_i\Sigma[B(Enc+ Ecc+ Soc)t-C(Enc+ Ecc+ Soc)\ t] \geqslant 0$

such that $_i\Sigma[B(Enc)\ t-C(Enc)\ t] \geqslant 0$, $_i\Sigma[B(Ecc)\ t-C(Ecc)\ t] \geqslant 0$, $_i\Sigma[B(Soc)\ t-C(Soc)\ t] \geqslant 0$ conditions should be fulfilled for the complete sustainability for all value of t. The condition, that is net benefits, obtained from the three components individually less costs incurred in those components should be greater than or equal to zero for defined project space-i (i = 1, 2,…, n) and time horizon-t (t = 1, 2,…, n,….). The space and time would have to be defined as per the project's possible impacts, and benefits and costs are obtained after defining the measuring indicators of analysis based on system quality, as discussed previously.

In the sustainability analysis of a MHP project, wherever applicable, input capital and output capital of three components have to be valuated and analyzed separately (see figure 4.6). If that project fulfills the criteria set by the complete sustainability, then the project is promoting sustainability of the system, region, community or the country respectively in different scales. Mathematically,

$$[_t\Sigma[B(Enc)t-C(Enc)\ t] \geqslant 0,$$
$$_t\Sigma[B(Ecc)t-C(Ecc)\ t] \geqslant 0,$$
$$_i\Sigma[B(Soc)t-C(Soc)\ t] \geqslant 0] \qquad \text{Eq (4.1)}$$

[50] Or set of projects within micro level boundary- for example, 15 trees are to be cut down to built power house of a MHP plant and planting 30 similar types of trees in the vicinity.

[51] However, if micro level compensating approach is considered, that could be acceptable in certain conditions, i.e. cutting the trees of near-by residential areas and planting more than the amount cut down and similar types of trees in the surrounding areas of the village. However, a govt could implement such macro level policy looking to the macro level impacts but those projects would not be sustainable at the micro level.

For complete sustainability, net benefits must be greater than or equal to zero[52] individually in all dimension of sustainability because "under the sustainability criteria, minimum amounts of different types of capital [*economic, ecological and social*] should be independently maintained, in real physical and biological terms" (Ayers 2001: 160 *emphasised, see figure 2.3 as well in Chapter Two*).

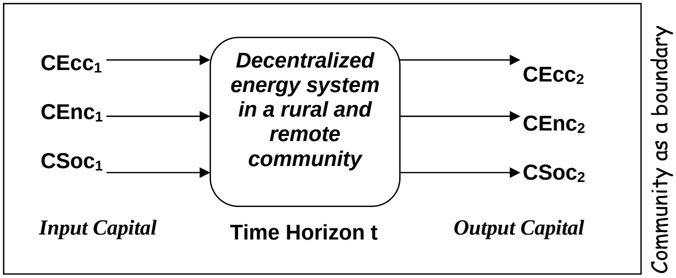


**Figure. 4.6 Input and output capital to an energy system within a defined boundary**
Source: Author

By taking a community as a boundary in the analysis of the community owned MHP projects, sustainability at local level could be examined. Since "regional sustainability and national sustainability should be consistent with global sustainability" (Ayers et al 2001:167), community level sustainability must be consistent with the regional or the national level sustainability. If in analysis, a MHP system is satisfying the criteria of community level sustainability then it would be consistent with the national as well as the global sustainability, provided the boundaries of their impacts are taken into account properly (i.e. impacts of CO2 etc.). However, the macro level issues or impacts are also to be included in each dimension of sustainability, so that it could be exemplified how MHP is promoting sustainability of the country. So for the macro level analysis the country's national level indicators would be guiding the analysis taking national level boundary (i.e. job creation, trade balance, import reduction etc.).

[52] The question can be raised on how an activity or a project can bring the change (output –input) that is always greater than zero although the laws of thermodynamics state that it is impossible to achieve something without losing part of that. Nevertheless, a project's outputs are not always measured in the physical quantities, but measurements are in different scales.

## 4.5 Factors to be considered in the sustainability analysis of community owned decentralized MHP projects in Nepal

In the above discussions, it has been raised the issue of traditional analysis dominated by financial and economical perspective, which could not encompass many sustainability issues that were raised in previous chapters. However, economic as well as financial aspects of the project could be also the part of project's sustainability analysis. The idea of economic efficiency was central to welfare economics, which was the branch of theory developed to justify a social change (or public involvement) in the private economy (Brent 1998:16). Although this theory dominates the current practices or analyses of developmental projects, there have been already arising critics since sustainability discussion surfaced and few alternative or modified analyses are also immersed (e.g. Pearce 1978, van Pelt 1993, Pezzy 1992). There are also issues raised about the analysis methodology (or analyzing tools itself) by these discussions. Mostly CBA was put into in-depth analysis and either few modifications on existing analysis was recommended or development of alternative analysis were suggested. Clayton et al (1996) brought up the few broader aspects on systematic approach of assessing sustainability. However, the focus of the discussion here is to develop a sustainability analysis or evaluating tools for the development projects, especially in developing countries like Nepal, and more specifically decentralized MHP projects in Nepal.

Community owned micro hydropower projects that are mainly meant for socio- ecological as well as economic development could not be analyzed as private enterprises oriented only for financial profits. Therefore, sustainability analysis of MHP projects should include the following major factors:

- financial viability,( at least to get return on people's investment cost -more on this will be discussed in Chapter Six while analyzing the economic dimension of project in Chapter Seven),
- equity and fairness (encompasses basic need factor and distribution factor),
- risk, uncertainty and climate change factor and
- externalities of rural energy use (will be discussed in Chapter Five).

### 4.5.1 Equity and fairness considerations

The "poverty" and "stubbornness" of individual as well as of society is causing unsustainability. And semantically, poverty is the metaphor of inaccessibility or lacking of basic needs whereas stubbornness is the negligence and selfishness, in our previous discussions. For Rodgers, "…many attempt to delude and comfort themselves with the belief that the poor are the victim of their weakness. Elaborate myths about the poor are perpetuated by the mass media, written into textbooks and transmitted from one generation to the next" (Rodgers 1979: 209). Poverty, a deprived off condition, morally as well as from the perspective of equality is not wanted situation. "It may be expedient but it is not just that some should have less in order that other may prosper" (Rawls 1971: 15). So at least "primary goods" based on community's necessity is to be provided. "All social primary goods-liberty and opportunity, income and wealth, and the bases of self respects- are to be distributed equally unless an unequal distribution of any or all of these goods is to the advantages of least favored" (Rawls 1971:303). Well-known assertion that poverty has strong causality with unsustainability could also justify the case of the fulfillment of basic needs. Because without solving the causes of degradation of any sustainability components, sustainability could not be achieved as "the concepts of sustainability (something enduring into the future) is applicable not just to the environment or environmental economy, but to society itself" (Jacobs 1999:37).

The goal of maintenance of well-being of human being is seen from the different perspectives. From the development perspective it is the meeting the basic needs, whereas goal of environmental sustainability is "the unimpaired maintenance of human life-support systems- the environmental sink and source capacities" (Goodland 1999:709). However, both goals are interrelated – one cannot be achieved without achieving the other. Finally, three essential things needed for people: to lead a long and healthy life, to acquire knowledge and to have access to the resources needed for a decent standard of living before she or he has other opportunities (UNDP, 1995). Without providing basic needs, provided opportunities could not be equally distributed, as those lacking basic needs would be dragged into the poverty alleviation measures only. Importantly, "an equality of opportunity must enhance the opportunities of those with the lesser opportunity" (Rawl 1971:303).

In case of Nepal, "poverty is primarily a rural phenomenon that largely exist in remote hills and mountains" (Dahal 2000: 23). Opportunity, to alleviate such poverty, will be enhanced once a catalytic agent of existing situation improves. Existing situation would have several prerequisites. Among them, especially in the rural areas, electricity is several times quoted as catalytic agent of rural development and rural development, in general, thought to be providing several opportunities (e.g. Pearce 1987, Munansinghe 1990, Lovins 1977, REDP 2001). Access to opportunity would have positive causality to meet basic needs. On the equality aspects of basic needs, adequate amount of energy for cooking, heating, and lighting would be needed for a decent standard of living to rural poor as well. Yang (2003) has also discussed the impact of rural electrification projects in China and concluded that the intervention through investment related rural electrification and consumption of electricity has strong relationship in poverty reduction. Not only that but also the transformation or enhancement of current subsistence living condition is also essential (e.g. Bajracharya 1986). Enhancement of livelihood and drudgery can be done through several means but providing access to clean energy is one of them. In the case of rural renewable energy projects, basic needs, and equity issues are being brought into discussions based on the above-mentioned milieu.

As small fraction of Nepalese population is enjoying facility from the state[53], a marginalized large populace is deprived off access. This is clearly a case of poverty because "when in poverty one is deprived off certain essential or basic needs" (Brent 1998: 225). So considering the conditions of the remote rural poor of Nepal, analyses of any rural renewable energy development project like MHP must include several factors and some of them will be discussed in the following sections.

#### 4.5.1.1 Basic needs factors

The question of basic needs came because not all people of our society are having sufficient means or access to be in the subsistence level – a case of deprivation. This condition is generally said to be “poverty” because “poverty is, of course, a matter of deprivation” (Sen and Dreze 1999: 22, also Brent 1998:225). “The poor are those people whose consumption standards fall short of the norms ...” (Sen and Dreze 1999:9). In general, to define consumption standards is very difficult and it depends upon several factors like the region, society and time horizon. Nevertheless, for the given region, community and for the given time, individual’s minimum needs can be roughly defined or measured.

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[53] The grid based national electricity utilities are still state undertaking in Nepal.

For Max-Neef, any human need that is not adequately satisfied reveals a human poverty. In the case of energy or especially of electricity, how much is needed can be defined from the several references like the existing patterns of living standards. Hardly few people live without any short of lighting equipments or appliances of either primitive or modern types. Household consumption survey of Rural Nepal 2000/2001 by CBS (2002c) found that almost all people of surveyed areas are using different energy resources for lighting and 81% of them are using kerosene as a fuel mainly for the kerosene wick lamp. This indicates that lighting is a basic need for the present society of Nepal. The question is, how much is needed? But, at least one kerosene wick lamp and one pair of dry cell battery is needed- or these could be replaced by one/two electric bulbs[54]. This assumption is more appropriate while discussing the basic needs of energy for lighting.

For Lovins (1977), the questions of energy strategy are not mainly technical or economic but rather social and ethical. “If [energy] poverty is to be considered a social issue, there is no alternative to including [energy] poverty as a separate factor that is part of project appraisal” (Bernt 1998:281). Rural energy development or rural electrification should be handled as basic needs comparing with education and health programs. One has to link those basic needs with other factors so that project’s viability is rightly evaluated based on the facts and such endeavors are justified explicitly rather than implicitly. Providing basic energy needs is one of them that have to be taken into account. In this chapter, we consider minimum amount of lighting from ‘clean’ electricity or other renewable resources is a basic need that is needed to remove at least one or more components of poverty.

The World Bank (1996) mentioned that it is committed to alleviate the "energy poverty" of large portion of developing world's rural population. This indicated that the WB has accepted that energy is a basic need, which has to be considered like food, water and education. As in Chapter Three, it has been discussed about the minimum energy required to human beings, electricity to rural Nepal is part of that which makes their life better than before. Improving energy supplies could contribute to the alleviation of certain characteristic problems of rural areas (see Chapter Six too) because the conventional energy strategies fail to help meeting the basic human needs for the poor in developing countries.

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[54] Can be verified from survey data of ten VDCs in different parts of Nepal, see **Annexes**.

If the objective is to supply energy (electricity) that is partly to fulfill the basic needs of rural and remote people then the basic needs factor[55] has to be considered while analyzing the benefits and costs of investment and subsidy because the exclusion of equity aspect in analysis is the problem with the traditional analysis (Lumely 2002). "From a general perspective, welfare objectives concern the attainment of certain level of literacy, housing and health standards, etc. Such goals will be fulfilled to the extent with which a relationship between them and the provision of electricity can be established" (Aguado_Monsonet et al 1997:9 and also compare Goldemburg 1995, Elliott 1997, Hourcade et al 1990, Templet 1996). That is why, in any decision-making activities, process, or methods, the developed biases based on basic needs, are set in such way that they reflect the fundamental socioeconomic objectives of the society. Providing electricity through renewable technology fulfills such objectives.

Basic needs factor in the case of electrification through decentralized system could be calculated by taking rural electrification case of the few villages in Nepal. The immediate electricity demand of rural Nepalese is about 100 watt[56] (on the average) per household for an average of 6 hours per day for lighting. If basic needs of lighting of the rural masses have to be met with centralized plant then the cost will be high due to expensive and long transmission (e.g. Schramm 1993, Pandey 1994). Decentralized small scale and environmental friendly system could be more appropriate in such cases. Because the simplest way of integrating basic needs criteria into project appraisal is to use the cost effectiveness approach where one first assumes that a particular objective is worthwhile, and then tries to obtain the benefits at minimum cost (Brent 1998). On the other side, basic needs of electricity have to be fulfilled giving equal opportunity among the citizen from the intra-generational equity perspective. The poor people are far from the place where centralized system reach, only available alternative could be small-scale isolated systems like MHP. If decentralized systems are ecologically not problematic then they can fulfill the objectives. Therefore, the basic needs factor has to be included in the analysis of decentralized sustainable community owned systems.

Assuming the basic needs is the function of several attributes.

[55] Brent (1998) assumed that the basic needs factor consideration itself encompasses distributional factor in it. However, this assumption is only partially true because distribution objective aims to fill the gap between rich and poor where as the basic needs objective aims to provide at least subsistence level of requirement to the poor and needy. Distribution is related to inequality and "inequality is fundamentally a different issue from poverty [lack of basic needs]" (Sen & Dreze 1999:14).

Basic needs $Y = f(x1, x2, x3, \ldots xn)$. Minimum 'unit[57]' of lighting is also a basic need and let us say it is x3. If people are having x3' units of lighting ($x3 > x3'$) or they are paying more for x3 units of light after new situation than they were paying before, then the basic needs factor has to be calculated. Let's assume that people had paid P units of money before and now for the same 'units' of lighting they are supposed to pay P' (P' is the price of units of lighting as per traditional economic analysis), provided that $P' > P$ (If $P' < P$ then it is not necessary to consider the factor). And their willingness to pay for the new situation might be P"[58]. That means there is a factor between P, P', and P". It is always easy to calculate such a value in quantitative terms. From this assumption, the basic needs factor ($\delta$) needed for the sustainability analysis of the rural electrification projects like MHP, can be calculated as

$\delta = P'/P$ or if $P'' > P$ but $< P'$ then $\delta = P'/P''$

Let us assume that basic need of electricity for the time being be 100 watt per family on the average. Minimum requirement of electricity is to be provided even if there is no positive financial gain but other environmental and social gains after replacing fossil fuels. Let us assume in a village, X amount (assume in watt) of electricity from a MHP has been produced. As per basic needs criteria X' amount of electricity is needed to meet the basic needs[59] of the people independent of their 'income status'. The rest amount of energy has to be charged or priced as per the 'real price[60]' of electricity. People who are using more electricity (more than basic needs) in the community have to be priced based on real cost by the community themselves. In an analysis, the revenue generated by such projects could be calculated as

Income or revenue of the project is to be calculated = Unit price $(P) * X' * \delta + P' * (X - X')$

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[56] e.g. from REDP/UNDP projects data collected by the author and CES (2000).

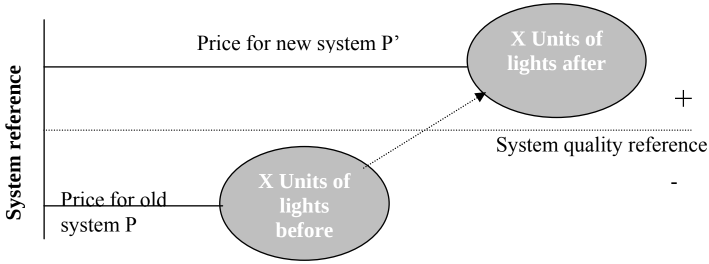
[57] Here the unit does not mean kWh or capacity of appliances but the number of appliances that are replacing the old one, for, at least, same amount of needs.

[58] In reality P" should be at least equal to P because of the new situation that provides better lighting, and from neoclassical perspective more utility theoretically.

[59] This means at least minimum of electricity needed is at subsistence level.

[60] To find the real price, all externalities have to be internalized. In this case, for the sake of calculation one can assume the price from traditional analysis although it would be different once externalities are internalized.

**Figure 4.6 Old systems and new systems of lightings and respective prices and quality**




When 'electricity – using' level is subsistence then the basic needs factor giving extra weight is justified[61]. The reason why lighting (energy for domestic lighting) has been dealt as a basic need has been already discussed. Now the question is why electricity is taken as a basic need. Why can status quo not be maintained in the domestic lighting? The answer is simple. In this chapter, the discussion is focused on the replacement of lighting source with a sustainable resource. People are and were using only for subsistence level of lighting, they are being provided better and sustainable source of lighting after the project has been implemented. There are also critical warning that such basic needs consideration may jeopardize the analysis (see Nash 1978:23). Nevertheless, energy for basic lighting is not a means for luxury and basic needs factor is considered only for subsistence level of lighting[62]. Here, the discussion is on a need of a subsistence level and replacing unsustainable resources by better and sustainable alternatives, which could bring other benefits explicitly as well as implicitly.

### 4.5.1.2 Distribution factors

Intergenerational equity was quoted several times while referring sustainability issues. May be because of that Heyes et al (1995) criticized mentioning, "it may be that those

[61] Chapter Seven empirically illustrates the concept while discussing the subsidy.

[62] The following sentence of Sen (1989: 45) reflects a strong point: " A thoroughly deprived person, leading a very reduced life, might not appear to be badly off in terms of the mental metric of unility, if the hardship is accepted with non-grumbling resignation. In situations of long-standing deprivation, the victims do not go on weeping at the time, and very often make great efforts to take pleasure in small mercies and to cut down personal desires to modest – "realistic" – proportions. The person's deprivation, then may not at all show up in the metrics of pleasure, desire-fulfilment etc., even though he or she may be quite unable to be adequately nourished, decently clothed, minimally educated and so on".

embroiled in the environmental sustainability debate have become so obsessed with intergenerational equity that intragenerational equity consideration has been swept under the rug" (Heyes et al 1995:3). Most of the strong sustainability definitions focus mainly on future generations (e.g. Daly 1999, Pearce et al 1990).

The question is why intra-generational equity aspects are being given less weight in sustainability issues[63]. Nevertheless, even before issues of sustainability flooded, John Rawls (1971) in his theory of justice has given due attentions to intragenerational equity. Providing electricity does not mean that people are being given equality on all aspects. However, electricity could provide opportunity to do several things from which each individual would accomplish better status.

In my opinion, the intragenerational equity problem is politically as well as economically complex in implementation because they (equity problems) are real and any efforts to solve such issues will have results within the current generation and everyone will judge efficacy of such efforts. Economists and politicians could have realized that the great risks have to be bore in such equity theory. Whereas, in intergenerational equity theories fewer risks have to be bore by the economists as well as politicians. Because the future generations are not there and the outcome of such endeavors could not be judged by the current generation. Critically saying, that could be one of the reasons behind focusing only the future generation by many proponents of sustainability. In the similar context, rural energy development or rural electrification could be one of the major areas where intragenerational equity has been given less weight in lots of countries[64]. Nevertheless, after the development of renewable and alternative energy technologies, the rural people have been given a focused attention. Behind such endeavors, there could be several reasons hidden but the pace of the development of renewable energy and momentum of providing energy to rural people came simultaneously, at least in developing countries.

Because of the issue of prevailing inequality and huge gap in living standard of the people of different regions, it is necessary to develop optimum and acceptable methodology for making intragenerational equity aspect operational even in policy level. "As with markets and regulations, equity requires socially sanctioned rules and norms that guarantee that the

[63] Although Azar et al (1996) and few others have focused this issues strongly.
[64] Urban people are using electricity since several decades even in poor countries whereas the rural masses have to wait still more decades, e.g. in Nepal, part of the capital city was electrified in 1911 but even after more than 90 years, only about 20% people have access to electricity and most of them are from urban areas.

final distribution of power and responsibilities is socially sanctioned" (O'Riordan 1998:111). For such a distribution, an acceptable policy is required. Because any theory, policy or "public subsidy or intervention requires socio-economic justification" (Cecelski 1996:5). Any intervention without justifications is vague and liable to criticisms.

This is what exactly is discussed here. Rural people's access and command need to be enhanced to have command over sustainable energy system. The people who can pay full cost of energy supply often reside in different parts of the country from those with the greatest need and if the concept of fairness are introduced to government policy and into allocation of scarce resources, micro hydro power meant for remote electrification is likely to have an important role in spreading the access to electricity even if users cannot pay the full cost (e.g. Khennas et al 2000).

Centralized system generally neglects the losers[65]. Whereas decentralized system relatively covers all stakeholders[66]. On the other hand, "there may be real differences in the benefits and other social and economic effects of decentralized compared to centralized electrification" (Cecelski 1996:5). Schramm (1993) has also mentioned that the network (grid) electrification, generally, is premature and expensive for rural areas to satisfy basic needs for energy. That is why, a simple logic is: even "if two policies have the same total costs and total benefits, one might argue on equity grounds that the policy that does more for the poor should be preferred" (Kniesner et al 2000:4). Taking these aspects into account and distribution aspects of decentralized energy systems, a weighing system be developed. Distribution factor generally used in project analysis with the objectives of incorporating considerations to reduce the gap between the rich and poor would be useful in sustainability analysis of the decentralized systems.

The distribution factor covers several facets and the reasons why such factor is needed in sustainability analysis of the decentralized MHP projects are discussed in the following paragraphs:

a) Utilization of big hydro is strongly influenced by urban and plain's (in case of Nepal, its Terai region where almost all industrial activities are concentrated) industrial and

[65] Assuming that all possible stakeholders are not being served equally- in the case of big dam hydro sometimes affected are also not getting electricity and such examples are plenty in Nepal as quoted by Bandyopadhyay et al (1994).
[66] This has been observed in the community owned MHP programs meant for rural electrification; all households of the communities are having access to electricity.

economic interests in one side and on the other side such investments in hydro sector in the mountains bring very few changes in the mountain communities and are far too marginal in a quantitative economic sense (Bandyopadhyay et al 1994). As Bandyopadhyay et al further exposed the unbalanced benefits of the big hydro mentioning that the urban societies and industries have been the beneficiaries while remote mountain societies and hinterland subsistence farmers have to bear much of the costs. From decentralized systems managed, run and operated by the communities the above-mentioned issues will be avoided.

b) The important equity question is that the remote, hinterland and mountain communities have a greater right to have a say and benefits from mountain rivers. There is also weight in the argument that people in remote and rural locations 'deserve' electricity as much as poor people in other parts of the country (e.g. Khennas et al). The amount of energy consumed, especially commercial energy, by the mountain communities is far below than energy consumed by the rich in urban community in Nepal (comparing data of WECS 1996, see also Chapter Five).

c) The fact that life in the hills, a continuous fight against verticality, must be judged in terms of actual labor and its impact on village lifestyle, and not simply the hours of actual labor; and energy needs in the hills must be judged against this background (e.g. Bandhyopadhyay et al 1994). Electricity fills mostly a social function in aiding night-time cottage industry, education, health and safety, and in augmenting a general sense of well being.

d) Distribution factor may avoid the misuses of subsidies provided to fossil fuels thus reduces the financial burden in Nepal. Because it is frequently mentioned that the subsidies provided to the fossil fuel is being utilized by rich people (e.g. WB 1996, Nepal 2000). If government helps remote and rural communities to promote environment friendly technology like micro hydro considering these issues as a part of weighting factor then there might be no need of subsidies in kerosene, as current subsidies are meant for the rural poor.

e) Since the rural communities are by definition widely dispersed, this leads to higher distribution costs and higher unit costs per connection and per kWh than urban households and low load factors contribute to high marginal costs (Cecelski 1996). Such costs could be reduced by decentralized systems although decentralized systems have high front costs.

f) While analyzing rural electrification through central grid Pearce and Webb (1987) mentioned that generally, rural electrification through central grid has positive elasticity between electricity demand and electrical appliances – showing that better off villagers will enjoy more. Similarly, they have said that only rural rich get connected electricity in the case of centralized system. Moreover, several studies and reports (e.g. ITDG/ICIMOD 1997, Khennas et al of ITDG, REDP 2000b, 2001) and author's own experiences and field visits to the community owned decentralized MHP reveal that almost 100% of households of that area have electricity connected. Therefore, this clearly indicates that decentralized community owned MHP must be weighted more than centralized system.

g) In case of centralized system, "decisions about who shall have how much energy at what price also become centralized- a politically dangerous trend because it divides those who use energy from those who supply and regulate it. Those who don't like the decisions can simply be disconnected" (Lovins 1977:55).

h) "Small energy systems adapted to particular niche can mimic the strategy of ecosystem development, adapting and hybridizing in constant co-evolution with a broad front of technical and social change" (Lovins 1977:99).

i) "…external costs of distribution (in case of centralized system) may well be substantial because of the enormous aisles in forest (for trunk lines) and the resulting threat to some endangered species. Decentralized electricity generation could possibly avoid some of these externalities" (Hohmeyer 1988:26 *emphasis added*).

Therefore, including provisions of fair allocation of government resources, the extra benefits to the society because of decentralized system are to be included in the sustainability analysis. The value of such factor (let us say a distribution factor ß) in decentralized MHP projects can be calculated easily to a certain extent and it is certain that there exists some value of ß, which has to be considered in project analysis and decision-making. The value of ß can easily be found by comparing average human development index (HDI) of the people in the country and target groups that are getting electricity as a basic need of lighting. A similar discussion on fair allocations and contributions to the European Union from the European countries was also discussed by Lootsma et al (1998) by considering the individual countries' GDP, population and areas. Azar et al (1996) have also developed sustainability indicators based on distribution of income, development benefits and resources. The factors that are enhanced by the clean form of decentralized electricity producing system would increase the HDI, that is why HDI can be taken as a reference for the analysis of distribution factor in the case of decentralized form of electricity producing systems.

$$\text{Distribution factor } \beta = \frac{\text{Average Human Development Index of the country (HDI)}}{\text{Human Development Index of targeted groups (HDIi)}}$$

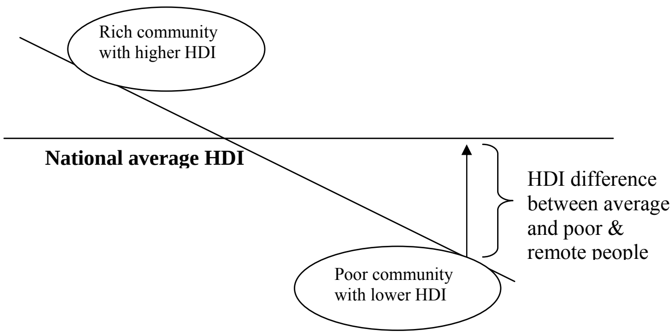



**Figure 4.7 Average HDI and difference between poor and rich community**

As several authors have shown that, there is a relation between HDI and energy use as well as situation of the environment (compare Goldemberg 1995, Templet 1996, see Chapter Three as well), the existing HDI could be modified by including percentage of people having access to electricity[67] through renewable resources, taking into account of the environmental aspect of electricity generation. Moreover, by including environmental condition and electricity access into HDI of the nation, it will make HDI a bit better to reflect the living condition of the people, as there are several indicators to reflect the well-being of people (e.g. UNDP 1997).

[67] Electricity seems to be the basic need of everyone's living condition; electricity is to be taken synonymously as energy for lighting in our calculation. Although in poor countries like Nepal, electricity's share is small percentage of total energy consumption.

### 4.5.2 Climate change, risk and uncertainties factors

Risk has been defined as the context, in which the probability distribution (estimates of the probabilities) is known that the events will take place or certain outcomes will incur, whereas, uncertainty is being defined, as the context in which we do not know what probabilities are attached to the events or outcomes but we would know certain events will take place (Pearce 1983, Bernt 1998). "Uncertainty is a normal aspect of economic life" (Tisdell 1993:117). However, uncertainty in the economic life and other sectors are of different in nature. Some changes, which were uncertain, are irreversible, e.g. melting of glaciers and snow cover in the Himalayas due to global warming etc. As Tisdell (1993) stressed, some of the events due to environmental changes happen without forewarning. Floods and glacier burst are some examples that are very hard to forecast if they happen to be of abnormal, i.e. not regular phenomena. Such uncertain events are frequently damaging hydropower dams and plants in Nepal but economic analysis does not incorporate these issues.

Energy system and resources also come under several uncertainty of different level when we look at global issues and events. In the regional and local level, the uncertainties are there which are not normal as in economic life. Because of forced abnormal changing patterns of ecological life, risks are higher and uncertainties are greater. At the local level, especially due to climate change, the risk to the energy resources and systems have been increased. In the context of Nepal, where hydro resources were abundant, the scenario is becoming different because of potential of climate change. Regarding the uncertainties in environmental degradation, natural calamities, climate change, and its impacts on water resources in Nepal, the following issues can be drawn from IPCC (2001) Third Assessment Report, Gyawali (1997), Bandyopadhyay et al (1994) and others:

a) over the subtropics (10° N to 30° N), land surface rainfall has decreased on the average (0.3%/decade) although some sign of recovery has been seen and Nepal is within this range and its water resources are vulnerable to climate change,
b) the worldwide decrease in mountain glacier extent and ice mass is consistent with worldwide surface temperature increases; glaciers and ice mass in the mountains of Nepal will have also similar phenomena and the rivers originating from the mountains will have severe impacts on their flow amount and flow period,

c) the precipitation will increase in south Asia and Nepal may have frequent flood problems and flood magnitude and frequency could increase in many regions as a consequence of increased of heavy precipitation events,
d) the retreat of most glaciers may disappear (*high confidence*),
e) natural system can be especially vulnerable to climate change and risk includes glaciers, alpine ecosystem,
f) the Himalayan Rivers carry some of the highest sedimentation loads in the world (Bandyopadhyay et al 1994:16) and with increasing floods and denudation of forest the situation will be aggravated causing several damages to hydropower,
g) summer monsoon is the major supplier of water to the overall Himalayan Mountain system (Bandyopadhyay et al 1994) and due to climate change the scenario could be different.

Climate change will have different impacts. The glacier burst and snow melting will have greater impacts in big dam hydropower. Increased level of precipitation reported in south Asia and in Nepal has been the major cause of flooding that has been responsible for the loss of human life and capital. There are already some signals of impacts of climate change in hydropower sector although Nepal has said to be exploited less than one percent of its theoretical potential of 83,000 MW. The amount of damage is low because of nonexistence of hydropower systems in many rivers of Nepal. But Annual Report of NEA, has mentioned few climatic effects on large or grid based hydropower systems (NEA 2001)[68].

The climate change impacts on big hydropower projects, some even having dams, are hardly mitigatable locally and Nepal alone cannot bear the costs needed for the adaptation and mitigation. The events of possibility of glacier burst (e.g.Tscho Rolpa), devastating floods are increasing (Gyawali 1997). These are the sign of either melting of ice cover in the mountains more than previously or higher precipitations. As data of department of hydrology and meteorology indicate that the temperature in Nepal is rising (see **Annex 4.1**) and amount of precipitation is also slightly increasing (CBS 2002b). In this scenario, Nepalese big hydropower projects are highly vulnerable. These aspects have to be considered in any project or costs - benefits analysis. Nevertheless, risks and uncertainty to

[68] The generation of Marsyangdi Hydro Power Station (75 MW plant) was reduced by 5.80% due to unfavorable hydrological condition, the generation of Kulekhani - I Hydro Power Station (60 MW) was reduced by 29.61 % because of insufficient rainfall - that could be due to the changed rainfall duration and period (time shift), and similarly, the generation of Kulekhani - II Hydro Power Station (32 MW) was reduced by 33.36 % that partially due to unfavorable hydrological and other reasons (NEA 2001). Similar events are also reported in Mirza et al 1997.

hydropower depends upon its size and type. Generally, well-reported risks and uncertainties of big as well as micro hydropower in Nepal are listed in Table 4.4.

There were several glacier lake out bursts (GLOF) in Nepal. According to Gyawali et al (1997) the biggest of such types of snow GLOF are active with the largest known GLOF was 450 years ago and within the 19th century more than 12 GLOF were reported in Himalayan region of Nepal and Tibet. These had several impacts on Nepalese riparian land. In 1985, a hydropower was washed away in Khumbu region (Gyawali 1997, Thompson 1994). The reasons of GLOF are said to be high monsoon precipitation and warmer summer temperature. As per Gyawali, the Tsho Rolpa GLOF only may affect several thousand people and infrastructure located up to 100 km in the down stream, including hydropower dams and other structures.

Snow melting will have very negligible problem as very few MHPs are in the snow feeding river regions. Longer dry period could cause impacts on MHPs as their perennial sources of water are from streams[69]. The adaptation and mitigation activities are easier in the case of MHP sites. Impact of climate change to the MHP is mainly on availability of perennial source of stream flow during longer dry season. Such impacts could be manageable in hilly and mountain regions through afforestation to some extent (see Acharya 1993). Growing awareness and growing activities on community forestry[70] is the encouraging sign of impact mitigation activities that benefits the MHP. Such activities are being managed locally with negligible financial costs and people's active participations.

The unceasing perpetual costs and benefits from a particular project or an activity are uncertain and the uncertainty cannot be assigned to exact quantitative values. Although probability concept has been quantifying quantifiable risk, non-quantifiable risks are again hard to give a probabilistic value. Pearce (1983) mentioned that even taking traditional and simple considerations, assuming to avoid risks and uncertainties, we have to add risk premium to discount factors, making NPV less. Therefore, in the context of climate change uncertainties, MHPs are less vulnerable because of locally manageable impacts to some

[69] As per data of CBS (2001) the average annual rainfall measured in 21 rain gauge stations in different part of the country from 1988 to 2000 shows the average rainfall remains almost the same or slightly increased (see **Annex 4.2**).

[70] There were about 338 community forestry users group covering about 17,766 hectare in FY 1991/92 in Nepal whereas in FY 1999/2000, about 9,930 such ushers groups are controlling about 1,028,961 hectare forest areas for the proper management and conservations and the trend is increasing in Nepal, especially in the hills and mountain regions (CBS 2002b).

extent. Such advantages must be included in the analysis with some factors. Moreover, implementations of less vulnerable projects are to be considered as a part of mitigating activities and are to be supported with incentives. (For relevant discussions, see financing of the projects in Chapter Seven).

**Table 4.2 Risks and uncertainties of big and micro hydro projects in Nepal**

| ***Big Hydropower*** | ***Micro hydropower*** |
|---|---|
| Change in flow quantity due to climate change, environmental change thus uncertainty in energy production | Change in flow quantity due to local environmental change but can be mitigated locally, i.e. afforestation. |
| Flood, glacier burst due to climate change (global warming) rupturing, breaking down of dam, thus loss of lives and properties and down stream catastrophes | Chances of land-slide but can be prevented to some extend by selecting suitable sites and afforestation programs. |
| Sedimentation due to soil erosion because of weak Himalayan geo-structure, deforestation and glacier burst thus reducing the life of dam, mechanical components, Mirza et al (1997) have mentioned that reservoir life of several hydropower projects in Nepal have been reduced drastically by several factors because of unexpected amount of sediment carried by heavy floods | Minor impacts as projects are small and cumulative of small project's impacts would not be greater than impacts of one big project |
| Washed away incident for plant structure, components etc, by floods | Rivers are small and structure temporary or semi-permanent, so minor impacts |

Source: Author

An uncertainty and risk factor could be assigned for the cumulative probabilities of the risks and uncertainties arising due to the reason listed above. A decentralized MHP system would have lower vulnerability. Any advantages to the society are to be included through a factor for the purpose of sustainability analysis. However, this issue is dealt here only implicitly, an in depth study is needed in this aspects.

**Conclusion of theoretical underpinning**

The main issues discussed in previous chapters were sustainability, operational definition of sustainability - especially at the project level, importance of renewable energy for sustainability and some socio-ecological issues that have to be addressed while planning, designing, implementing and evaluating the energy projects in poor communities. Taking the reference of numerous definitions that are available for global, very general to a specific field of application, a sustainability constraint equation has been formulated. As per this rule, all components of sustainability, in other words, every dimension of a project must fulfil the constraints laid down, i.e. net change in capital or output must be greater than zero without making any negative impacts. A project cannot be entitled as a sustainable project unless and until it fulfils such constrains in each dimension of sustainability.

Other important issue discussed was that the degree of 'sustainabilityness'. A project may not cause complete sustainability to the system. If a project improves one dimension only then it leads the project towards sustainability and promotes the sustainability partially. However, that project should not have negative impacts on other components. For example, a nuclear power plant can reduce the GHG and could be economically sustainable but the risk of human catastrophe is said to be higher and marginalizing other benefits. This means the project does not leads towards sustainability. However, a project itself can be a sustainable one and promoting the systems sustainability partially if other benefits are not marginal compared to costs. In addition to that, a project can be partially sustainable and promotes sustainability of the system partially.

The main issues of sustainability definition are to define the time horizon, space and quality that has o be achieved by the project. As discusses previously in Chapter Four, a system's sustainabilityness also depends on the definition of these factors. Therefore, a sustainability definition must define and encompass these three factors in its definition. Such issues have also been exemplified already.

Traditionally, more concentration on project evaluation and analysis is being given to financial sustainability, and environment is sometimes a secondary binding issue. Social and ecological aspects are mostly dealt as non-binding issues. The project analysis itself is dominated by the financial analysis in its conception already. Whatever is being analyzed is being tried to convert into financial values or costs and benefits. So analyzing the project by converting all qualitative or quantitative values into the monetary values is being practiced nowadays and is also popular. However, individual analysis of components of a project from the perspective of sustainability separately and looking at whether that component brings net benefits or not, has not been done so far or not so popular. That is why; this dissertation has formulated the sustainability constraint through the discussions in previous chapters that the individual dimensions, by analyzing separately, must bring net positive change to entitle the project as a sustainable. Analyzing a dimension of a project individually reflects the output in that dimension and makes the task of grading of sustainabilityness of a project very easy.

In a poor society, to bring the development benefits and providing a just access to such benefits to all members of society, a few socio-ecological factors have to be formulated so that in the project analysis (or policy formulation), a justifiable biasness toward poor and needy can be included. The existing human development index is a measure of people's living standard averagely. The difference between HDI of rich and poor communities can be taken as a reference to encompass the equity issues. Similarly, people's paying capacity to the project output and financial burden that is occurred in the perspective of financial sustainability, can also be taken as reference. These issues are dealt in previous chapter and exemplified in Chapter Seven.

The importance of renewable energy has been illustrated at global and national level. Energy and it's linkages with socio-ecological as well as economical sectors have clearly supported the sustainable energy system like MHP in Nepal. The energy sustainability issues in the Nepalese context at different level have also been brought in. However, not all issues raised could be included in analysis in details in empirical analysis. The most important issues are being covered while analyzing the sampled MHP projects in Nepal. The hindrances and bottlenecks issues like externalities will also be focused in Chapter Five with limited data that are available in Nepal. However, the gist of theoretical discussions in previous section would be the base for empirical analysis in next section.

# Chapter Five

## Externalities of Rural Energy Use in Nepal

### 5.1 Background

Internalization of externalities is a part of sustainability endeavor to avoid the misallocation of scarce resources. Internalization of externalities also assists the alternatives to be equally treated and given equal level playing in the market. Externalities are also defined differently in different contexts. However, in this chapter, externalities of rural energy use in Nepal, especially in cooking, lighting and small-scale enterprise sub-sector are discussed. That is because, MHP is being compared with other potential technologies and potential resources in the hilly and mountainous region of Nepal.

More importantly, the internalization of externalities is mainly to correct market failures. However, Daly is critical to internalization theory saying, “As a general solution to environmental problems, it is providing inadequate” (Daly 1996: 45). Daly questions the assumption that once the price in the market reflects full social marginal opportunity costs, the environmental problem is solved. Certainly, internalization of externalities is to do justice to the environmentally as well as socially friendly development activities and a way forward towards sustainability, although it is necessary but not a sufficient condition. As from well-known definitions of externality, it is clear that externality imposes the cost to an independent third party because of the first and second party’s uncompensated activities. The imposed costs are not only financial but also social and ecological.

Well - known economist P. A. Samuelson in his famous book 'Economics' mentioned "externalities (or spillover effects) occurs when firms or people impose costs or benefits on others *outside the marketplace*" (Samuelson et al 1992:42). Whenever a party ‘A’, who is not concerned with party ‘B's’ activities of pursuing any objectives in the *market or utilitarian environment*, bears an amount of unaccounted costs or benefits resulted from the party B's activities then these costs and benefits are known as externality (e.g. Kolstand 2000, Devlin 1998, Hohmeyer 1988, Pillet 1986). Baumol et al define condition for externality as "whenever some individual's (A’s) utility or production relationships include real variables, whose values are chosen by others without particular attention to the effects on A’s welfare" (Baumol et al 1988: 17). From this condition, it is clear that Samuelson's 'outside the market place' does not mean that the activities are not related with market. His main point could be that the market could not cover that part of the costs and benefits even though it has some sort of connections.

In other way (e.g. Buchanan et al 1987, Pillet 1986)

Utility of A, $(U_A) = f(X_1, X_2, X_3, \ldots\ldots X_n)$ without externality

Utility of A, $(U_A) = f(X_1, X_2, X_3, \ldots\ldots X_n, Y_1)$ because of externality

X1, X2, …Xn are the variables on which A's utility depends. Variable $Y_1$ is imposed on A because of other party's activities or decision-making, which are causing the externality. Other party, not A, chooses variable $Y_1$'s values. So A's utility is affected either on the benefiting side or on the detrimental side.

The definitions of externality are still being related to the preoccupied free-market's utilitarian concept. All costs and benefits that are not covered by the markets are known as externalities and market is taken as a reference point. However, if market does not have connections with these externalities, then the situation becomes not so easy, because the values on suitable numeraire are tagged taking reference of market[71]. There are several definitions of externality and most of them are saying that externalities exist because of "market failure", and the government has to intervene markets and introduce corrective measures (Hussen 2000, Pearce et al 1990, Hohmeyer 1988, Pillet 1986). Variable $Y_1$'s values in A's utility function are also not controllable in the free market only. Because in the presence of an externality, "competitive economy will generally no longer attain a Pareto equilibrium (Pillet 1986:78)" and resource allocation through the guidance of a free-market system would lead to inefficiency and misallocation of societal resources (Hussen 2000, Devlin et al 1998, Hohmeyer 1998). This will cause an inappropriate amount of consumption or production of goods and resources, whereas in perfectly competitive markets it is assumed that the externalities do not exist or are ignored (e.g. Pillet 1986).

Nevertheless, as per Pearce et al. (1990) economists do not recommend elimination of externality because they argue that the optimal externality is not zero. Therefore, the main concern of several neoclassical economists is to make the market, as a perfect (or optimal)

[71] Even though, there are several methods to calculate the value of non-marketed goods, but the process itself creates surrogate markets that is why market is always taken as reference.

one even if some amount of externality is left or neglected. That means, the sole dream may not be the elimination of externality completely but to make sure that nothing has to be left to consider inside the market place. On the other side, presence of externality that is not covered by the free-market is enough to debate that there is place where Adam Smith's 'invisible hand" has still no access even though production and consumption of goods, services and related decisions are taking place. Then the definition, in terms of economic sense, will be simple when we say, externalities are those costs and benefits arising from production and consumption of goods and services and related decisions that could not be covered by conventional free-market in its price mechanism or related decisions. Therefore, those costs and benefits which are still 'invisible' and are external to our conventional free-market mechanism because that are inaccessible to invisible hand, are causing externalities.

Scarcity (excess demand) of products or services compels individuals to have unwanted choices in the markets for their survival. The unwanted choice has less to do with rational choice that is considered to be needed for the pure market mechanism. As a result, this must be creating again the problem of externalities. Similarly, “an existing externality can cause a consumer to select a sub-optimal mix of goods and services because the prices of consumer goods don't equal to their marginal social costs” (Lesser et al 1997:142 also e.g. Pillet 1986:78). An individual living in a mountain village of Nepal is forced to buy kerosene for lighting because he is not able to afford a Photo Voltaic (PV) system or similar environment friendly system. Even knowing that the kerosene could have significant external costs, he or she cannot (or may not like to) live in the dark but compelled to choose 'bad' system of lighting at lower price although "resource price would be much higher if the environmental externalities were internalized" (Neumayer 1999:59). However, on the other side, "it has to be assumed that market price does not adequately represent increasing scarcity and that the market is imperfect because it does not adequately represent the interests of future generations" (Hohmeyer 1988:72). It shows that the arguments that market solves the externality problems could be blamed to be misconception at least in the context of the energy supply system of the remote and poor region of Nepalese hills and mountains.

Externality has also been defined by the Pace Report as " a residual or side effect of an economic activity in which a benefit or cost is conferred upon a party who is not a party to the original transaction either as a producer, consumer, or agent" (PACE 1990:640). Here the issue of consumer has also been raised. According to this definition consumers of electricity, residing down stream of a big dam that diverts water to generate the power and reduces the local people's (who are also consumers) marginal benefits from fishing are not the third party. The reduced marginal benefit, which may not be accounted in the price of electricity, is an external cost but according to the Pace report that is not externality because they [people in down stream] are the consumers [a party of project] of electricity. That is not fair even economically. The reduction on income or marginal benefits of the stakeholders because of project's impacts is an externality unless and until the side effects of such activity will not be included in its service or product's monetary value or in decision-making. For Pillet (1986) if no corresponding compensation is provided to the victims that is externality. For Hohmeyer (1988) defensive expenditure by the public or by private individuals to prevent or reduce damages from environmental pollution is also externality.

Some externalities or spillovers might be neglected by the public sector even though it is necessary to consider all of them. For Tisdell (1993) this is one of the challenges faced by society to ensure that public organizations take into account the externalities properly. Big hydro projects implemented by public sector could be exempted from internalizing externalities, if above-mentioned perceptions are accepted. Such arguments carry pure anthropogenic and narrow views. Because arguments behind such views might be that people would own as well as endure the public projects and externalities - no external costs or benefits in an anthropocentric sense. However, in ecological perspectives and to compare the alternative development activities, such externalities have to be covered in the analysis.

There has been lots of work on externality of energy sectors too (e.g. ExternE Reports 1994, Prognose 1993, PACE 1990, Hohmeyer 1988). This chapter will particularly discuss and analyze the externality of rural energy sector in Nepal, especially from a macro perspective, comparing micro hydro in the Nepalese aspect with other rural energy technologies and resources, especially for lighting, cooking and agro-processing. As operationalization of sustainability has several stages, internalization of externalities is one of them. So to promote the sustainability in the rural energy sector identification, quantification and monetization of externalities is needed to compare the alternative possibilities and allocation of resources efficiently.

## 5.2 Estimation, quantifying and monetizing the externalities

There are various approaches available to estimate externalities. The "top down" approach is used mainly at macro level (European Commission 1995: 7). It calculates the aggregate externality of a particular system of energy by taking aggregate data. This method is said to be easier but not accurate. This method can help policy makers to have an idea of externalities and decide accordingly. Hohmeyer (1988) pioneered this study for the German Energy Systems, especially of coal, fossil and nuclear power and compared it with solar and wind energy system. Bottom up approaches are considered to be costly, difficult but infer more accurate results than top down approaches. These methods can be applied to site-specific conditions like hydropower projects. Impact pathway method applied by ExternE projects of EU is more accurate to assess the externalities but costly and lengthy. There are various approaches to estimate externalities of energy system, technology and resources.

There are several approaches to evaluate and estimate the externalities or burdens of impacts discussed by Garrod et al (1999). As per Garrod et al, the demand curve approach is also used mainly to valuate public goods nature of externality. This approach is divided mainly into two groups: revealed preference and expressed preference. The basic of demand curve strategy is the 'commodification' (Perman et al 1999) of the services or externalities that the natural environment provides or suffers in the anthropogenic perspective and designate their value in terms of money. Because it is assumed that the values of public goods (bads) in terms of money will make economic decisions transparent and acceptable. The figure 5.1 (in next page) shows a flow chart illustrated the process of assessing and quantifying externalities.

The need to integrate environmental concerns when selecting between different energy resources & technologies is one among several reasons for internalizing externalities. Valuation of externality and their weighting should be done considering different factors like local conditions, life- span of energy system, resources used and several other costs and benefits. A part of that calculation or estimation of externality and their monetization are also different, depending upon types of externality. The effect of $CO_2$ emission will be global and last for centuries, whilst irritation caused by noise is localized and mostly instantaneous (European Commission 1994). Burden of bigger system is certainly a bigger one. However, total social cost per unit of energy produced has to be calculated to make a transparent decision. The main obstacle is to quantify the impacts caused by burdens.

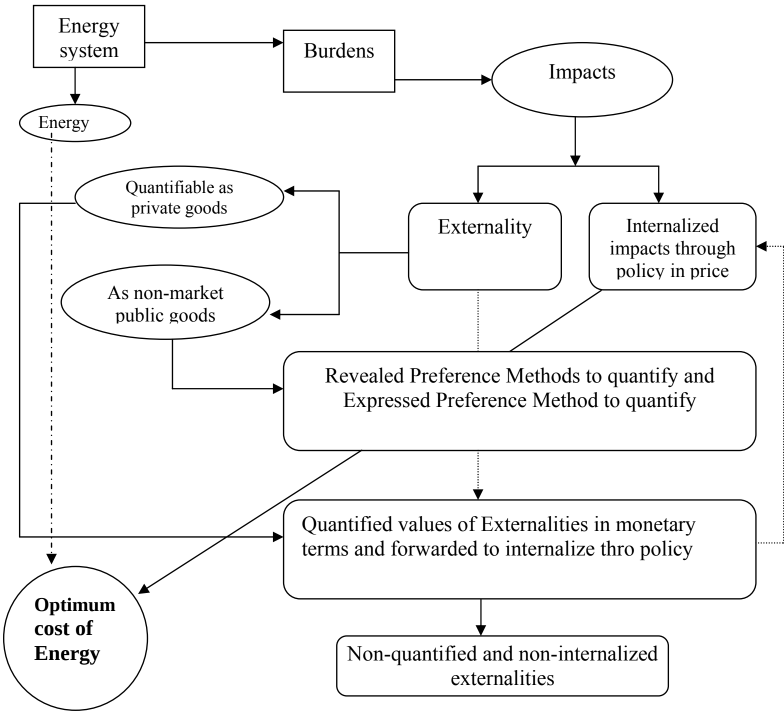



**Figure 5.1 Energy system, energy cost and externalities**

Source: Author

Certainly questions can be asked, can we change all externalities into other terms rather than economic terms? Because social, environmental values are being tried to convert into economic (monetary) values, then why not other way round. Does it make any sense or difference in decision-making? Are there any tools available that evaluate according to total social value in the social terms other than economic terms? It is a hard question and cannot be answered easily. However, all political decisions that are interconnected with economics, society and environment are not only based on economic factors. Because "monetization only means using one unit of measurement for a variety of different gains and losses" (Hohmeyer 1988:18).

Going outside economic terms to include externality is a difficult task and if costs and benefits are incurred in other terms, let us say in ethical terms or societal terms but not in economic terms it is still considered vague and non-transparent to apply in any decision-making[72]. However, in real world monetary units are universally accepted and the quantitative and qualitative externalities are tried to convert into monetary units, although, some qualitative externalities are listed implicitly.

As discussed previously, there are several ways to quantify and monetarize externalities even though controversies are strongly presence (e.g. Hennicke 1993, Schleisner 2000, Friedrich et al 1993)). Some externalities are not quantifiable and some even if quantifiable cannot be monetarized easily. In the case of rural energy use in Nepal, quantification is used based on available information on all sectors concerned.

### 5.3 Externalities in Nepalese rural energy sector

In economic terms, especially of production and consumption aspects, the definition of externalities has, more or less, to do with impacts on output and utility (Kolstand 2000). From traditional welfare economics' perspective, externalities on energy are related to economic decision-making, i.e. consumption and production process and its consequences. Nevertheless, energy has also relation with other social and environmental parameters of livelihoods (e.g. Goldemberg 1996). Externalities may include both negative economic effects (damages) and positive economic effects (benefits) on the economy, environment and society. Externalities of energy, of course, are not limited to environmental and health related impacts only as generally perceived; impacts on job market, energy and economic security and societal matters also give rise to externalities (e.g. Hohmeyer 1988, European Commission 1995).

As it has been discussed in Chapter Three, most of the rural people of Nepal use biomass for cooking, heating and small scale- enterprises; kerosene and electricity are used in domestic lighting; diesel, mechanical energy from water wheels and electricity are used for agro processing as well as water lifting in the irrigation sector. Some small interventions of

[72] For example anthropogenic damages done by the climate change can be converted to human value (nos. of human suffered) but its hard to accept such numeraire because our preoccupied habits with money units.

renewable energy technologies are also there as listed in Table 3.4 and 3.5 (in page 73). All these resources and technologies have some externalities in the economic, environment, political and social sectors. Biomass, if not used in a sustainable way, efficiently and correctly, has externalities but if it is used in a controlled manner (which is not impossible) then the issues of externalities are not strong in the environmental aspects, although other aspects of externalities i.e. indoor pollution, drudgery, etc., could be significantly important. Nevertheless, the main issues focused on in this chapter will be especially lighting and agro-processing. This dissertation is mainly looking the MHP projects in Nepal and until now, MHP has been used only for lighting and agroprocessing mainly, although cooking has also been started in few isolated places. Externality calculation in this chapter focuses mainly on the objective to acquire, if people are provided with electricity from MHP, how much externality will be avoided. In other words, if all externalities are monetized, how much monetary value can be saved or how much positive externalities will be gained? Because there exists technical and economical potential to provide electricity from MHP to the significant numbers of families of Nepal those living currently in the remote hills and mountainous regions (e.g. Pandey 1994)[73]. With that objective, nearly one-third of hills and mountain region's households[74] can be served with MHP.

Definition of externalities of energy in the case of rural energy sector may not be only environmental aspects but social and economic as well. As people are living under energy poverty – there is no such large-scale use of fossil fuel and other energy carriers at household level. The energy use except biomass has fewer impacts on climate change compared to urban transportation and industry. Kerosene is the major source of fossil fuel, used mainly for lighting. Diesel is used significantly less in rural areas compared to urban consumption. Therefore, the definition of externality in the rural energy sector could be different from urban sector because it has not only environmental impact as generally assumed. But energy externality, in the context of rural Nepal, could be defined as the unaccounted costs and benefits to the society that are not being incorporated in the price

[73] As per water resource strategy of Nepal 2002 (WECS 2002), the projected population of Nepal in the year 2027 will be about 26.85 million in rural areas and total population will be about 38.83 million; only about 60% will have electricity if current strategy works as planed, which has not happened in the past. There will be still 40% people without electricity, most of them in the remote hills and mountains. The MHP could serve the 20% of total households of Nepal within next 20 years with available potential.

[74] As per census of 2001, there are about 2,302,640 households (HH) that are living in hills and mountains and 834,875 HH could be targeted to provide electricity facility through MHP. By 2027 about 803970 families will be served ,as per scenario developed in chapter seven.

mechanism of energy or energy related decision-making process. Externalities of rural energy could also cover the faulty decisions, economic burdens, unaccounted labor and drudgery contributed by an inappropriate system to fulfill the energy needs.

**Table 5.1 GHG gas (CO2) emission from energy carriers in Nepal**

| Energy carrier | Energy consumed | Units | Consumption in GJ | CO2 Ton/GJ | Total emission in tones |
|---|---|---|---|---|---|
| Kerosene | 316,381 | Kiloliter | 11,471,975 | 0.0723 | 829,424 |
| Diesel | 326,060 | Kiloliter | 12,367,456 | 0.074 | 915,192 |
| Petrol | 59,245 | Kiloliter | 1,984,115 | 0.073 | 144,840 |
| ATF | 63,130 | Kiloliter | 2,606,006 | 0.073 | 190,238 |
| F.O | 20,999 | Kiloliter | 759,534 | 0.078 | 59,244 |
| LPG | 40,102 | Ton | 1,974,622 | 0.0659 | 130,128 |
| Fuelwood | 6,068 | TOE | 258,628 | 0.0832 | 21,518 |
| Agr. residue | 299 | TOE | 12,744 | 0.0832 | 1,060 |
| Animal dung | 457 | TOE | 19,478 | 0.0832 | 1,621 |
| Electricity[75] | 108 | TOE | 4,603 | 0 | 0 |
| Coal | 246 | TOE | 10,485 | 0.095 | 996 |
| Total | | | 31,469,647 | | 2,294,260 |

Source: Compiled from CBS (2002a, 2002b), Baskota el al (1987), WECS (1996), NEA (2001).

By accounting only the environmental variable, the externalities will not be defined because other variables would be left out. In some cases, there are even negligible environmental externalities when we take only national boundary i.e. imported solar PV home system in Nepal, but it has economic as well as political externalities. PV systems are being imported by draining valuable foreign reserves with negligible customs duty and almost no major components are being manufactured locally. Nevertheless, in the European and other developed countries, PV system may have very negligible economic as well as political externalities. As per Hohmeyer (1988), except occupation of land in case of large installations, there are no other significant external impacts of an installed PV system but when one analyses its life cycle from the beginning of cell manufacturing, there could be some environmental impacts and externality (e.g. Cassadey 2000, Elliot 1997). For finding and quantifying the impacts as well as different burdens, a reference quality is needed as discussed in Chapter Four. While calculating marginal impacts on environment

75 As per ORNL (1994), there is no direct CO2 emission from Hydropower, and in Nepal, thermal power plant (Diesel) produces only 27.14 GWh of electricity, but that has already been calculated in the diesel consumption of the country. CO2 emission from agriculture residue and animal dung is assumed equal to fuelwood.

different types of reference state with respect to quality, time and space are needed (e.g. European Commission 1994). While finding the externality of rural energy sector in Nepal, a national boundary for the most of the impacts could be selected whereas for GHG global perspective can be assumed from the available data collected from concerned secondary as well as few primary sources.

## 5.4 Types of externalities in the rural energy sectors of Nepal

There are different types of classifications of externalities in literature. Technological externalities and peculiar externalities and other classifications like depletable and undepletable externalities and Pareto-relevant and Pareto-irrelevant are also been discussed by several authors (e.g. Ward et al. 1991, Baumol et al 1988, Buchanan et al 1987). Pillet (1986) classified externalities while discussing with economy and environment interface, into three groups: Economic and market externalities, environmental externalities and energy externalities. According to Daly et al (1994), there are localized and pervasive externalities. Nevertheless, in the case of rural energy sector of Nepal, considering several aspects like landlocked country, geographical difficulties, non-availability of known fossil fuel resources, past political embargos by neighboring country, trade deficit, social burden etc., and energy externality could be divided into four sub-externalities as:

- economic externalities,
- environmental or ecological externalities,
- social externalities and
- political externalities.

To narrow the concerned areas looking for externalities, the rural energy use in lighting, cooking and agro-processing is taken into considerations because micro hydropower is generally used or would be used in these sub-sectors only. For these end uses, electricity from national or decentralized systems, petroleum products and different renewable energy technologies are being used. The impacts, which are responsible for externalities of rural energy uses, are being listed in Table 5.2 (next page). Externalities, which are partly impacts and partly unaccounted costs and benefits, are of different in nature. As per Hohmeyer (1988) all externalities have to be summed incurred during all stages of production of goods or services. Therefore, some products or services may have different types of externalities in different stages before they are consumed or used. For example, kerosene used for rural lighting may have economic externality during import, transport, environmental externalities during transport and burning, and socio-political externalities by indirectly creating an environment to use fossil fuels and providing subsidy in the context of Nepal[76]. Considering the national boundary and energy related activities in the rural Nepal, the macro level externalities will be calculated comparing with MHP.

**Table 5.2 Negative impacts of energy resources and technologies used in Nepal**

| *Resources* | | Purpose | Impacts | | | |
|---|---|---|---|---|---|---|
| | | | *Economic* | *Environmental* | *Social* | *Political* |
| Kerosene | | Lighting | Resource cost | GHG | Health | Dependency/ embargo |
| | | | Transport cost | Indoor Air Pollution | Drudgery | Economic unrest |
| | | Cooking | Hard currency | Pollution during transportation | Accidental | Trade deficit |
| | | | Dist./adm. cost | | | Subsidy |
| Gas | | Cooking | Resource cost | GHG (?) | Health | Dependency/ embargo |
| | | | Transport cost | | Accidents | Economic unrest |
| | | | Foreign currency | | Financial burden | Trade deficit |
| | | | Dist./adm. cost | | | Subsidy |
| Diesel | | Lighting | Resource Cost | GHG | Health | Dependency/ embargo |
| | | | Transport cost | | Drudgery | Trade deficit |
| | | Agro processing | Hard currency | Pollution during transportation | Accidents | |
| | | | Dist./adm. cost | | | |
| Bio-gas/Mass | | Cooking | High initial system cost for biogas | GHG/CH4 | Drudgery in fuel & fodder collection | Subsidy for biogas |
| | | Lighting | | Indoor air | | |
| Micro hydro | | Cooking | System cost | Landslide | Water rights conflict | Subsidy |
| | | Lighting | | Aquatic life | | |
| | | Agro processing | | | | |
| Solar | Thermal | Cooking/heating | System cost | | | Subsidy |
| | PV | Lighting | O & M cost | Battery | | Import burden |

Source: Author

[76] As Nepal does not produce or refines fossil fuels, especially petroleum, the externality during the production is not considered. Similarly, export and import of externalities has also not been discussed.

### 5.4.1 Economic externalities

Most of the original concepts of externalities came because of 'economic inefficiency that is caused by externalities'. Economic externalities focus mainly on profit maximizing firm that causes externalities and utility maximizing individuals (or victims) (e.g. Baumol et al 1988) but not from the pure environmental perspective. Terms of trade deficit, unwanted or unjustifiable subsidies were also seen as economic externalities. Economic externalities are mainly of unwanted economic costs accrued to the energy systems or resources. If the unit cost of energy of big hydropower plant is cheaper than micro hydropower (MHP) due to exclusion of other factors (which have economic consequences) then the economic burden is accrued by big hydropower to MHP. Such burdens would be economic externalities of big hydropower imposed on MHP. Similarly, if kerosene has not been priced properly and becomes cheaper, villagers are not buying electricity from a micro hydropower owner because of cost factor even though the price of electricity is optimally fixed, then such burdens created to MHP are economic externalities.

When we consider the rural energy sector of Nepal, external effects are not only important in terms of the environment. In macro level, resources drain, i.e. drainage of hard currency, would be the example of economic externalities. For rural lighting either kerosene or electricity is used. Electricity is produced either big hydro or diesel or micro hydro and solar PV. In big hydro, there are several economic externalities i.e. burden of import of components that need again foreign currencies, unnecessary transportation and distribution networks, etc. Trade deficit and impacts on balance of trade are major economic externalities. Economic externalities are being defined presuming that there exist known alternatives, which are economically feasible once the economic externalities are being internalized. However, such internalizing efforts are not pursued creating economic burden to the country and society. The term 'foreign currency or hard currency' has significant value as well as meaning for the poor countries as they have huge debt[77] to payback in hard currency (foreign currency) and also have very limited means of collecting such hard currency, for example negligible export surplus. Therefore, drainage of hard currency is an economic burden to the poor countries.

[77] Trade deficit, debt and nominal GDP of Nepal in the fiscal year 1999/2000 was about US$ 689 million, US$ 2.546 billion and US$ 5.234 billion respectively.

Therefore, in the case of rural energy sector of Nepal, a few economic externalities can be listed as followings (see and compare Hohmeyer 1988:60).

- import of resources/fuel for electrification or rural lighting which might not be needed if feasible alternatives are utilized, i.e. kerosene, diesel, coal or fuels imported for generation of power, heat, or for lighting could be replaced by RETs,
- import of components of energy systems or energy resources itself (which could be manufactured locally or alternative feasible forms are available) by paying hard currencies causing impacts on balance of terms of trade for example, importing kerosene needed for rural lighting, whereas locally manufactured micro hydro are not causing such large-scale economic burden but fulfill the need of lighting to some rural areas,
- employment effects, income from wages, salaries, profits and
- income to the community, public agencies and the government.

#### 5.4.1.1 Economic externality in kerosene

**Resource drain:** The import of petroleum product in the FY 2000/2001 is 33.6 percent of commodity exports, and in the FY 2001/2002, it is expected to remain at 44.1 percent (HMG/N 2002). Kerosene covers 39.2 percent of total import of petroleum products. Fossil fuel supply system in Nepal is controlled by a state-owned Nepal Oil Corporation (NOC). The financial status of NOC is being reported in the verse of bankruptcy. The Kathmandu Post (2002) has reported the financial situation of the NOC as shown in Table 5.3.

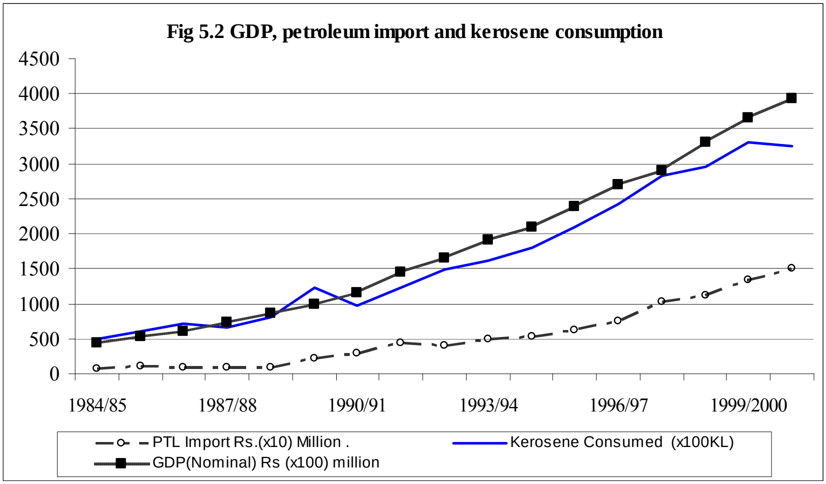
**Table 5.3 Scenario of fossil fuel consumption and pricing (FY 2001/2002)**

| Particulars | Petrol | LPG | Diesel | Kerosene |
|---|---|---|---|---|
| Unit | KL | Cylinder[78] | KL | KL |
| Price (Rs.) | 52 | 650 | 26.5 | 17 |
| Consumption/yr | 65,000 | 4,000,000 | 250,000 | 360,000 |
| Loss million Rs. | - | 360 | 1,500 | 2,880 |
| Profit million Rs. | 715 | - | - | - |
| Subsidy/litre Rs. | - | - | 6 | 8 |

Source: Compiled from Kantipur Daily (2002), CBS (2002a) and NOC (2002)

[78] One cylinder is 14.2 Kg gas.

From Table 5.3 (previous page) and Figure 5.2, it is clear, on the average, the government is expending huge amount of public money for the import of fossil fuel that is being unequally distributed among the citizen. This could be a case of externality. Government's expenses to import petroleum products and the ratio of import value of fossil fuel to export value of different commodities are given in **Annex 5.1**. The figure does not include the data of coal and more important is that the trend of import of total fuel is increasing.




Source: Compiled from HMG/N (2001 and 2003), CBS (2002a) WECS (1996)

As per NOC (2002), the resources drained to import kerosene, is increasing every year (see **Annex 5.2**). Taking the average of last five years data, about US$ 0.31 per liter has been paid to import kerosene. That means, on the average, about US$ 12.13 per rural household[79] per year has been drained to import kerosene, whereas for MHP it would be approximately about US$ 2.71[80]. That means US$ 9.42 will be the external cost of resource drain per rural family per year in the case of kerosene. In other technologies like the grid and solar PV there would be a significant resources drain as the technology is

[79] As per WECS (1996) and survey from 10 villages about 39.14 liter kerosene is consumed by a family per year in rural Nepal for lighting only. This data will be used in our analysis.

[80] Comparing with MHP, even if we consider that the materials used for electromechanical components are also imported the amount will be lower than that. Taking the average of 43 MHP, the total investment per family is about US$ 155 and if we assume 70% of that is electromechanical components then about US$ 109 will be needed. Again, assuming that 50% of electromechanical cost is material cost that is imported then about US$ 55 per family is the resource drain in 20 years, i.e. US$ 2.71 will be the resource drain per family per year for MHP.

imported solely. In the case of biogas it must be very low as only one or two components are imported.

**Subsidy:** As per household consumption survey of CBS (2002c), only about 7% of rural Nepalese are using kerosene for cooking[81]. About 25% of total imported (and subsidized) kerosene is consumed by the industry (Ohashi 2003). From the household surveyed data collected by the author (see **Annex 5.3**) and WECS (1996), the average consumption of kerosene by a rural household is about 39.14 liter per year for lighting. Then taking the data of FY 2001/2002 and average consumption of rural family, only about 38.81% of imported and subsidized kerosene is used by the rural households and the rest is used by other non-targeted people[82]. Providing such subsidy to the non-targeted people also induces the externalities. So as consumption amount increases drastically, more and more kerosene is being consumed by the urban families and industries.

**Table 5.4 Subsidy provided to rural households on kerosene for lighting only**

| Specific consumption of HH, Liter | Nos. of HH without electricity[83] (80%) | Total consumption Liter/year | Subsidy provided to kerosene used for lighting in million Rs. | Subsidy Rs./HH/year |
|---|---|---|---|---|
| 39.14 | 3,339,499 | 130,707,991 | 1,045,663,927 | 313.12 |

Source: Compiled, calculated and adapted from NOC (2002), *Kantipur Daily* (2002), CBS (2002b), WECS (1996) and household survey.

From the above-mentioned figure, it is clear that on the average each rural family gets about Rs. 313.12 subsidy per year. This could be taken as an example of externalities because kerosene, an unsustainable and imported fuel carrier draining hard currency, is being given subsidies despite other feasible alternatives, at least in the part of the country. Urban households have also been provided more subsidies than rural ones. Considering the Ohashi (2003)'s data the industry is using 25% kerosene, then the rest amount (36.19%) of kerosene is used by the people who are having access to electricity. They are also getting

[81] As per CBS (2002b) there are altogether about 13.53% of Nepalese are cooking using kerosene as a fuel.
[82] The scenario is changing fast as urban people and industry are also using kerosene because of cheaper price due to subsidy. In FY 1980/81, the share of domestic consumption in the country's total kerosene consumption was 95%, 88.01% in 1986/87 and 71.71% in 1990/91 (ICIMOD 1993). Similarly as per NOC (2002) within the last five years, there is 22.19% increment in kerosene sales in Nepal.
[83] The number of households without electricity is taken as 80% because less than 20% Nepali households are having electricity.

subsidies on kerosene, on the average, Rs. 1,275/HH/year[84]. Similarly, industry is also getting subsidies about more than Rs. 720 million per year on kerosene alone. This subsidies distribution to urban areas and industries despite feasible alternatives is also an economic externality. MHP is also getting about US$ 4.67 per household per year[85] as a subsidy as per policy of HMG whereas for kerosene, it is about US$ 4.16. In biogas, the amount is almost twice because of its shorter life than MHP. For the grid, it is complex to calculate in the state owned system in Nepal and is just mentioned the existing data on transmission and distributions.

#### 5.4.1.2 Economic externalities in dry-cells

Dry-cell use in Nepal is in increasing trends although there exist no such data of consumption. However the capacity of the local manufacturing companies is increasing as shown in Figure 5.3 (next page), and the use of different varieties of dry cells are growing in the market. As per census of manufacturing establishment by CBS/Nepal in 1996/97, the gross fixed assets of accumulators, primary cells and battery was 98.6 million rupees (CBS 2001). After that, the investment in this sector could have been increased because of increasing demands of dry-cell battery because of increasing consumption of electronic goods and appliances like radio, torchlight, cameras and portable cassette players. Mainly carbon-zinc types of dry cells are used in rural Nepal. Normally UM1 (large-sized batteries or D size), UM2 (medium-sized batteries or AA size) and UM3 (pencil-sized or AAA-sized batteries) are used. The locally available batteries are either paper or metal clad. The deficit amount[86] of these batteries is imported either from India or from China. The following table shows the different types of dry cells and their application.

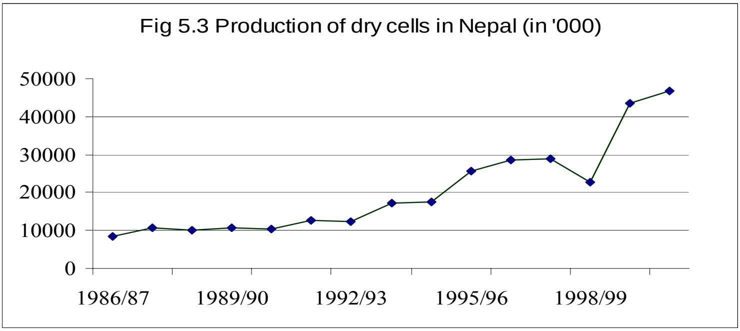
**Table 5.5 Typical household dry-cell batteries used in rural Nepal**

| Primary cells (Non-rechargeable) | Common uses |
|---|---|
| Alkaline | Cassettes players, transistor radio, torchlight, portable cassette players (walkman), etc. |
| Carbon-zinc | |
| Lithium and Mercury | Cameras, calculators, watches, etc. |

Source: Compiled and adapted based on Niemeyer (2002), Krishnakumar (2000)

[84] Assuming 18.64% living in the and semi urban and having electricity are consuming remaining subsidized kerosene (159.32 liter/HH/year) that is after reducing the rural (38.81%) and industry (25%) consumption.
[85] NRs 70,000 per kW is being provided and considering 10 HH per kW and 20 years of plant life.
[86] Deficit amount is total consumption minus local production of dry cells.

From the perspective of cost, the dry cells are expensive in remote areas. On the average, 2.76 pairs of dry cell (normally carbon-zinc) for radio and torchlight have been consumed paying on the average about Rs. 67.87 by each family per month[87] (see **Annex 5.3**). This consideration does not include the consumption by cameras, watches and others things. If electricity is made accessible through clean sources, the consumption will be reduced drastically or abandoned especially for radio, cassette player and torch light. It has been found that in few cases, after MHP people are using rechargeable Ni-Cd batteries despite their ecological impacts (see in the following pages)




Source: Compiled into graph from HMG/N (2001)

**Table 5.6 Expenses on dry cell battery by rural households**

| Total HH in Nepal | HH in rural Nepal | Average dry-cell use pair /year | Total dry cell use pair (million) /year | Tentative expenses from dry cell (million pairs) | Potential expenses from electricity | Potential saving in Rs. million | Saving per HH Rs. |
|---|---|---|---|---|---|---|---|
| 4174374 | 3339499 | 33.14 | 110,670,997 | 774,696,978 | 193,674 | 774,503,304 | 231.92 |

Source: Author (based on CBS 2002b, Nile power 2003)

From the cost perspective, such consumption is very expensive. “A dry-cell battery source of energy is on average US$400 per kWh compared to a US 0.05 cost of hydro generation” (Nile Power: 2003[88]). From the amount of energy consumption perspective, about 8,000 times expensive than hydropower electricity. Considering that electricity from MHP is a

[87] From the household survey of hilly and mountain villages, the amount of kerosene consumption found resembles with the data of WECS (1996). So considering this accuracy, the figure obtained for dry cell battery is assumed applicable to all rural areas as in the case of kerosene. Based on this assumption relevant calculations are also made.

bit expensive, let us say US$ 0.10[89] per kWh, then the difference will be the factor of 4,000. From the perspective of energy consumption, if dry cells will be completely replaced by electricity, then the cost saving be as shown in Table 5.6 (see page 149). It is an externality and comes about Rs. 231.92 per year per family, on the average.

Considering only 80% of total households, on the average, consume about 2.76 pairs per month, the total consumption of dry-cell batteries is about 221.341 million per year[90], where as Nepal's own production is about 46.844 million per year in FY 2000/2001. The remaining dry cells are imported. Therefore, there is also a burden of resource drain. However, there will be no 100% reduction of battery consumption in household level after electrification but dry cell use in torchlight, radio, and cassette player will be drastically reduced, especially in rural areas, saving lots of resources and money. The impact of employment after the reduction of the use of dry cell battery in the manufacturing sector could not be calculated but there must be some impact. However, because of extensive increase in the use of electronic goods, the production of local battery will not be stopped and local industry would have minor impacts.

### 5.4.2 Environmental or ecological externalities

Environmental economics has given much attention in this externality. Proponents of strong sustainability say that economy is a subsystem of ecology and depends on ecological environment for its input as well as waste assimilation (Daly 1999, Costanza 1997 et al, Goodland et al 1992, Hohmeyer 1994). Environmental perspective of externalities is also being tried to cover through the Pigouvian tax, i.e. producers of externalities be taxed on their products equivalent of marginal social damage done by environmental externalities.

In the context of Nepalese rural energy sector, the local, regional as well as global level environmental externalities could be perceived. Use of kerosene and diesel may have both GHG emissions as well as local level environmental impacts that include in-door air pollution causing health impacts. Similar to biogas, use of LPG in cooking may not have

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88 This figure has been referred from the AES Nile Power internet site of Bujagali Hydro project in Uganda.
89 More can also be referred in Pandey (1994) and ITDG (1997b) regarding the tariff calculation of MHP in Nepal.
90 Nevertheless, it has been also reported that Nepal throws straight away minimum of 200 million dry-cell batteries per year (http://www.lutw.org/LEDtechnowhat.html). The above-mentioned estimate of 221 million is plausible.

significant problems. Leakage of gases could contribute some level of GHG like methane and others. Micro hydro system may have local level ecological impacts of small-scale deforestation and landslide. Small-scale deforestation has been normally recoverable by community initiatives of afforestation, whereas landslide could be significant in some cases.

#### 5.4.2.1 GHG as ecological externalities

In the rural energy sector, as per data of WECS (1996)[91] sustainable yield of fuelwood is about 5.447 million tons. Even making optimistic assumptions that the sustainable yield of fuelwood will remain the same, there is a deficit of 5.525 million tons of fuelwood. From the unsustainable rural energy supply,[92] $CO_2$ emission is about 0.511 tons of per capita as an external cost in rural cooking and lighting in Nepal. As per WECS (1996) the rural people consume 7 liter kerosene, 562 kg of fuelwood, 180 kg agriculture residue and 112 kg of animal dung per capita per year for cooking, lighting and heating. That means about 0.02 ton of $CO_2$ per capita in lighting is the externality of rural people.

**Table 5.7 CO2 emission from energy carriers in rural Nepal**

| Resources[93] | Unit | 1994/95 | 2000/2001 | | |
|---|---|---|---|---|---|
| | | Total | Total | Total in GJ ('000) | CO2 Emission in ton |
| Fuelwood | 000' kg | 10,248,149 | 10,972,673 | 183,792 | 15,291,517 |
| Ag residue | 000' kg | 3,281,729 | 3,511,630 | 44,106 | 3,669,625 |
| Animal dung | 000' kg | 2,047,670 | 2,185,014 | 22,921 | 1,907,010 |
| Kerosene | Kiloliter | 125,614 | 136,563 | 4,952 | 358,014 |
| Total | | | | 255,771 | 21,226,167 |

Source: Author (based on WECS (1996), CBS (2002a, 2002b), Baskota et al 1997)

The $CO_2$ avoidance cost of renewable energy technology for lighting is ranging from Nepalese Rupees (NRs.) 1,187 for biogas to NRs. 8,543 for solar PV per ton of GHG emission in Nepal, and similarly, the $CO_2$ avoidance cost of lighting through MHP is about NRs. 1,777 (Pokharel et al 2003). Considering MHP, this would be about US$ 23.69 (Rs. 1,777) and US$ 2.37 per family per year.

[91] From 6.627 millions hectare of forest, shrub land including non-cultivated inclusion (NCI) only about 47% was accessible to have about 5.447 million tones of sustainable yield of fuel wood per year (WECS 1996).
[92] Animal dung is assumed to be unsustainable because diverting dung to fuel has an impact on agricultural sectors and ecology.
[93] As per WECS (1996) there is no diesel in the specific energy consumption list in the hills and mountains.

**Table 5.8 CO2 emission from unsustainable[94] energy carriers in rural Nepal**

| Energy Resources | Unit | In 1994/95 | Unsustainable resources in 2000/2001 | | |
|---|---|---|---|---|---|
| | | Total resources | Total | Total in GJ ('000) | CO2 Emission in ton |
| Fuelwood | 000 kg | 10,248,149 | 5,525,133[93] | 92,546 | 7,699,825 |
| Anm. Dung | 000 kg | 2,047,670 | 2,185,014 | 22,921 | 1,907,010 |
| Kerosene | Kiloliter | 125,614 | 136,563 | 4,952 | 358,014 |
| Dry-cells | Pairs | | 112,552,411 | | |
| Total | | | | 120,419 | 9,964,850 |

Source: Author (based on CBS (2002c), WECS (1996), Pokharel et al (2003) and survey data)

#### 5.4.2.2 Ecological externalities of dry cell batteries use in rural Nepal

As per Niemeyer (2002) dry-cell batteries may produce the following potential problems or hazards:

- pollute the rivers and streams as the metals vaporize into the air when burned,
- contribute to heavy metals that potentially may leach from solid waste landfills,
- expose the environment and water to lead and acid and
- contain strong corrosive acids that may cause burns or danger to eyes and skin.

The major raw materials used for the manufacturing of dry cell batteries include zinc, carbon rods and manganese dioxide (Krishnakumar 2000). Heavy metals of dry cell are said to have the potential to leach slowly into soil, groundwater or surface water. When burned, some heavy metals such as mercury may vaporize and escape into the air, and cadmium and lead may end up in the ash. In the rural areas of Nepal, the used dry cells are simply thrown in the garden or in open space- sometimes thrown where animal dung are collected for fertilizer. It was also found that people are using the carbon of used battery to paint window and doorframes and also walls and floor of houses. The quantitative externality caused by the dry cells in ecological aspects is still not known at micro level and no such study has been done in the context of Nepal. However, there are also the impacts due to the use of Ni-Cd rechargeable batteries.

### 5.4.3 Social externalities

This part of externality is not simple to quantify even though, sometime, they could weigh more than other externalities. Considering negative social externalities of kerosene, health

[94] Unsustainable because of fossil fuels, deficit amount of fuelwood and burning of animal dung.

impact causing respiratory problems and drudgery in transportation might be some examples. The positive externalities are also significant, especially in the renewable energy technologies. There are always pro and contra arguments regarding benefits and impacts of rural energy technologies and resources - especially of rural electrification (see Pearce 1987, Hourcade et al 1990, Mackay 1990, Munansinghe 1990, Foley 1992, Schramm 1993, Cecelski 1996, WB 1996, Aguado-Monsonet et al 1997, Broek et al. 1997, Rijal 1998, WB 2000, ITDG 1997a). Few social externalities either of positive or negative of renewable energy and traditional as well as fossil energy uses are as follows:

- employment effects,
- financial burden,
- health benefits,
- accidental losses,
- feeling better living situation and
- gender biasness and drudgery,
- uncertainties.

#### 5.4.3.1 Employment

It is hard to find the exact data of how many people are being employed by management, distribution and marketing sector of kerosene and dry cell battery used in the rural areas[95]. Based on the analysis and compilation about 6,589 people (see **Annex 5.4** for details) are being involved in the import, transport and distribution of fossil fuel in Nepal and its management. The employment opportunities related to kerosene consumption in rural areas only is about 769[96]. From the calculation (shown in **Annex 5.4)**, the job provided by the kerosene consumed rural areas is 0.000006 person per year per liter. Comparing with MHP per kW (for 10 households), the job or employment opportunity is 0.0022 person per year. However, regarding dry cell there is no such data. Nevertheless, in the case of the MHP systems, it will be discussed in details in the next chapter. On the average, about one person per kW per year is the employment generation. Moreover, 25% of that job will be needed to maintain the system after installation (see Chapter Six for details). The average

[95] According to NOC (2002) about 507 people are being employed in its organization, except transporting, selling and dealers.

[96] Excluding transportation by households or small shopkeepers after buying from the kerosene dealers.

income of a normal worker from the data available from the MHP manufacturers is about Rs. 36,550 per year. Similarly in the case of community owned system, on the average Rs. 25,116 is earned by each operator and manager working in the system under community management (see **Annex 5.5**). There is also variation in the salary with respect to capacity of the plants. The regional variation is there because of unemployment problem at the local level. The employment and poverty reduction impact of MHP will be discussed in the next chapter. However, the scenario of employment opportunity of bio-gas, kerosene, solar could not be discussed here. In the case of biomass, creation of job would be complex and a normal family in the hills needs at least, on the average, 200 hours per month to collect fuelwood (on the average, 80 hours male and 120 hours female, based on survey data of the ten VDCs, see **Annex 5.6** ). If this is counted as employment, then there would be different scenario, however, it is a compulsion and drudgery, not the employment in real sense. However, if a family would earn their livings or reduce their expenses by doing job as a fuelwood collector then this must be accounted. From above analysis it is clear that traditional form of fossil fuel like kerosene offers very less job and employment opportunities than MHP. In our calculation, we left it as a research topic that needs further work.

#### 5.4.3.2 Financial burden and revenue

As it has been found from the study in Myagdi district (it will be discussed in chapter six) that the rural households generally, pay around 2.5 - 3% of their average GDP of a family for lighting energy (kerosene and dry cell battery). On the average, such regular burden could be reduced, if electricity is available. However, the average investment cost is the obstacle for rural households, in the case of MHP or other similar RETs. On the average, there could be reduction of almost 1 - 1.5% monthly financial burdens (Details will be discussed in chapter six) for the household after MHP.

The financial or economic burden is also the issue for the macro-level. The ratio of fossil fuel import expense and GDP is ever increasing as shown in Figure 5.2 (page 146) and **Annex 5.1**. Such macro-level burden will be transfered to the poor people directly or indirectly because of the import and use of unsustainable energy resources. Considering 10 families per kW of MHP and electricity would replace diesel and other fossil fuel used in agroprocessing, about Rs. 13,012 per year per kW of MHP would be stopped to drain from a community after the installation of MHP[97],[98] (see more in chapter six).

**Table 5.9 Average per capita consumption of household in rural Nepal**

| Region | Total consumption In Rs | Food | | Non-Food | | % of PCI of a family consumed for lighting energy* |
|---|---|---|---|---|---|---|
| | | Consumption in Rs. | % of total | Consumption | % of total | |
| Mountain | 12,214 | 8,089 | 66% | 2,819 | 23% | |
| Hill | 12,868 | 7,658 | 60% | 3,714 | 29% | 10-18% |
| Terai | 11,085 | 6,694 | 60% | 3,339 | 30% | |

Source: (Compiled from CBS (2002c:25-26), *Surveyed data )

### 5.4.3.3 Accidental losses and health issues

From MHP there are hardly any fatal injuries but after installation, electricity can bring accident. From kerosene, there are several cases of burning injuries and whole village has been gutted into the fire. Such data are not available empirically and systematically but daily newspapers report such news frequently

In rural energy sector, especially in lighting, the kerosene has impacts on the respiratory system of the people and dry cell battery has impacts on several aspects i.e. skin, polluting drinking water and consumption of lead through vegetables as batteries are generally thrown in the gardens or rivers or around the houses where normally vegetables are grown. There is difficulty to quantify these impacts as far as health impacts of kerosene and dry cells are concerned; there is no separate long-term study. However, impacts of combined indoor pollution because of fuelwood and kerosene are mentioned by WB (1996). Nevertheless, it is hard to tag any monetary value without long-duration time series studies. The health impact studies done in Europe and USA are for electricity generation not directly consumption of kerosene at home. Transfer of such data is not reliable and legitimate without detailed study. This study will just mention it qualitatively such impacts.

[97] Taking the case of four MHP plants in Myagdi and about Rs 439 per family per year equivalent of diesel or other fossil fuels are saved in industrial and commercial activities.
[98] Certainly, importing MHP components may initially drain some resources.

#### 5.4.3.4 Feeling better living situation, gender issues and drudgery aspects

Certainly, because of the better lighting the living conditions will be better after electrification. As Cecelski (1996) and many others mentioned that rural electrification may create employment as well as a source of social change and feeling of 'modernity'. Kerosene lighting and electricity lighting makes the family feel being of a different status (see more in Chapter Six). Nevertheless, such impacts are again hard to quantify.

There are still Nepalese villages where people walk about 2-4 days to pick up kerosene and salt. In the perspective of energy needed for lighting, kerosene induces more drudgery than electricity. In case of agroprocessing, kerosene could not reduce drudgery as done by water turbines or electricity-operated mills (more in Chapter Six).

### 5.4.4 Political externalities

It could be a bit philosophical to say that wrong political paradigms are a sort of externalities. In reality, it could be blamed as a normative definition. However, in my opinion, externalities or hurdles that are due to wrong political decisions are political externalities although such decisions are having impacts on all other externalities. More importantly, several externalities could be controlled by good policies as well. If a political system does not have a policy of internalization of externalities and has no 'wrong' or 'biased' policies then the state is “neutral”. In the case of neutrality, there would be only three types of externalities for rural energy sector of Nepal as explained above. When a government has a wrong policy of subsidizing the kerosene or a neighbor country places the blockade on energy then the costs and benefits arising due to such activities must be termed as political externalities. As per Krupnick et al (1994) whether damage or benefit is an externality or not, is also a political question. Politics generally decides the boundary of externalities and if such boundary is inappropriate, there exists political externalities because if a boundary is wrongly defined, economic, environmental and social could not cross the boundary and could not illustrate or encompass all possible externalities.

Various approaches, which are being used to incorporate environmental externalities, could not be the optimum and if, because of these approaches, a new situation is occurred causing extra costs and benefits, then this externality must be calculated and placed under the political externalities. The following figure clears how political externalities can occur.

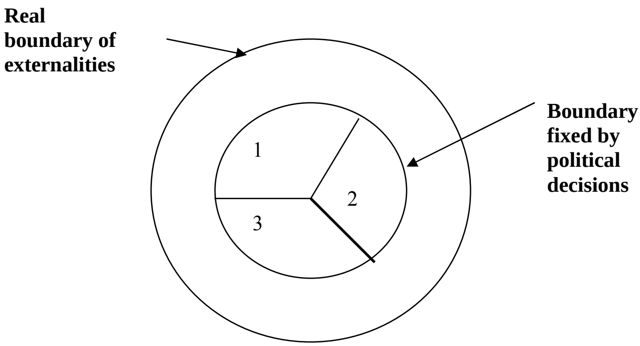


Figure 5.5 Definition of political externality (1, 2, 3 are possible externalities components)
Source: Author

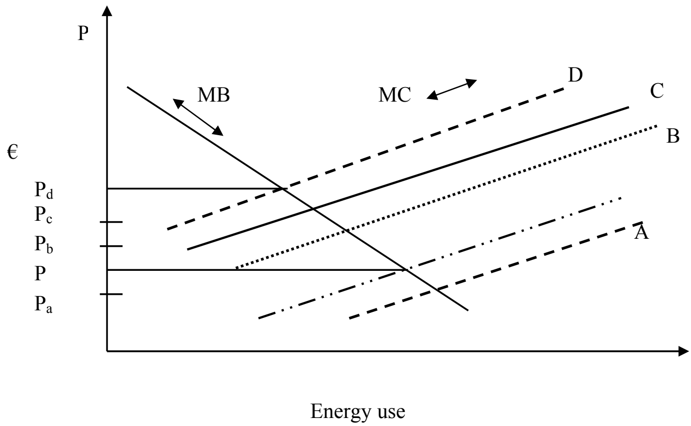


Figure 5.6 Political externality
Source: Author

P = Marginal private cost (MPC)

Pa = MPC - subsidy as per policy1 | Pb = MPC + added externality by policy2

Pc = MPC + 'actual' externality | Pd = MPC + added externality by policy 3

So, the political externalities could be (Pd –Pc) for policy 3 or (Pc- Pb) for policy 2 and (Pc-Pa) for policy 1. Although, the policy 1, 2 and 3 could have mentioned that externalities were internalized. In the case of Nepal, in the rural energy sector the followings could be the political externalities

- unjustified subsidies,
- improper custom duty free facilities, inappropriate tax,
- expensive electrification extension in the presence of alternatives,
- deprivation of resources rights and its services and
- uncertainties of supply and such impacts.

### 5.4.4.1 Custom duty

For example making custom duty free or subsidies on kerosene and on the components of big hydro, the locally built micro hydro may not compete in the market. This variable is also an externality. As per electricity acts 1992, the following provisions are made:

- "The licensee, who has obtained license for hydro-electricity generation, transmission, and distribution shall be exempted from income tax for fifteen years from the date of generation, transmission, and distribution of electricity for commercial purpose (Article 12 clause 3)
- Only one percent customs duties shall be levied for the import of materials, which are not produced in Nepal, and no charge for import license and sales tax shall be levied for such imports (Article 13 clause 7)."

The above-mentioned policy is normally meant for hydropower of any range. Micro-hydropower is the local technology and manufactured locally. However, no such import facilities and tax incentives to the MHP component manufacturer have been provided[99]. MHP Manufacturers are also paying normal customs duty for the components (*See Box*). The manufacturers are also paying all types of tax per year as mentioned in the Chapter Six. The policy mentioned above has been promoting bigger hydropower. As bigger hydropower are not so environmentally friendly if not planned, designed properly considering several criteria laid down by world commission on dam (WCD 2000) and several hydropower of MW range in Nepal could not have fulfilled such criteria. If such policies are causing negative impacts on MHP or other resources or technologies, providing such facility of customs duty free, no charge on import license and sales tax is an externality. However, such data are available only from a hydropower implemented by an Individual Power Project (IPP) to calculate the externality. The 60 MW Khimti

[99] Based on the interaction with the five manufacturers of MHP in Nepal.

Hydropower Project[100] has paid about Rs. 2,581,824 because as per Electricity Act (1992) clause 12 (7) only 1% custom duties have to be claimed for importing the electro-mechanical and construction material for the implementation of a hydropower plant. This indicates that when the government implements bigger hydro providing such facilities then the revenue from custom duty is about Rs 43.03 per kW, if Khimti hydropower project is taken as an example[101]. The similar figure for MHP would be different as shown in the table below. Then assuming 10 families per kW in both the cases, the benefit to the government will be about Rs 297.83 from MHP and Rs. 4.30 from big hydro per beneficiaries HH from customs duty.

**Table 5.10 Customs duties paid for MHP components import[102]**

| MHP scheme/ District | Capacity kW | Selling cost in quotation | Real cost of manufacturer | Customs duties paid | Customs duties paid /kW |
|---|---|---|---|---|---|
| Sanimkhola/Myagdi | 8 | 116,625 | 87,468.75 | 26,240.63 | 3,280.08 |
| Mahakhola/Myagdi | 11 | 160,100 | 120,075.00 | 36,022.50 | 3,274.77 |
| Barsadkhola/ Tanahun | 23 | 298,930 | 224,197.50 | 67,259.25 | 2,924.32 |
| Bagarkhola/Myagdi | 35 | 378,650 | 283,987.50 | 85,196.25 | 2,434.18 |
| Average customs duty paid to the government per kW of MHP | | | | | 2,978.34 |

Source: Author

Even though major MHP components are manufactured locally, few components as discussed in Chapter Seven, are being imported paying about 30 percent custom duties, according to the manufacturers. The average custom duty paid by MHP is about Rs

[100] The information regarding Khimti Hydropower Project (60 MW) implemented by a private sector is received through e-mails from the General Manager Mr. Tor Bendik Midtgarden and Finance Manager Mr Sunil Manandhar of Himal Power Limited on 28, 29 and 30th of July, 2003. Himal power limited is also complaining that government has not refunded the deposited amount that was paid for custom duties initially as per act even after the implementation of the project. Government seems not obliging the policies or acts formulated in 1992 in practice.

[101] From other two IPP hydropower projects the data on the actual custom duty paid could not be received despite several requests to the company as well as concerned authorities. However, the per kW cost of Khimti is average cost of such MW hydropower in Nepal. There are even expensive hydropower than Khimti. Khimti is a good example of IPP from cost perspective. So, taking Khimti as an example may represent other hydro of similar range tentatively.

[102] Data are from the quotation submitted to the communities of Myagdi district by the manufacturers. About 25% profit is assumed to be added the cost in quotation. According to the manufacturers (NYSE and GE), about 30-40% customs duty is charged in the import of MHP components.

2978.34 per kW. This is the revenue of government whereas Hydropower of MW range, based on the example of Khimti hydropower is about Rs. 43.03 per kW[103].

**Box 5.1 Biased policy-inducing externalities**

The generator needed for MHP is worth about 10% of the MHP electro-mechanical cost. MHP manufacturers have to pay about 30-40% customs on the generator import. Insulators needed for the transmission and distribution components of MHP costs about Rs. 15 in the local market whereas the customs office in the boarder valuated the fixed rate of Rs. 50 per piece randomly. That means MHP manufacturers have to pay more customs. The other components that are to be imported are also levied same percentage of customs as generators, whereas bigger hydropower pays 1% custom duty only. Therefore, this case already shows the biased custom duty policy towards MHP.

**Based on the interaction with Manufacturers- NMSS and TE in Butwal, Nepal**

#### 5.4.4.2 Subsidy in the grid

Expansion of the grid is said to be highly subsidized in Nepal. The public investment for the grid including generation, transmission and distribution systems in Nepal are costly and are about US$ 550 per family for 100 watt connection as compared to MHP, which is about US$ 74[104] (Pandey 2003). Grid extension in Nepal is said to be 100 percent subsidized under ESAP/DANIDA Programme[105]. Subsidizing the grid despite of

[103] The liberalized policy of Nepal, Hydropower Development Policy 1992, 2001, Water Resources Act-1992, Electricity Act-1992 collectively providing several benefits to the foreign investors. The lucrative one is providing customs duty free charging only one percent on the import of electromechanical as well as construction materials needed to implement private owned MW power plants. Assuming the example of 60 MW Khimti Hydropower, which has to pay only one percent customs duty of about US$ 34,424 for the implementation of the project. If the customs duty was levied equal to MHP components import then extra one million US$ could have been earned which could have been used to subsidize 1 MW of MHP in Nepal. If Nepal will invite foreign investors and implements 600 MW project with the similar condition as Khimti then government will loose about US$100 million in customs duty, which could be utilized to provide subsidy to 100 MW MHPs, which are of kW range. However, other way round, if government facilitates to implement MHP of 100 MW, it received, assuming present condition, 3.97 million US$ as custom revenue. The employment opportunity will much more higher than big hydro.

[104] Average government grants, promotion, and monitoring costs for the installation of renewable energy technology, as per Pandey (2003).

[105] Personal interaction with Mr. Bikash Pandey, Director, Winrock International/Nepal.

economically feasible alternatives is an act of inducing externality. The grid transmission and distribution even with medium and low-voltage are not so cheap compared to MHP[106].

From Table 5.11, the average cost of transmission and distribution system of MHP is about Rs 62,744 per kW and the cost to a family is about Rs. 5,553. These includes the required MCBs, PTCs, and control systems. Where as the load control system may not be counted in case of grid system under the transmission and distribution system. The following table compares the costs of transmission and distribution of grid as well as MHP.

**Table 5.11 The average transmission and distribution costs of MHP in Nepal**

| MHP capacity in kW | Transmission length kM | HH nos. | Total transmission distribution cost Rs. | Cost Rs./kW | Cost Rs./HH | Remarks |
|---|---|---|---|---|---|---|
| 2.5 | 1.60 | 25 | 144,780 | 57,912 | 5,791 | Includes transmission, distribution, MCB, load controller with ballast heater, wooden poles, installation charges |
| 3.5 | 3.00 | 30 | 220,200 | 62,914 | 7,340 | |
| 11 | 7.55 | 82 | 473,900 | 62,768 | 5,779 | Includes transmission, distribution, MCB, electronic load controller with ballast heater, wooden & steel poles, transportation and installation charges but excludes the cost of generator |
| 30 | 22.50 | 264 | 1,771,300 | 78,724 | 6,709 | |
| 35 | 23.50 | 300 | 1,270,720 | 54,073 | 4,236 | |
| 50 | 25.20 | 437 | 1,513,833 | 60,073 | 3,464 | |
| Average cost Rs. | | | | 62,744 | 5,553 | |

Source: Author (based on the quotations of different companies submitted to REDS Myagdi and internal reports of REDS Myagdi after the installation of MHPs in the district.)

From Table 5.11 and 5.12 (next page), it is clear that from the MHP system for rural electrification, there is at least Rs. 62,744 per kW and Rs. 5,553 per family. The cost difference with the Grid per household is about US$ 76 even with cost minimizing

[106] The construction cost, in the case of the grid based MW hydropower in Nepal, for 0.4 kV transmission line is about US$ 4,700/kM (single circuit), for 11 kV US$ 5,400 /kM (single circuit), for 33 kV US$ 6,700/kM (single circuit), for 132 kV transmission line US$ 100,000 per km (double circuit) and for 66 kV transmission line US$ 80,000 per km (double circuit).
(Source: Transmission Line Expansion Plan, final Report ,Norconsult/ADB/NEA,1998 and information

approach. With the reference to MHP this amount is a political (economic) externality as both type of systems provide almost similar facility[107] of lighting to the rural villages. In case of transmission and distribution via medium voltage line, the difference in cost is about 12 times and with low voltage line which could be similar to MHP the difference is about 6 times as compared to MHP.

**Table 5.12 Transmission and distribution cost of the Grid and MHP in Nepal**

| Grid with Medium-Voltage Transmission and Low-Voltage Distribution | | MHP with 220 Volt transmissions and Distribution including service wire, MCB, steel poles, earthing sets, etc.[108] | |
|---|---|---|---|
| Type of System | Cost US $/kWh | System | Cost |
| 3 km spur line, 20 HH | 0.45 | Includes transmission, distribution, MCB, Electronic Load Controller with ballast heater, wooden and steel poles, and transportation, installation charges but excluding generator | Rs. 62,744 per km (almost equal to US$ 837 as per tentative average exchange rate in 2002) |
| 3 km spur line, 50 HH | 0.20 | | |
| 1 km spur line, 20 HH | 0.15 | | |
| 3 km spur line, 50 HH | 0.07 | | |
| Medium-Voltage Line | $ 10,000/km | | |
| Low-Voltage Line | $ 5,000/km | | |
| Cost/HH (distribution)[109] | $ 150 | Cost/HH | Rs. 5,553 eqv. (US$ 74) |

Source: Author (Based on data from World Bank (1996) and the quotation submitted by manufacturer & installer of Dajunkhola MHP (commissioned in the year 2000), Okharbot, Myagdi in Nepal)

## 5.5 Internalization of externalities

Neo-classical economists are trying to internalize these externalities through market mechanism because going out of market mechanism is considered as equal as atheist[110] to them. This can also be realized from the Coase theorem: "If there are well-defined property rights for all goods and services and zero transaction costs, the equilibrium allocation of

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provided by Technical Services Division, Distribution and Consumers Services, NEA October 2003, through e-mails and personal interaction).

[107] In the perspective of lighting and small nos. of household appliances the facility provided would be similar but the grid could provide unlimited power to a family, which is hardly needed in the present context.

[108] Cost of steel pole is received from similar quotations submitted to REDS/Myagdi by different installers. This includes installation charge of electrical system of MHP.

[109] This cost is the lowest possible cost that could be achieved with intensive public participation in Nepal as per World Bank (1996:52)

[110] Here the word atheist means the act of non-believing on the main stream economic thought is equivalent to religious atheist as per neo-classical perspective; Beckerman (1974)'s criticism to the "no growth lobby" would be the better example.

goods and services will be efficient and there will be no externalities". Certainly, who will have the property right of clean air? Who will own flora and fauna of river that will be dried after dam is built? Such questions are not answerable as per Coase theorem. "Unless externalities cover dynamic impacts – including evolutionary effects of activities, decisions made now "internalization" or "optimization" of such externalities is inadequate to realize environmental sustainability" (Ayers 2001 : 165 *emphasis added*). But even though internalizing concept is widely discussed and accepted to some extent, the main problem that hampers is the quantification and monetization of external effects as methods available are not totally certain and exact (compare Friedrich et al 1993).

Internalization of externalities attempt to convert all into economic terms because most of the economic methodologies used are based on welfare economics. "This implies underlying premises such as utilitarianism, willingness to pay as a measure of value, and the possibility of substitution between environmental resources and other goods" (European Commission 1995 Vol 6:Vii). However, Lee (1994) suggested, "an externalities tax that is directly based on estimates of external costs is one way to internalize externalities" (Lee 1994:95). Although such substitutions or anthropogenic willingness to pay values do not reflect true value and are thus controversial (e.g. Heal 2001). Nevertheless, inclusion of 'anthropogenic economic value' of non-marketed or non-traded goods (bads) or services in decision-making is a step forward in recognizing their values, at least economically. Therefore, unless and until better alternatives are available such internalization process should continue, so that costs and benefits are compared optimally.

Externalities of private decisions must be internalized by the government's intervention into the market, since the lack of internalization may lead to a serious misallocation of funds and resources and to serious losses in the achievable level of social welfare (Hohmeyer 1988:19). Internalization of externalities in an economic sense is that the external costs and benefits are considered in the price of the products or services that are responsible for the externalities. Such types of internalization will not allow diverting from a point where marginal social cost of damage is equal to marginal cost of externalities reduction. That means there will be a certain amount of real residual externalities on the economic perspective. For comparison between technologies, it would clearly be wrong to disregard the residual externality (the cost below the optimal position) of any technology or resources (e.g. European Commission 1994). The residual externalities, most of the time are unknown. While comparing technologies of different types this factor can also influences the decision-making and thus outcomes.

The concept of internalization of environmental externalities has also been questioned. For Daly and Cobb, “internalization of externalities is a good policy for improving allocation, but it provides no answer to the issue of optimum scale” (Daly et al 1994: 59). Hennicke (1993) questioned, ”Wenn nun gar die Internalisierung der in Geld bewerteten Katastrophe als “externe” Kosten zur Debatte steht, werden die Fragen noch grundlegender und die Antworten noch kontroverser: Können durch verbesserte staatliche Rahmenbedingungen (z.B. Steuern, Abgaben, Zertifikate) die marktwirtschaftliche Regulierung und privatwirtschaftliche Ordnung umwelt- und klimaverträglich gestaltet werden oder ist das auf Konkurrenz und grenzenlose Expansion aufbauende System der privaten Kapitalverwertung an einer “Naturschranke” angelegt?” (Hennicke 1993:22). However, for Famulla et al (1996) and Heal (2000) in present economic societies decisions are thought to be based on economic factor and economic profit despite lots of controversies. Therefore, internalization of externalities after monetizing will at least discourage the activities that are producing all sorts of bads because of wrong economic decisions. Similarly, Masuhr (1994) warned that if external energy-use costs are not incorporated in the decision-making strategies as well as in the energy-policy sector, the function of the price in market mechanism ceased to be effective and massive misallocation will occur in every part of economy. That is also true for Nepal, a poor country, in the context of scarce resource allocation in the rural energy development sector.

## 5.6 Findings and conclusion of the chapter

In this chapter, some externalities of rural energy use in Nepal have been tried to quantify and illustrate with reference to MHP. It has been assumed that MHP will replace kerosene and dry cells in lighting and diesel in agroprocessing and other small-scale technologies used in the rural cottage industries. It is clear that the externalities and value listed in Table 5.13 (next page) would not precise and complete because data are not sufficient. There are several assumptions and aggregations. However, for the beginning, it indicates that the externalities are hindering the development of renewable energy technologies and such enterprises in Nepal.

**Table 5.13 Average externalities in the rural energy sector of Nepal**

| **Externalities inducing activities** | **Comparing with MHP[111] from the perspective of HH per year (in Rs.)** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Lighting | | | | Agroprocessing | | | Cooking | |
| | Kerosene | Dry cells | Grid[112] | Biogas | Diesel | Grid | Manual | Biogas | Fuelwood |
| Subsidy | +312.13 | na | + | +650 | +53.73 | na | na | + | + |
| Resource drain[113] | +706.31 | +184 | na | na | +268.63[114] | + | na | na | na |
| Ecological (GHG, etc.) | +177.7 | + | + | na | +75 | + | na | na | + |
| Customs/ revenue | +248.57[115] | na | +293 | na | +37.79 | + | na | na | na |
| Transmission, distribution | na | na | +220 | na | na | na | | | |
| Drudgery | + | na | | + | | | 3,942[116] | | + |
| Employment | +62.2[117] | + | + | + | + | + | | + | |
| Health | + | + | | | + | | + | | + |
| Gender | + | + | + | +[118] | + | | + | + | + |

(Note: + indicates MHP would be beneficial than the alternative and it is assumed that there is no subsidy for MHP in the calculation in this table.
Source: Author

[111] Plant life of MHP is assumed 20 years, biogas 10 years, solar PV 20 year excluding battery, grid 20 years and no discount factor is considered.

[112] Comparing with only distribution subsidy provided to the grid excluding voluntary labor and without transmission cost, but in case of MHP transmission and distribution is included.

[113] Resources drain due to import of MHP components has been assumed previously. In the case of dry cells, imported nos. that about 178.256 million dry cells per year is considered and import price is tentatively taken Rs 7 per pair as per information provided by few traders.

[114] Assuming at least an agroprocessing mill that consumes one-liter diesel per hour and runs 6 hours per day for 250 days in a year (10 month and 25 days in a month). Similarly a saw mill (or similar facility) that consumes 0.5 liter and runs the same period and a commercial enterprise like poultry or video club or similar facility that consumes 0.456 liter per day and 250 days in a year, per MHP plant, on the average. See potential diesel replacing or consuming end-uses in **Annex 6.8**.

[115] Customs duty for the kerosene, as per NOC (2002), is about Rs. 0.3 per liter. If we multiply it by yearly consumption of kerosene by a rural household, then it is about Rs. 11.66 per year per family for kerosene. And diesels share is reduced.

[116] This is a bit hypothetical after assuming that the saved hours from drudgery will be utilized to earn money at the rate of Rs 60/day, the official wage rate of Nepalese government, i.e. 700 hours per year per family will be saved if manual agroprocessing is avoided. However, this is a hypothetical opportunity cost.

[117] See **Annex 5.4** for details. From Chapter six job/employment opportunity was found to be one person per year in implementation and 0.25 person per year in operation, repair and maintenance. This figure has been compared with job/employment opportunity provided by kerosene consumed in rural areas. The employment figure is multiplied by the net earnings of a person in a MHP plant, on the average, as shown in **Annex 5.5**.

[118] Biogas needs fodder for cow dung and in rural areas, the collection of fodder and fuelwood is the job of women.

There are several types of externalities, which could be internalized easily through government's proper policy. Renewable energy, especially MHP, that is being blamed as financially unsustainable could change this status of financially unsustainability once externalities are internalized. Externalities were limited with rural energy use and in lighting and agroprocessing sub-sector. The main aim was to compare MHP with other alternative technologies that are being used for lighting, agroprocessing and small end-uses. Once overall sector is covered, the analysis could bring more accurate figures than the mentioned one. Few issues or activities as mentioned in Table 5.13 (in previous page) may not be sufficient to cover externalities. But these are currently the prevailing issues in Nepal.

One important point to be mentioned is the classification of externalities into four types, which may not widely popular because externalities exist mainly due to lack of policy to correct it. However, political externalities exist because of lack of optimum policy in the existing policy itself. It has been tried to define by illustrations. This issue has been touched here only narrowly because it is beyond the scope of work planned. A critical study is needed in this aspect.

One important point is the figures of externalities are brought down to per household level. It is because, for rural areas the energy supplying policies in poor countries are targeted taking household as an unit, e.g. subsidy in biogas, incentives for solar home system and capacity of MHP plant.

The analyses done are of very limited because of available as well as reliable data constraint. However, for the MHP technology in the context of Nepal it could provide some plausible figures that will enhance the genuine case of MHP sustainability and financial viability. More in dept study and research is needed to illustrate the externalities of the energy sector in Nepal.

# Chapter Six

## Sustainability Analysis of Micro Hydro Technology in Nepal

### 6.1 Background

Squire and van der Tak (1975) have mentioned that government would prefer the projects that generate more investment than the projects that lead to the consumption. Such investment generating projects would prefer only a profitable outcome not equity oriented output and neglect other issues. Returns from the investment-generating projects, if seen broadly, could be sustainable only if such investment improves the livelihoods of the citizens in all aspects. On the other side, generating more economic capital by the government in developing countries would not mean the common citizen would have the better living conditions (e.g. Thapa 1997). Then the question is - is the generated economic capital more important to the citizens or governments? If capital generation is so important then the generated capital must be seen differently, not from the narrow financial aspects only. That means the generated capital must include all components i.e. ecological, social and economic dimensions. If so, then the projects implemented by the governments, the public sectors and communities with such objectives of generating “sustainable investment capital” must be analyzed with sustainability approach. Generated capital has to fulfill the criteria of sustainability, and all components of capital.

Considering the case study of MHP projects in Nepal, this chapter will discuss whether the investment or the development of MHP technology in Nepal could enhance the “sustainable investment capital” that encompasses all dimensions of sustainability. To illustrate such potentiality of MHP, its macro as well as micro economic, ecological and social aspects must be analyzed. Moreover, from the existing data, every aspects of MHP will be analyzed to thrash out how and at what level MHP is promoting sustainability in Nepal.

### 6.2 Sustainability analysis and issues of MHP

Analysis of MHP may be one of the possibilities of providing energy to the rural poor because, its significance, if any, would be better to illustrate and ascertain in the analysis rather than implicitly mentioning advantages. Such endeavors will bring the transparency in the system's analysis in more acceptable version and small-scale sustainable systems would get due weight. As it is certain that finding the true value of electricity supply to the rural community through MHP becomes particularly complex, if all the factors have to be taken into account.

After switching people from kerosene to electricity generated from sustainable technology like MHP, there should be more social benefits like enhanced livelihoods, better distribution of development benefits, less drainage of hard currency, lower risk in the investment from the aspect of climate change, etc. Because of these possible benefits, subsidies have been provided to the technology. However, until today solely financial indicators are taken as a base in the decision-making (see. ESAP/DANIDA's financial guidelines for MHP in Nepal). That has to be changed at least in the decision-making process for sustainability-promoting projects. These projects are to be analyzed through the improved approaches like sustainability analysis[119]. The following section will discuss the real examples of sustainability analyses considering issues that were discussed in the previous chapters.

It is very normal to say, "it is easier to make a profitable micro hydro plant socially beneficial than to make a socially beneficial plant profitable" (Khennas et al 2000), in the case of isolated MHP plants. However, the question is about the objectives of such plant's implementations. Khennas et al (2000) have also categorized the three different objectives of implementing MHP. Social infrastructure development objective and profit oriented objective that handles MHP as a market product and the third objective is a catalytic support to create economic activities making MHP financially sustainable. However, the first and third objectives can be combined because enhancement of social infrastructure always boosts other activities beneficial to the people. In the case of MHP for rural electrification, it is already discussed from several studies mentioned in this thesis and author's own field research that electricity enhances the economic as well as social and environmental activities.

So here, more analysis will be done on the social infrastructure as well as on the spin-off aspects rather than on the objective of dealing MHP as a market product only that has to be sold to make the profits. In the case of Nepal, community owned MHP's objective would

[119] This is done in the following sections of this dissertation.

be more compatible with "to make socially beneficial plant profitable" in all aspects and must be evaluated and analyzed accordingly.

### 6.3 Selection of the case study areas and project sites

As discussed in chapter one, to generalize the case study, secondary data of about 40 community MHP sites were selected from different part of the country. Investment cost, beneficiary households and capacity of the plant were analyzed. The analysis of these characteristics shows that there is strong relationship among the three characteristics of 40 MHP sites (see **Annex 1.4** for details of analysis using SPSS 10.0). It is assumed that these MHPs from the 10 hilly and mountainous districts of Nepal can represent the characteristics of MHP projects in the hilly and mountainous regions in Nepal. So analyzing few of them could represent the minimum character of MHP although social setup of the community, purchasing power of the community, etc. would be different. However, MHP for basic domestic lighting and agriculture-based industry would have similar character in farmer-dominated villages.

### 6.4 Ecological dimension of MHP

In Chapter One, it has been already discussed that the ecological component of sustainability has carrying capacity as a reference parameter. The carrying capacity as a reference parameter has mainly three factors: resource consumption rate, waste generation rate and population growth rate. Based on these factors of the given reference parameter, a project's output and input of ecological capital are valuated. In other words, a project's ecological conditions of virgin stage (before the project implementation) and new stage (after the installation and operation) would be analyzed and valuated.

The new stage could be a prognosticated stage, (like electrified village after MHP). In such cases, the possible impacts or uncertainties are to be valuated by the existing methodologies of the impact assessment. Assigning the values for the prognosticated outcome is very complex. It would not be possible to tag the numeric values to all values accomplished from the valuation, but few need in binary scale and others are in ordinal or ratio scales. The scale must not be based on in monetary units because before and after comparisons can be made without monetary units. However, if net benefits have to be brought into a single index it could be done through existing methods, normally in the monetary units. That is because economic units and scales based on monetary units are dominating the decisions. So, in sustainability analysis in this Chapter, both methods, i.e. comparing after and before in individual dimensions and finally bringing it into a single index is being tried. If a project has no positive or negative impact then the change of ecological capital would be zero. The constraint for sustainability in the ecological component was laid down as $\boldsymbol{dCn_t/dt \geq 0}$, (from figure 2.3 and 4.6 $Cn_2 - Cn_1 \geq 0$) for the community owned MHP in Nepal. This condition, in case of the decentralized MHP indicates that the changes in the ecological capital must be greater than or equal to zero after the system is being installed, operated and used.

The ecological capital is understood as the capital available in our nature and providing us directly or indirectly some services or possesses such possibilities. In the case of decentralized MHP, the ecological capital, as input and output are water and surrounding environment- forest, vegetation, air, etc. Other capitals are the electro-mechanical components of the system, canal and other accessories needed for the system's transmissions, distributions and operations. Looking at inputs, the impact and the gained ecological benefits from the output, ecological components based on the reference parameters and factors, are analyzed. The following indicators could be taken to analyze the ecological capital of a MHP project at project level:

a. Ecological conditions of the project site and the benefiting community before the project is being implemented and after the project is completed: Condition of water and air and condition of emission in air, water and such possibilities
b. Ecological impacts of mechanical and electrical components including transmission and distributions
   i) GHG emission during manufacturing
   ii) Natural resource degradation and impact on local environment
c. Ecological impacts of canal and other civil components
   i) Soil erosion and vegetation and loss of flora-fauna
   ii) Irrigation and other gained benefits
d. Ecological impacts avoided due to the use of output from the system
   i) GHG in lighting agroprocessing and income generating activities
   ii) Natural resource degradation of fossil fuels (national as well as global)
   iii) GHG emission saving in energy supplying systems

### 6.4.1 Analysis of the ecological capital in the beginning

Ecological conditions of the project site and the benefiting community before the project is being implemented are taken as the basis for discussion. The condition of water, air, and any such conditions could also be analyzed but only the existing ecological condition from the perspective of energy use that has been substituted by MHP will be focused. The air pollution in the villages in the beginning may have some value due to kerosene and fuelwood burning. Looking at the pollution potential of kerosene, the villagers, who are now using MHP, have emitted, on the average, 0.1005 ton of CO2 per year per family in lighting only before electricity from MHP came into use (see Table 6.1 in next page). However, about 0.4266 ton per year would have been emitted by a family if one kerosene wick lamp for a bulb had been used.

The emissions from cooking, heating and other activities are not included in the Table 6.1. This emission amount is relatively low as compared to the western countries like the USA and Germany where emission is few tonnes per capita per year. The Table 6.1 (in next page) just indicates the air pollution in terms of CO2 only; it does not include other gases and fumes emitted by kerosene. In the case of pollution from energy technologies or resources used for lighting before MHP implementation, the dry cell comes second. The dry cells used were not in a tiny quantity when comparing the ecological aspects at micro level. The dry cells used in some REDP Programme VDCs, where MHPs are being implemented, are given in the **Annex 5.3.**

The ecological pollution potential of dry cell battery is on air as well as soil and water in villages because of open the disposal of the used batteries. On the average, 2.76 pairs of dry cells are used per month per household in rural villages (see **Annex 5.3**). The GHG emissions from the previously existing diesel mills would have to be calculated. By assuming only Okharbot VDC in Myagdi, the figure as in Table 6.2 (in next page) is to be seen. That means the main ecological impact before the implementation of MHP was on air pollution (especially indoor), soil and water due to kerosene and dry cell battery from the perspective of lighting and small amount of GHG from the use of diesel in mills. These are small in amount but are on the rise because of increasing population and consumptions.

**Table 6.1 Kerosene consumption and GHG emission in 10 different villages in Nepal**

| VDCs/ Districts | Kerosene consump-tion liter/ HH/Month | GHG emitted ton/yr by a HH | Capacity of MHP in kW | No. of HH using MHP | GHG emission by HHs before MHP in lighting (ton/year) | GHG that would have been emitted if one bulb is equal to one wick lamp (ton/year)[120] |
|---|---|---|---|---|---|---|
| Bima/Myagdi | 3.1 | 0.09752 | 8 | 48 | 4.69 | 32.160 |
| Arman/Myagdi | 4.09 | 0.12867 | 11 | 82 | 10.56 | 44.220 |
| Marang/Myagdi | 3 | 0.09438 | 20 | 272 | 27.59 | 80.400 |
| Lulang/Myagdi | 2.76 | 0.08683 | 25 | 252 | 22.08 | 100.500 |
| Okharbot/Myagdi | 2.98 | 0.09375 | 30 | 264 | 24.78 | 120.600 |
| Bhuktangle/Parbat | 3.56 | 0.11199 | 27 | 258 | 28.93 | 108.540 |
| Sarkuwa/Baglung | 3.14 | 0.09878 | 24 | 290 | 28.68 | 96.480 |
| Taman/Baglung | 3.2 | 0.10067 | 20 | 200 | 20.16 | 80.400 |
| Sirsha/Dadeldhura | 3.81 | 0.11986 | 22 | 129 | 15.48 | 88.440 |
| Thampalkot/ Sindhupalchowk | 2.3 | 0.07236 | 26 | 271 | 20.48 | 104.520 |
| per HH (Average) | 3.24[121] | 0.1005 | | | 0.102 | 0.4266 |

Source: compiled from HH survey data of REDP/UNDP programme districts and *Baskota et al (1998)*

**Table 6.2 End-uses and their GHG (CO2) emission in Okharbot before MHP**

| Technology using diesel fuels | No. | Amount of diesel liter per year | GHG emitted ton CO2/year | Remarks |
|---|---|---|---|---|
| Previously existing mill | 1 | 1,500 | 4.210 | 250 days x 6 liter[122] |

Source: Author

[120] On the average, one bulb is equal to 25 watt (although some are lower than that like energy saving bulbs etc.) and 40 bulbs in one kW.

[121] It is interesting to compare the several studies done in Nepal regarding the average kerosene consumption of a HH per year in the rural areas. The Pre-electrification baseline survey carried out in 10 REDP Programme VDCs shows that on the average 3.24 liter of kerosene is consumed by a HH for lighting per month. This data resembles with the data of WECS (1996), which mentioned about 39 liter/HH in rural areas per year. However, the similar pre-electrification baseline survey carried out by the ICIMOD (1991) in Jharkot in Mustang District mentioned that the average kerosene consumption of a HH is about 2.5 liter per year. Interestingly, the same report mentioned that the lowest income earning family of Jharkot applied for subscription of two bulbs minimum. On the other hand, REDP (2002), Shakya et al (2003) have also mentioned that each rural household consumes about 5 liter of kerosene per month. However, in my calculation I take the average of ten villages in different parts of the country.

[122] As per ITDG/CRT (1995) study, the general agroprocessing diesel mills used in Nepal are using about 1 to 1.5 liter Diesel per hour and are running 5.83 Hours per day and 300 days in a year. In Okharbot VDC of Myagdi District, about 1 liter per hour and 6 hours per day for 5 kW diesel engines has been used for about 250 days in a year, as per the authors own study in 2002. This has also been assumed here in the calculation.

### 6.4.2 Analysis of the ecological outputs

From the aspects of environment, there are two types of benefits: firstly, betterment of environment because of MHP and secondly avoidance of possible environment problems that could have been occurred if MHP had not been implemented. Improvement of environment because of MHP could be the forest in its catchments areas. Because of the need of maintaining perennial water flow and prevention of possible landslides in canal areas, people, especially in the community owned MHP, tend to keep trees and forest intact. This has also been observed in the community owned MHP projects of REDP (see also REDP 2000a). This is very hard to quantify such benefits in the short term.

The second benefit occurs because of avoidance of certain environmentally damaging behaviors, practices or products after the installation of MHP. Such benefits as listed below could be quantified to some extent:

- reduction of indoor air pollution due to the reduction of kerosene use[123],
- reduction of GHG by abandoning kerosene as a fuel for lighting and sometimes diesel for agroprocessing,
- avoidance of GHG emission and air pollution because of providing clean energy to upcoming enterprises like sawmills, bakery, agroprocessing mills which otherwise could have used diesel, kerosene or other unsustainable energy resources and
- reduction of soil pollutions and poisonous gases due to the avoidance or reduction of dry cell batteries previously used for radios, cassette players and torchlight.

Looking at the MHP system as a whole or MHP cycle as a whole, there are environmental benefits. Considering an example of a project site in Myagdi District, the Dajungkhola MHP, there is almost no water pollution problem observed physically. The civil component has used cement, sand, and stones[124]. Sand and stone were collected locally and were available freely that is without making any other destructive works or explosions.

[123] Additionally, due to the brighter light inside the rural houses, fuelwood smoke could be seen as dirt by the households and would try to reduce that from improved wood burning methods, as observed in the villages where MHP has been implemented. MHP may not change all the conditions but the pollution from kerosene and battery waste could be changed, and would induce the reduction of the fuelwood smoke as a spin-off effect. The brighter light exposes all dark corners and people would like to make that cleaner.

[124] For this 30 kW system of Dajungkhola, stone 383 cub m sand 104 cub m, aggregate 9 cub m, cement 31 tonnes and wood 3 cub m were used during the construction. Similar details for other sites have been given in the **Annex 6.17.**

There are no such impacts from the civil components (canal, diversion etc)[125] because of minor works.

In the community owned MHP system, communities have followed the environment management guidelines prepared by the facilitator of the MHP schemes - REDP/UNDP (e.g. REDP 1997). Such guidelines are also applicable to other agencies or the private entrepreneur operated MHP through the local authorities, if policy could be made. Slope stabilization and erosion control efforts explained by the guidelines are to be followed by the community. The checklist prepared (mentioned in guidelines) by the REDP for the environmental parameters of MHP guides to the community to make less impact on the water resources and the surrounding environments. Condition of local air and water is more or less in acceptable standard because of trivial changes by any civil construction works in MHP. The diverted water generally goes back to the stream if it could not be used for the irrigation and drinking purposes. Therefore, from the water pollution or impact on water resource perspective, the project has very tiny impact, if there is any. River ecology nearby villages are not in virgin and undisturbed site from the perspective of human interference, so negative ecological impacts for run of river type MHP are small (e.g. Spreng 1992:4 in PROGNOS)[126].

In **Annex 6.1,** the impact of civil components in the few MHP sites in Nepal has also been listed. That will illustrate the scale of the impact of civil components. Nevertheless, as suggested by mitigation measures in Environment Management Guidelines of REDP (1997), the MHP owning community must follow the directions to have trivial or minimum impact in the local ecology during as well as after the installation of MHP in their vicinity. The guidelines are simple and locally manageable and any impact that could arise is mitigable. Therefore, one can say that civil components of MHP are not environmentally unsustainable[127]. Table 6.3 (in next page) shows a few ecological impacts of MHP as compared to fossil fuel plants.

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[125] Certainly, there are some impacts (health impact to the worker, etc.) due to the use of cement and could be other impacts in the production cycle of cement. Regarding GHG and other impacts of total MHP cycle, Table 6.3 illustrates some data considering all needed material for MHP.

[126] However, as PROGNOS report, there were also controversies regarding MHP's ecological impacts in European countries, however, in Nepal environmentalist are in the favour of MHP projects. It is true that ecological impacts of MHP are also to be considered.

[127] However, there are few cases that the canal of MHP has induced the landslide problems. Such cases could be avoided in planning or through locally manageable afforestation programmes.

**Table.6.3 Ecological impacts of MHP other than GHG**

| | | | | | | |
|---|---|---|---|---|---|---|
| Quantitative | Land use Sqft/kWh | Flying Dust Residue | Ashes | Other Solids | Remarks | |
| | | lb/kWh | | | | |
| | 0.00022 | 0.0000 | 0.0000 | 0.0000 | For MHP | |
| | *0.00003* | *0.04733* | *0.00508* | *0.00796* | *For Oil-electricity* | |
| Qualitative | Residuals | Accidents | Micro-ecology | Land use | Special aspects | For |
| | | | - | - | Multipurpose facilities | MHP |
| | - | - - | - - | - | *Tanker Accidents* | *Oil-electricity* |

Source: Compiled from Fritzsche (1990). The environmental impact reference is based on MHP's 50 years of life and 5,000 hours of operation per year. "-"indicates the extent of qualitative effects.

The above-mentioned environmental impacts of MHP are based on so-called TEMIS program (Total Emission Model for Integrated Systems) applied for US data. However, it has been mentioned that these data are applicable to other countries too. The comparison between oil - based electricity generation and MHP shows that MHP is more advantageous except in land use impacts. Almost all non-renewable and renewable energy technologies are having such impact. The above-mentioned impacts also include the ecological impact of electromechanical components. The air pollution or GHG pollution aspects of MHP is given in the following paragraphs.

Outputs of the MHP are electricity and/or mechanical energy, which, normally in the context of hilly and rural regions of Nepal, replaces kerosene used for domestic lighting, replace diesel used for agroprocessing and human labor. Table 6.4 shows how environmental benefits even after considering MHP life-cycle and $CO_2$ emission are outweighing the kerosene use. In other words, ecological capital in the perspective of avoidance of $CO_2$ emission could be considered increased after the installation, operation and use of MHP. Therefore, the condition of constant or increased ecological capital could be positive. The Table 6.4 compares the ecological impacts of lighting by using a kerosene wick lamp and a 25-watt[128] bulb by a poor family in rural village.

**Table 6.4 Kerosene and electricity in rural lighting from ecological perspective**

| Details | Before MHP | After MHP | Remarks |
|---|---|---|---|
| Source of lighting | Kerosene | Electricity | |
| Type of lamp | One kerosene wick | One 25-watt incandescent bulb | Majority of users |
| consumption[129] of Fuel/Energy per year | 39.85 liter (equal to 387 kWh) | 54 kWh | 1 liter kerosene = 9.7 kWh |
| Lighting duration | 2.7 hours/day | 6 hours/day | 39.85 liter kerosene is needed for a year when 2.7 hours/day lighting is done |
| Nominal power consumption ) | 400 watt | 25 watt | Energy content of kerosene is 36.26 MJ/liter |
| GHG emission[130]/year (CO2 equivalent) | 218.64 x $10^{-3}$ ton from one wick-lamp | 0.5475 x $10^{-3}$ ton from one 25-watt incandescent bulb | 25-watt bulb emits about 218.0925 x $10^{-3}$ ton less CO2/ year. |
| Local air pollution | indoor especially for learning children | No | (e.g. Banskota et al 1997 mentioned that MHP has insignificant impact) |

Source: calculation based on authors collected data and Banskota et al (1997), Broek et al (1997), WB (1996), Fritsche (1990)

A rural family consumes about 39.24 liter kerosene per year that is equivalent to 2.7 hours[131] lighting per day (as it would be the average duration in the Nepalese villages). However, in case of MHP, they get the facility of at least more than the double duration of lighting from electricity. Moreover, the amount of pollution from kerosene wick lamp is significantly higher than from electricity. From ecological point of view, a 25-watt incandescent bulb for 6 hours of lighting is far better than 2.7 hours of kerosene wick lamp. According to the data in Table 6.5 (in next page), about 8.278 tons of GHG would be reduced by a household in 20 years after MHP implementation if one 25 watt bulb equals

[128] Before MHP project, people were using, on the average, one kerosene wick-lamp per family and a kerosene wick-lamp is being compared with a bulb taking the case of Dajungkhola MHP of Okharbot VDC. The case is applicable to all VDCs because of similar patterns of MHP in other VDCs.

[129] Considering 2.7 hours of lighting in the case of kerosene wick lamp because of the average consumption of 39.85 liter/hh/year from studied data; and the consumption of kerosene per wick lamp is about 0.041 liter/hr (e.g. Broek et al 1997). For electricity, 25-watt bulb is considered for 6 hours of lighting. Nevertheless, while calculating CO2 emission it is considered that the electric lamp lights whole year (at least 5,000 hours per year)- as CO2/kWh emission of MHP is based on life cycle as per Fritsche (1990).

[130] GHG CO2 equivalent (CO2e) emission of MHP-life cycle is 0.0025Kg/kWh and of Kerosene is 0.0723 T/GJ only when burning but not its life cycle emission, which could be more than the mentioned figure.

[131] As per Broeck et al (1997), about 0.041 liter per hour is consumed by a kerosene wick lamp.

to a wick lamp. However, at the current practices, i.e. avoiding kerosene that was used before MHP, the average reduction would be about 1.929 tons per households in 20 years.

**Table 6.5 Ecological benefits in terms of GHG after MHP installation**

| VDCs/ Districts | MHP capacity | Kerosene consumed monthly | CO2 from kerosene per year in ton | CO2 from MHP per Year in ton | CO2 reduction per Years in ton | CO2 reduction if one bulb equals one wick lamp |
|---|---|---|---|---|---|---|
| Bima/Myagdi | 8 | 3.1 | 4.69 | 0.08 | 4.61 | 18.665 |
| Arman/Myagdi | 11 | 4.09 | 10.56 | 0.11 | 10.45 | 42.140 |
| Marang/Myagdi | 30 | 3 | 27.59 | 0.30 | 27.29 | 110.055 |
| Lulang/Myagdi | 25 | 2.76 | 22.08 | 0.25 | 21.83 | 88.064 |
| Okharbot/Myagdi | 30 | 2.98 | 24.78 | 0.30 | 24.48 | 98.808 |
| Bhuktangle/Parbat | 27 | 3.56 | 28.93 | 0.27 | 28.66 | 115.436 |
| Sarkuwa/Baglung | 24 | 3.14 | 28.68 | 0.24 | 28.44 | 114.474 |
| Taman/Baglung | 20 | 3.2 | 20.16 | 0.20 | 19.96 | 80.425 |
| Sirsha/Dadeldhura | 22 | 3.81 | 15.48 | 0.22 | 15.26 | 61.696 |
| Thampalkot/ Sindhupalchowk | 26 | 2.4 | 20.48 | 0.26 | 20.22 | 81.675 |
| Average per HH | | 3.24 | 0.102 | 0.010 | 0.0964 | 0.389 |

Source: Author (Compiled from household survey data)

In Table 6.5, it has been considered that after the installation of MHP, there would be no use of kerosene as well as dry cells for lighting and radio. Similarly, the ecological benefits in terms of GHG avoidance from MHP in the perspective of the end-use technologies can be calculated based on previous Table 6.2 considering the examples of Dajungkhola MHP in Myagdi district. From Table 6.6 (see next page), GHG (CO2) that would have been emitted by the users in Dajungkhola MHP from the end-use technology is about 0.042 ton of CO2 per family (see similar example and similar figure in Thampalkot VDC in Sindhupalchowk district in **Annex 6.2**).

**Table 6.6 GHG (CO2) avoidance cost and benefits in Dajungkhola MHP**

| Diesel mills | No. | Diesel (equivalent) used liter/year | GHG emitted/year |
|---|---|---|---|
| Previously existing mills (now with electricity) | 1 | 1,500[132] | 4.210 |
| End-uses (mills) technology after MHP | 1 | 1,500 | 4.210 |
| Saw mill | 1 | 750 | 2.105 |
| Poultry farming | 1 | 113.9 | 0.320 |
| Total | | 3,863.9 | 10.845 |

Source: Author (calculation based on Pokharel et al (2003a))

Considering the macro and micro level impact of kerosene and diesel import, there will be a large amount of kerosene and diesel saving due to MHP. Installation of MHP will save about 391 liter of kerosene per kW per year only for lighting. A significant amount of diesel will be saved avoiding agroprocessing through diesel mills and running diesel based sawmills. From the data available from ten VDCs in several parts of Nepal, about 302 pairs of dry cells per year can be saved[133] from one kW MHP. The ecological pollution potential of dry cell battery will be reduced on air as well as on soil and water because of open disposal of the used batteries. Reduced use, thus reduced disposal, will improve the air, soil and water condition[134].

From the above discussions and data, it is readily proved that after the installation of MHP, the rural communities as well as the nation has significant ecological benefits, which are either monetarily visible or qualitatively realizable. The difference between previous condition of ecological capital and ecological capital after the installation of MHP shows that the results are in favor of human beings as well as to the nature. The carrying capacity of ecology will be enhanced after the installation from the perspective of lighting and agroprocessing and the three factors like waste (GHG and other pollutants) generation rate, resource (kerosene, battery and diesel) consumption rate and the ‘population of kerosene lamps’ (increase in population of battery and kerosene wick lamps will cause ecological damages) are reduced drastically and in some cases completely avoided. Moreover, the

[132] As per field study data and CRT (1996), the average consumption of diesel by diesel mill is taken 1 liter/hr and diesel mill is assumed to be running 6 hours per day and 250 days in a year, on the average.
[133] Saved means avoided use of such dry cell batteries.
[134] However, there is no study done at this aspect in Nepal until now.

growth of MHP projects beyond the carrying capacity of a river or a stream is almost impossible because of the technical limits, i.e. suitable site, canal construction, available flow, etc. Several MHP projects are having similar character but civil components are very much site specific and their impacts during the construction could be different. However, with proper planning and guidelines similar to that of REDP/UNDP Nepal, negative ecological impacts of construction can be minimized and benefit will be achieved. Therefore, the ecological component of sustainability is easily satisfied as per the constraint laid down by the ecological dimensions of complete sustainability in case of MHP in rural Nepal.

### 6.5 Economic dimension of MHP

Most of the projects are being analyzed economically or financially to determine whether there are any benefits for the country, for an entrepreneur, a community. Without any strong economic indicators of expected output, most of the projects are rejected. In the case of a private utility or an enterprise, a good financial return is considered necessary for the investment. Even under the umbrella of holism or sustainability approach, the economic sustainability also plays a major role. If a project is not accruing a broader economic benefit (that is not a narrow financial benefit only), then the project is said to be economically unsustainable. In the sustainability analysis, one of the major components, the economic analysis will have to be focused considering all backward and forward linkages of the projects before any decision is made. In the long term, investment or allocation of resources depend upon, including other factors, return on investment or generation of investment capital.

The economic analysis will be done easily where required conditions of quantitative data are no hurdles and economic mechanism of Laissez-Faire works. However, there is the presence of strongly influencing qualitative benefits and Laissez-Faire cannot work perpetually. Occasionally, the ad hoc policies are brought into to internalize such benefits in the existing conditions. It had been reported that, in the thirties, the rural electrification projects were supported with subsidy in the USA, as private utilities were not there to play the market game because of unfeasible conditions that could not meet the requirement of 'profit'. Similar cases were also reported in France in the twenties (Hourcade et al 1990).

That is because "priming of pump" approach is needed to bring sustainable technology a step forward. However, in the long-run they should only be provided equal level playing through policy intervention. "…if the prevailing economic order is founded on unsustainable practices, then it may be impossible for sustainable projects to be economically viable when competing with projects that are allowed large and unacknowledged subsidies …. anomalies of this kind would only be resolved if the entire global economy was reformed on the principles of sustainability, so that all economic operations were obliged to absorb energy, resources and emission costs that are not currently borne. In this situation, all projects would compete economically on an equal basis. Such a global macroeconomic set of rules does not currently exist" (Clayton et al 1996: 136-137). However, in the project level, economic aspects of sustainability issues of MHP in Nepal could be incorporated in the economic analysis by including the following factors of the micro as well as national level macroeconomic issues:

***Micro-level***

a. Revenue collected by an individual system
b. Investment cost, annuity, interest, depreciation, etc. involved in such a system
c. Subsidy, loan and other economic capital involved
d. Economic activities and its linkages

***Macro-level***

e. The employment benefits,
f. Revenues or tax collected by the government from the manufactures,
g. Reduced burden in terms of trade due to the reduced import of fossil fuel or saved hard currency and other socio-economical benefits
h. Subsidy policy

Micro level will analyze the MHP projects where as macro level looks into overall benefits from the MHP technology in Nepal. In sustainability analysis of the MHP projects, micro level would be appropriate at project level. However, to illustrate the benefits and costs of such projects at national level macro level study is also important.

### 6.5.1 Micro- economic aspect of MHP in Nepal

The microeconomic aspects of MHP have several fronts. Starting from the manufacturing industries to the end users, the microeconomic aspects of MHP has significant effects on the local life style. Being a small-scale technology, normally implemented as a decentralized system, micro economic aspects of MHP plays a significant role in the promotion of sustainability at the local level as well as at the national level through enhanced economic activities in scattered poor communities. In the following sections, it will be tried to illustrate the micro level activities and issues related or concerned with MHP technology in Nepal at the project level.

#### 6.5.1.1 Demand and supply of energy from MHP

The average domestic consumer subscription rate for micro hydropower lies some where between 75 - 150 watts (CES 2000). The average power consumption is about 105 watts per household[135] in the case of community owned systems. Installation of the plants by the community is generally envisaged to utilize electricity for lightings, for entertainment and communication equipments like TV, radio etc. Initially, there is lower demand but later it increases as numbers of households grows, people buy some new appliances and few would like to use more power[136]. Excluding a few isolated cases, on the average power demand will increase and community has to look for further options, either through energy conservation adopting Compact Fluorescent Lamp (CFL) or installing additional plants or increasing capacity of plants if it is possible. In some MHP systems, the utilization factor is very low, so for few years, the installed capacity is enough.

The load factor of most of the MHP plants is very low because of low utilization of electricity in the daytime. Using power for other purposes than lighting only may increase the load factor and thus the revenue collected. The load factor of MHP is found to be around 0.30 to 0.38 in the four MHPs in Myagdi. Demand of energy, for a short duration, is already constant, as villagers have subscribed fixed no. of bulbs[137]. Except for radio, cassette player and TV (by a few households), there is no use of electricity especially at the household level, besides evening lighting. Nevertheless, this scenario will be different in future as people with external remittances[138] would like to have ironing, cooking with rice-cooker, color TV, etc. that will change the demand scenario. Nevertheless, initially, the household demand is more or less fixed.

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[135] Taking the reference of total households benefited and the installed capacity of MHP projects in the 40 villages of Nepal as mentioned in **Annex 1.1**., although not all power that is produced has been consumed, initially in several places.
[136] In Kyang VDC of Parbat District, initially the planned power was supposed to be sufficient but after one year, more people had color TV and needed more power. Similarly, during interaction with Mr Bir Bahadur Ghale, an entrepreneur of Barpak and a MHP owner of Gorkha District, he told that in 1992 a 40 kW MHP was sufficient for the village but now the demand is nearly 200 kW and he is in the process of installing another 100 kW MHP. Paradoxically, a few HH of Okharbot and Muna VDC of Myagdi are willing to reduce their subscription to two bulbs from 3-4 because of financial problem.
[137] Each family has been using at least one 25 watt bulb to a maximum of eight 25 watt bulbs for lighting.
[138] External remittance is received generally by retired British, Indian and Nepalese army and relatives or families of those still working outside the community – either in the urban areas or outside the country.

The demand also depends on the people's income. From the field study (see **Annex 6.3** for justification), the rural HH can be divided into three types of consumers as generally available in the rural areas of Nepal as shown in Figure 6.1. The group I is paying tariff with financial burden. The group II is the highest energy-consuming group because of cash income. They are government employees, or school teachers or (I)NGO employees or foreign remittance or pension receivers. They also have more energy consuming appliances like radio, TV, cassette players and similar things and some times rice cookers as well. The group III is self-sufficient farmers, who are producing enough for their use and using their products for other expenses also by selling surplus foodstuffs[139]. This group can be potential supplier of local inputs for the value addition business.

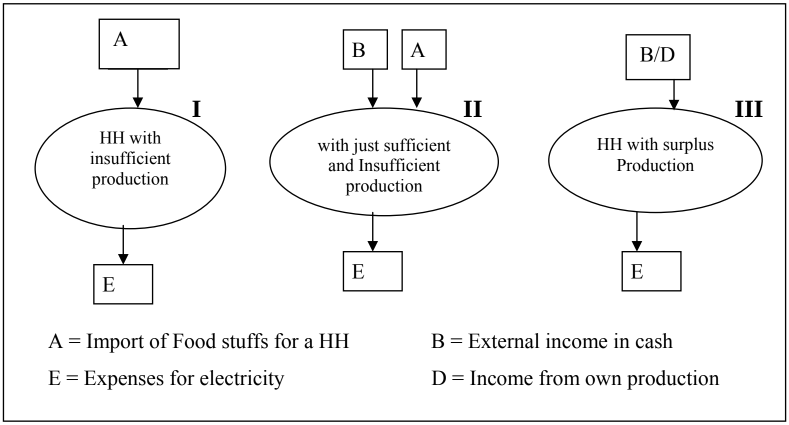


**Figure. 6.1 Status of households and their ability to pay in rural Nepal**

**(Source: Author)**

To know the demand of energy, one has to look into the socio-economic setup of the villages and its people. Electricity is used only for lighting by rural HH, in general. Only a few individual entrepreneurs would consume electricity for their electricity consuming enterprises. Ability to pay, willingness to pay and opportunity costs of all alternatives are the deciding factors. Without increasing the economic status or cash income of the people,

[139] As most of the rural people are subsistence farmers, only a few have relatively more land and producing more agro products that could be used as input to the small-scale rural and cottage industries in the region.

the demand of electricity will not be changing. However, from the sustainability aspects, the development process needs several constraints and catalysts. Electricity from renewable energy is one of the catalysts, which can bring the people in the process of development.

As the modern facilities like education and health systems, needed to the people for enhanced livelihoods, are depending on electricity either directly or indirectly, providing access to electricity means fulfilling few attributes of the development process. Moreover, electricity is enhancing additional activities on the economic sectors too, but it alone may not be sufficient to enhance the development process. However, it is a necessary condition for the better livelihoods, and better livelihood will motivate people to strengthen their capability to pay. All in all, present supply (or supply potential) and demand (or demand potential) could be balanced at the project level until people do not use electricity for cooking (see more discussion in chapter seven).

#### 6.5.1.2 Pricing of electricity

Pricing of electricity in most of the MHP plants is done on ad-hoc basis. Most of the MHPs under the community ownership, especially supported by the REDP/UNDP, are charging about Rs. 0.75 to 1.00 (0.009 to 0.0125 €) per watt (connection capacity) per month- that is about Rs. 4.45 to 5.50 per unit when we consider the lighting duration of 6 hours per day[140]. For the commercial use, it is different in different sites. There is also price elasticity found in the electricity demand. In some cases, community fixed the tariff at Rs. one per watt and some households were considering on reducing the no. of bulbs subscription. Nevertheless, when the community decided to reduce the tariff of electricity to Rs. 0.75 per watt then there were few people to add more bulbs and those who were considering on reducing, abandoned the ideas[141]. Nevertheless, there exists no known time series study yet regarding the price elasticity of electricity demands in case of MHP and the rural households in Nepal.

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[140] If the lighting duration is considered 10 hours per day, then the electricity price will be, on the average, about Rs. 3.00 per kWh.

[141] This, an isolated case, has been told by the villagers of Dajungkhola MHP and Darakhola MHP site in Myagdi District during the author's field study.

**Table 6.7 Tariff rate in few community owned MHP for lighting and end-uses**

| S. N. | Scheme/District | Tariff for lighting (Rs./ watt*/month) | Tariff for end-uses per month |
|---|---|---|---|
| 1 | Dajungkhola/ Myagdi | 0.80 | Sawmill, agroprocessing mills, bakery, poultry farm Rs. 500 |
| 2 | Sanimkhola/ " | 1.00 | No end uses |
| 3 | Darakhola/ " | 0.75 | Mills Rs. 1000, poultry Rs.500 |
| 4 | Darakhola II/ " | 0.75 | Mills Rs. 1200, video club Rs. 350 |
| 5 | Barshakhola/ Tanahun | 1.00 | Mill Rs.4.5/kWh, poultry Rs. 150, video club Rs. 500 |
| 6 | Daunekhola/ Kavre | 1.00 | Sawmill Rs. 500, agro-mills Rs. 2000 |
| 7 | Chaurikhola/ " | 0.80 | Mills Rs. 6/kWh |
| 8 | Khanikhola-F/ " | 1.00 | Mills Rs. 200 |
| 9 | Thadokhola/ Parbat | 1.00 | Mills Rs. 400 |
| 10 | Ghattekhola/ " | 1.00 | Mills Rs. 700 |

Source: Author (*Watt/ month is connected watt to each household)

Comparing the prices of electricity as shown in the Table 6.7 and the previously paid price of kerosene (**see Annex 6.4 and Annex 1.3**), one can argue that in most of the cases, people are paying lower price than before for the lighting only, because people use less than 100 watt per month (see Table 6.34 and 6.35). This is the case of reducing financial burden on the family. However, the financial sustainability has to be ascertained through the increased use of electricity. In case of stand-alone MHP system, it is the price of electricity and load factor that indicates the financial sustainability of MHP, but when there is an add-one system, the financial recovery also depends on the performance of the system, i.e. revenue from milling, grinding, husking and other activities of utilizing mechanical power and working hours of the system.

The rationale behind the pricing of electricity in the community MHP sites could be based on the following factors[142]:

- willingness to pay to sustain the MHP system, at least recovering the bank loan and the operational costs of the plant,
- as per neighboring village's practices of charging tariff (sometimes adopted without any considerations) because neighbors pay that tariff,

[142] Based on the field study of few MHP sites, interaction with community members and REDP/UNDP's local staffs working there.

- price fixing by the facilitators of donor agencies or they have facilitated to fix the tariff to sustain the system financially and
- capacity to pay the tariffs by the community members, generally fixed by the management committee of the community owned MHP.

In the case of the community owned system, the tariff is fixed by a functional group (user's group) on the consensus of community members considering the financial sustainability of the MHP systems, i.e. enough revenue for the maintenance and operation of the system and payment of the loan. This process provides the opportunity to the users to participate in the decision-making process. The social factors could be taken into account in tariff fixing for those who are 'poor'. As, in general, the community knows who is 'poor', there is no complexity as generally thought by the external experts. Subsidizing the poor would not be a problem, in one way or the other, i.e. providing jobs during the implementation or for the systems operation and management. Some concessions on tariff or other forms of incentives or subsidizing mandatory contribution to the community work[143] could be considered. For the tariff fixation, community owned system might consider several social and economic factors whereas private entrepreneur concerns mainly on financial profits. Nevertheless, community owned system should also consider the financial sustainability of the system.

#### 6.5.1.3 Consumer behaviors and capacity or willingness to pay

It is very difficult to find the elasticity of demand of electricity in short term. When calculating from the narrow financial perspective, kerosene could be cheaper than having light from electricity for a small and poor family using one kerosene wick lamp only for few hours of evening lighting. Nevertheless, people are striving for electricity and majority are ready to pay a bit higher price for electricity. From the neoclassical perspectives, it can be said that household is getting more utility from an electricity bulb than from a kerosene wick lamp. That is why they could pay more. When one applies the condition of consumer equilibrium in terms of utility, then the following would be true.

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[143] Such cases were found in Arman VDC, Okharbot VDC and Chimkhola VDC of Myagdi District. Lower cast poor people were given such incentives occasionally from the beginning of implementation works by providing job opportunity during transportation, implementation works, etc simultaneously with their mandatory voluntary works.

**Table 6.8 Tariff collection, willingness to pay and behavior**

| S. N. | Scheme/District | Tariff for lighting Rs./ Watt/month | Tariff payment |
|---|---|---|---|
| 1 | Dajungkhola/ Myagdi | 0.80 | About 90% HH paying tariff regularly, 1-2% are not happy with tariff |
| 2 | Sanimkhola/ " | 1.00 | All are paying and even ready to pay higher for financial sustainability |
| 3 | Darakhola I/ " | 0.75 | More than 80% paying regularly and around 5-10 HHs are complaining. |
| 4 | Darakhola II/ " | 0.75 | About 10% are having difficulties to pay tariff even with one bulb subscription (of 25 watt) |
| 5 | Barshakhola/ Tanahun | 1.00 | 20% are not paying regularly |
| 6 | Daunekhola/ Kavre | 1.00 | 100% tariff collection |
| 7 | Chaurikhola/ " | 0.80 | 100% tariff collection |
| 8 | Khanikhola-F/" | 1.00 | 98% tariff collection, but demand to reduce tariff to Rs 0.75/watt |
| 9 | Thadokhola/ Parbat | 1.00 | 100% tariff collection |
| 10 | Ghattekhola/ " | 1.00 | 100% tariff collection |

Source: Author

$$\frac{\text{Marginal utility of electricity (Mue)}}{\text{Price paid for electricity (Pe)}} = \frac{\text{Marginal utility of kerosene wick lamp (Muk)}}{\text{Price paid for kerosene for wick lamp (Pk)}}$$

From Table 6.8, it could be concluded that in the case of community owned system, on the average, more than 95% of the people are paying regularly the tariff fixed by the community themselves. The above-mentioned tariff rate of Rs. 0.75 to Rs. 1.00 per watt per month seems to be acceptable because if it is converted to kWh, then the price[144] comes to, on the average, about Rs. 3.00/kWh[145].

However, there will be another scenario if the tariff is fixed higher than that which the community has agreed. Community may subscribe less no. of bulbs. Tariff fixing by the community has two advantages: firstly, the tariff collection will be efficient because of agreeable tariff and secondly, at least the financial sustainability of system is also generally considered simultaneously with "the capacity to pay" of the members of the community, as

[144] The electricity price calculation is based on 6 hours of use only. If household uses electrical light for 10 hours then the price comes about Rs 2.67 to 3.33 per kWh.

[145] As per NEA (2003), energy charge to the domestic consumers in Nepal is Rs 4/kWh up to 20 kWh, Rs 7.30/kWh for 21-250 kWh and over 250 kWh is Rs 9.90/kWh. For the rural and cottage industry, the charge is Rs 5.45/kWh.

MHP system belongs to them. The consumer’s behaviors could not be studied in the short time as there is no fluctuation of tariff regularly. One point, which has been observed, is that the tariff rate is not increasing as the inflation rate of the local currency and as the price of kerosene in the markets. Therefore, the community must increase the price of electricity as per inflation rate making more financial benefits to the community itself. In practice, it is not seen. Therefore, in case of community owned system, the consumer behavior is not as in private market but follows the rules and regulations fixed by them. The tariff collection percentage shows that the majorities are happy and have participated in the decision-making.

#### 6.5.1.4 Market analysis

Looking at the electricity market of MHP, there is hardly any free market. However, the following conditions can be formulated in the case of community owned MHP in the rural villages of Nepal:

- The community representatives fix tariffs and all households are bound to pay. Households can cancel the subscription but it is bounded so rigid socially, one hardly rejects the tariff rate. Each household was involved in implementation so there is no question of canceling the subscription or hindering the access to electricity either by the consumer or by the management committee. In this case, individual is not the rational to fix the price but a representative group of the community who decides 'rationally'- at least theoretically, for the community in providing electricity.
- A household can reduce the demand by reducing the subscription of no. of bulbs. So in the case of quantity of energy that has to be bought, individual’s rational works. Individual household is having access to at least the minimum subsistence level of lighting through electricity.
- One cannot buy whatever amount he wants, as there is limited power (capacity of MHP) available. His or her unlimited wants cannot be achieved. This does not mean that the tariff rate would be increased because of higher demand. It is mainly because of social issue of equality. If such limitation or community ownership is not there, a rich household could buy large portion of power and other poor people may be deprived off their share. However, in the case of private MHP, it is up to the owner to whom he or she sells electricity. However, the issue of resource rights to the community members may reduce or hinder such approach, especially in rural area’s natural resource utilization to some extent.

#### 6.5.1.5 Uncertainties and risk

Risks at micro level are the unavailability of electricity in the villages for a longer period if some bigger technical problem occurs. Such problem can bring the financial burden to the community as well as to the owner of MHP if it happens to be privately owned system. Salaries would have to pay for the employees and enterprises will suffer. MHP plants are generally located at geographically difficult terrain and there are no easy transport facilities as mentioned by ICIMOD (1993), deLucia et al (1997), Rijal (1997a & 1997b). Turbine wear and tear, penstock leakages and bursting can cause several days or months to repair and bring back to the regular service. Nevertheless, the back up technical services providing facilities are improved drastically after the initiation of the rural energy service centers by the REDP/UNDP. Welding and other repair & maintenance works that need equipped workshop are difficult to do at the site. When a MHP plant of bigger size, i.e. more than 20kW, gets some problem within turbines and penstock, these heavy components will have to be transported. This causes uncertainty of power supply thus services that depend on electricity[146]. Civil component, especially of canal are also causing problems when there is seepage of water leading to land slides[147]. Villagers cannot have extra system, which could supply emergency power because such system would need the extra investment and be expensive. The occupational accidents thus causing the financial losses and system breakage or losses due to local natural calamities are also risks in the MHP systems because of non-availability of insurance system. Nevertheless, uncertainties and risks are of higher grade in the case of grid-supplied systems. There are villages in Nepal, who have to wait several months to have electricity supplied again after the breakdown of the grid system[148]. Comparatively, the risks and uncertainties can be reduced in the MHP systems with proper policy and planning making sustainable impacts on local communities.

### 6.5.2 Macro economic aspects of MHP in Nepal

Because of the locally produced technology, MHP macro benefits has also be analyzed. The macro economic sector, especially of employment creation, investment in

[146] Bagarkhola MHP of Chimkhola VDC in Myagdi had similar problem with generator, which has caused halting of power generation for few days.
[147] Mahakhola MHP of Arman VDC, Darakhola-II in Myagdi district is the good example of not having electricity for few weeks.
[148] Such news in daily newspaper is the common in Nepal.

environmentally friendly technology and development of small and decentralized industrial infrastructure are some of the benefits to the nation. Several studies were carried out to look at the micro level impact in several villages and sites (e.g. ITDG 1997, ICIMOD/ITDG 1998, Baskota et al 1997, etc.). Micro level impacts listed by these studies are showing several benefits as well as improvements needed. In macro level, no such detail studies are carried out to analyze the impacts on the economy, social and ecological sectors except a few basic studies, mainly, policies reviewing (e.g. ICIMOD 1993). The following sections will illustrate some of the macro aspects of the MHP in Nepal.

From the field study and several existing case studies ***related to the MHP***, the following arguments could be highlighted from the macroeconomic point of view:

- introduction of appropriate technology (or however in the perspective of rural and remote people- MHP for electricity would be a modern technology) may enhance their livelihoods by providing means of clean energy support,
- providing the clean energy supports the reduction of drudgery caused by manual work in agro-processing, avoidance of the use of unsustainable energy resources, running of small-scale food processing and cottage industries to the communities who are still not connected with road-network and such supports would help to enhance livelihoods,
- understanding the technological management process through the installed MHP systems could explore the idea of entrepreneurship in the rural communities to utilize their local products for the value addition and income generation, because lots of indigenous resources and products are sold at a lower value, thus making lower marginal benefit to the rural and remote communities,
- retention of rural entrepreneurs as well as rural resources in the rural areas for the enhancement of rural economic activities as post electrification enhances some cottage and small-scale production activities locally,
- enhancement of local employment opportunities from implementation, operation of the RET system itself and spin-off effects of the small-scale technology,
- development of network of supply and demand of the local products because several rural areas are niche and the value added products can be transferred easily to other places, i.e. dried apples from Mustang (near Tibet in western Nepal) to Cardamom producing Ilam (eastern hills of Nepal) and vice versa. This will help to

reduce the wastage of certain local products and may reduce the import of such products from foreign countries,

- circulation of money locally due to decentralized systems because of tariff collected from the local people will be utilized locally for the different developmental activities in the case of community ownership but not by central government whereas in the case of private ownership, revenue is retained locally thus inducing chances of further development of enterprises or infrastructures locally,
- reduction of the unit cost of production as Nepal has local technical as well as labor skills in the MHP sector to accomplish the construction, manufacturing the energy systems, provided there are economies of scale in the sectors concerned and the MHP sector for the foreseeable future can do that,
- enhancement of eco-tourism due to the availability of better environment and energy thus helping nation to increase the stock of hard currencies, economic activities and employment opportunities,
- development of economic networks and institutions locally so that a decentralized economy may develop,
- reduced economic risks of the infrastructural development related investment because of small-scale technology and risk is distributed among the community members in the case of community owned system,
- export of MHP components thus earning foreign currency as already done by few manufacturing companies in small scales, although it is very insignificant but has good potential and market as well as a good future prospect and
- enhancement of stability in economic as well as in social sectors caused by internal as well as external political turmoil if dependencies on fossil fuels are reduced.

The above mentioned macro level benefits are subjective unless these arguments are shown explicitly. The following section will illustrate some of the macro level benefits of the MHP sector in Nepal and will try to justify the hypothesis that the MHP sector promotes the sustainability in Nepal.

#### 6.5.2.1 Employment opportunities and jobs in the MHP sector

As per AEPC (2002), there are around eight government related agencies, 22 active non-governmental organizations, 23 private sectors working in the MHP areas of manufacturing and installations, four training institutions and 29 consulting agencies working for MHP design and survey. From the study of manufacturing companies (as listed by AEPC (2002)), it has been found that there are around 369 persons only in the private sectors involved in the manufacturing and installations. In addition to that, there are at least 18 formally registered service centers[149] that support MHP repair and maintenance works and pre-feasibility by employing about 105 people[150]. Based on the author's own field study and available literature, the following pattern of nationwide direct employment is available in the sector of MHP in the year 2002 (see Table 6.9).

**Table 6.9 Employment in MHP survey and manufacturing sector**

| Areas of MHP | No. of employees |
|---|---|
| Survey and design[151] | 76 |
| Manufacturing and installation | 369 |
| In service centers[152] | 105 |
| Total | 550 |

Source: Author

The figures mentioned in Table 6.9 do not include those employed by the MHP plants in the communities. From the field study, it has been found that most of the community owned stand-alone MHP under REDP/UNDP Programme are employing, on the average, three people per plant (**see Annex 6.5**). Similarly from the field visits of several sites in Myagdi district, and based on the existing study of ADB/N (1987) and from discussion with the turbine manufacturers, it has been found that there are about two to three persons employed (sometimes excluding the owner who also works there) in the water turbines used for milling. Moreover, the study done on turbine mills (mechanical power unit) by ADB/N has mentioned, "on an average each project has employed about three laborers out of which 1.4 laborers were skilled and rest 1.6 laborer were unskilled" (ADB/N 1987:31). Then the employment scenario in the MHP utilization (operation and management of the plant) sector will be as shown in Table 6.10.

149 There are fifteen in REDP supported districts and 3 area centers established by ESAP/AEPC.However a significant no. of such facilities are scattered in the county and no formal data is available on these.

150 There are no data available regarding the employment figures in electrical component producing sectors, used only for MHP.

151 Based on interviewed consultancies in Kathmandu valley as listed by AEPC (2002).

152 Based on 15 manufacturing companies - mainly mechanical components only.

There are also people working for house-wiring jobs and the data available from the villagers of REDP/UNDP project sites, show that on the average, "twenty person days" is needed to complete house wiring of the households that consume one kW of MHP (on the average eight to ten households per kW). By considering the existing capacity of stand-alone MHP as 4.672 MW and taking one person-month for the house-wiring job per kW, the total produced person-month is about 4,762 that is equivalent to 397 person-year. By taking this assumption, when Nepal generates three MW of MHP yearly, about 250 person-year is needed for house wiring. Then the job creation will be about 250 people per year[153].

**Table 6.10 MHP technologies and employment in operation and management**

| Type of Plant | No. till mid-July 2001 | Total installed capacity[154] kW | No. of employees |
|---|---|---|---|
| Mechanical milling | 799 | 7,064.9 | (3x799) = 2,397 |
| Stand-alone[155] | 347 | 4,672.2 | (3x 347) = 1,041 |
| Ghatta | 16,000 | - | 16,000[156] |
| Peltric-set[157] | 810 | 1,326.8 | 0 |
| Total[158] | | | 19,438 |

Source: Author (based on compiled data AEPC (2002), ADB/N 1987 and email correspondences with REDP/UNDP)

From the employment and job perspective, MHP is providing very optimistic figures for the macro economy of the country. With per kW installation, MHP offers more jobs

[153] Three MW capacity is the current technical capability of manufacturer and installer. This figure is obtained through interview with the manufacturers and installers. Also see Pandey (1994) and Rijal (1997a). The peltric sets have been neglected as these small units are having very simple house-wiring systems, normally done during the installation simultaneously.

[154] Interestingly, according to Fulford et al (1999), "the annual output from MHP in Nepal is 250,000 kW, which is about 10.50% of total national electricity production". However, AEPC (2002) listed only 13,065 kW including mechanical turbines, peltric-sets, etc from MHP. The figure mentioned by Fulford et al could be an exaggerated data.

[155] Especially, in the schemes supported by REDP/UNDP, there is an extra person to support communities and sometimes paid by the income from MHP (e.g. Dajungkhola MHP in Myagdi) but excluded in this calculation as only few plants have done so.

[156] According to AEPC (2002), there are 465 improved Ghattas installed by mid- 2001, and only one out of 465 was generating electricity and majority are used for grinding and a few for husking. One person in each Ghatta is considered while counting employment numbers, however, in reality Ghatta owner has his own land, cattle where he or his family works. So Ghatta work could be his part times work.

[157] Peltric set normally does not need full time employee. That is why it has not been included here.

[158] It has been assumed that all MHPs are functioning. The no. of employees may differ but the tentative average is taken here. The no. of employees found by several studies including ADB/N (1987) could not have considered the duration. From author's own experience, it has been seen that the employee that runs the mechanical power producing plant works almost 10-14 hours a day. Therefore, while taking an average any error could be compensated by these extra hours of labor.

directly as compared to the big hydropower. The forward and backward linkages of big hydro could be different but looking at the hilly areas where growth of bigger industry in foreseeable future is meager, the job provided by the MHP is significant. Therefore, employment sector of the country can profit from the MHP installation. Once employment opportunities are increased in decentralized manner providing access and opportunities to the poor people, the sustainability of rural society can be promoted.

**Table 6.11 Employment in hydro & electricity related manufacturing sector in Nepal**

| S. N. | Sector | No. of establishments | No. of persons engaged | No. of employees | Wages & salaries in '000 Rs. |
|---|---|---|---|---|---|
| 1 | Manufacturing of engines & turbines | 5 | 79 | 69 | 1,459 |
| 2 | Electric motors, generators & transformers | 3 | 153 | 142 | 4,980 |
| 3 | Electricity distribution & control apparatus | 3 | 104 | 98 | 2,452 |
| 4 | Manufacturing of insulated wire and cables | 17 | 1,064 | 995 | 30,526 |
| 5 | Electric lamps & lighting equipments | 2 | 0 | 0 | 0 |
| Total | | 30 | 1,400 | 1,304 | 39,417 |

Source: Compiled from the lists of manufacturing industries CBS (2002a)

**Table 6.12 Involvement of economically active manpower in different economic sectors**

| S.N. | Economic sectors | According to census of 2001 | |
|---|---|---|---|
| | | Active manpower | % of economically active population |
| 1 | Production, industry | 8,72,253 | 8.8 |
| 2 | Electricity, gas and water* | 1,48,218 | 1.5 |

Source: Compiled from CBS (2002a) (* including generation plants, transmission, distribution and other works)

From the data of CBS (2002a) based on the year 1996/97, there are the above-mentioned patterns of employment, salaries and no. of engaged persons in the sector related to electrical and turbine as well as engine's components producing industries. The statistics includes only 5 manufacturing establishments that are engaged in the turbines and engine sectors. This indicates that not all Nepalese MHP turbine manufacturers could have been included because during 1996/97 there were already at least 11 turbine manufacturers in Nepal (e.g. Rijal 1997a, Pandey 1994). Therefore, the employment generated by MHP could not have been included in the national statistics. Looking at the no. of employees and engaged persons in the MHP manufacturing, installation and maintenance sector at the national level (i.e. 550) that is about 20.35% of total no. of employees in similar sectors at the national level (2,704 from previous Table 6.11). Looking at the national scenario of employment it could be a significant.

**Table 6.13 Employment opportunities created by MHP implementation**

| S.N. | Activities | Employment opportunities | Remarks |
|---|---|---|---|
| ***A. Manufacturing and implementaion sector*** | | | |
| 1 | Survey design[159] | 0.5 to 1.0 | person-day /kW |
| 2 | Housewiring | 20 | person-day /kW |
| 3 | Manufacturing and installation of electro-mechanical components[160] | 44 | person-day /kW |
| 4 | Canal and other civil constructions[161] | 113 | person-day /kW |
| 5 | Transporation of components and construction materials[162] | 43.7 | person-day /kW |
| 6 | Production of electrical components | NA | NA= not available |
| Subtotal | | 220.5 | |
| ***B. Operation and maintenance sector*** | | | |
| 1 | Operation[163] | 82 | person-day /kW/year |
| 2 | Repaire and maintenance[162] | 8 | person-day /kW/year |
| Subtotal | | 90 | |
| Total | | 310.5 | person-day /kW |

Source: Author

From the employment opportunities perspective and data in Table 6.10 (page 192), it has been found that about 4.6 MW of stand alone electrical system is employing about 1,041 people directly and about 474 people are being employed by the manufacturers, repairers

[159] See **Annex 6.16** about the details of survey works and required work force.
[160] It does not include the production of all other electrical components except ELC.
[161] Based on the data of the four MHP plants in Myagdi and one in Sindhupalchowk and Dolakha Districts.
[162] However, it is very site specific as MHP will be implemented in the remote hills and mountains, the actual transport duration thus job created will be more than assumed. As per subsidy policy of HMG/N, about Rs. 8,750 to Rs. 21,000 per kW of transportation subsidy will be provided to MHP projects. Assuming a practical and real wage of Rs. 200 per day for a porter about 43.7 people could be hired for a day or a person can be hired for 43.7 days with the minimum amount provided as subsidy. However, the official wage rate of unskilled labour is Rs. 60/day (CBS 2002a).
[163] Considering installed capacity of 4,672 stand-alone system and employed people, as mentioned in a Table in this chapter and AEPC (2002).

and installers. Similarly, the survey and design, repair and maintenance and house-wiring sectors are also employing few people. Taking the average data of all activities as mentioned in Table 6.13 (in previous page), about one person-year per kW direct employment opportunity could be created (if we add production of local electrical components) by a new MHP project in total. That means, if the country implements about 3,000 kW per year, about 750 additional jobs will be created (because only 90 person-day per kW is needed to maintain, operate and repair, i.e. 25% of total person-day needed per year). Certainly, productivity factor will reduce the no. of labourers or human power needed in the system, but even then employment generation will be significant (see Chapter Seven for details on future scenario). Considering that figure of employment, and installed life of MHP as 20 years, MHP will continuously provide such decentralized job opportunities in Nepal thus enhancing the livelihoods of the rural poor people.

#### 6.5.2.2 Capital investment in the MHP manufacturing sectors

The prospect of private capital investment in the sector of production/manufacturing of MHP (mostly mechanical components) seems encouraging. Based on the interview taken with the 14 manufacturers of mechanical components, some electrical components and accessories only, as listed in Table 6.14 (in next page), investment and increment of investment is also significant. The mentioned rate does not include the inflation of the Nepalese currency. The scenario of inflation rate, as per the data of Ministry of Finance, is given in the **Annex 6.6**.

There are no exact data available regarding the investment figures in the electrical components and accessories manufacturing sectors separately for MHP. However, a study done by CBS Nepal in the year 1996/97 has found the scenario as mentioned in Table 6.15 (in next page). As most of the electricity-consuming customers are from urban areas, the consumption of electrical accessories is mainly in urban areas but those turbines and parts of the electrical components of transmission and distribution systems are certainly consumed by the MHP sector too. Even though the exact data could not be available, there must be a good share of MHP 's consumption, especially locally produced components. The list of CBS (2002a) shows that there are only 5 turbine and engine manufacturers and these would not be only from the MHP manufacturing sector. While comparing, the capital invested only in the MHP components manufacturing sector and the total mechanical and electrical components manufacturing sector listed by CBS (2002a), it indicates that MHP components manufacturing covers significant investment in that sector.

**Table 6.14 Investment in the MHP component manufacturing sectors in Nepal**

| Manufacturing companies[164] | Total investment in the beginning in ('000) Rs. | Year of establish ment | Current capital (end of 2002) of the company (fixed and working together) in ('000) Rs. | Growth of investment |
|---|---|---|---|---|
| AG Power | 1,000 | 2000 | 2,000 | 0.41 |
| BYS | 5,000 | 1972 | 20,000 | 0.05 |
| Housing S. Co. | 3,000 | 1980 | 10,000 | 0.06 |
| KMI | 4,000 | 1975 | 175,000 | 0.15 |
| Krishna Grill | 5,000 | 1990 | 15,000 | 0.10 |
| NHE | 7,500 | 1985 | - | - |
| NMSS | 150 | 1987 | 1,200 | 0.15 |
| NPP | 1,000 | 2000 | 1,800 | 0.34 |
| NYSE | 2,000 | 1976 | 15,000 | 0.08 |
| Power Tek | 1,800 | 1988 | 10,000 | 0.13 |
| Radha steel | 2,000 | 1990 | 10,000 | 0.14 |
| Structo | 1,500 | 1984 | 7,500 | 0.09 |
| GE | 1,500 | 1995 | 2,300 | 0.06 |
| TE | 90 | 1982 | 1,300 | 0.14 |
| Total | 35,540 | | 271,100 | Average 0.14 |

*Source: Author*

**Table 6.15 Assets in manufacturing of electromechanical components in Nepal**

| S. N. | Sector | No. of establishment | Gross fixed assets in '000 Rs. |
|---|---|---|---|
| 1 | Manufacturing of engines & turbines | 5 | 7,485 |
| 2 | Electric motors, generators & transformers | 3 | 30,300 |
| 3 | Electricity distribution & control apparatus | 3 | 976 |
| 4 | Manufacturing of insulated wire and cables | 17 | 266,013 |
| 5 | Electric lamps & lighting equipments | 2 | - |
| Total | | 30 | 304,774 |

Source: Obtained from the lists of manufacturing industry CBS (2002a)

[164] There are other manufacturing establishments too. AEPC (2002) has listed about 23 such establishments. Few such establishments are manufacturing MHP components simultaneously with other products as well and few are just dealers, suppliers or installers. The data provided by the manufacturers are tentative and in round figures.

**Table 6.16 Salary and tax paid by MHP manufacturers (in Rs for FY 2001/02)**

| Manufacturing Companies | Amount of salary paid/year in Rs ('000). | Amount of tax paid/year in Rs ('000). | Year of establishment |
|---|---|---|---|
| AG Power | 144 | 550 | 2000 |
| BYS | 660 | 1,000 | 1972 |
| Housing S. Co. | 400 | 800 | 1980 |
| GE | 65 | 55 | 1995 |
| Krishna Grill | 432 | 200 | 1990 |
| KMI | 585 | 1,300 | 1975 |
| NHE | 704 | 800 | 1985 |
| NMSS | 1,080 | 50 | 1986 |
| NPP | 624 | 275 | 2000 |
| NYSE | 468 | 600 | 1976 |
| Power Tek | 288 | 350 | 1988 |
| Structo | 350 | 350 | 1984 |
| Radha steel | 324 | 1,000 | 1990 |
| Thapa Engg. | 340 | 75 | 1981 |
| Total | 6,399 | 7,350 | |

Source: Author (based on interview with manufacturers in Dec. 2002 and Jan. 2003 in rounded figures)

Investment or assets in the industrial sector of the country that are related to the production and manufacturing of electromechanical components of hydropower or electricity generation seems not so big as compared to MHP sector only (Rs 304,774 million as compared to Rs 271.100 million in MHP). That means the MHP manufacturing sector will be the leading industry in the country's hydropower and energy sector. The future of this sector has sustainable and significant impacts as technology is available locally, local work force will be utilized and the economic opportunities will be enhanced. Although the total assets of the MHP components manufacturing sector (mechanical plus some electrical) is less than 0.1% of the total invested assets of the national manufacturing sector in Nepal[165].

[165] Considering data of 13 MHP manufacturers and CBS (2002a) list of total assets in industrial-manufacturing sectors in Nepal.

The total salary paid to the employees and tax paid to the government by the 14 MHP component manufacturers is about Rs. 14.094 million during the FY 2001/2002, whereas total GDP contributed by all manufacturing sector of the country, as per CBS (2002a), is about Rs. 34,616 million during the same period. The manufacturing sector contributed about 8.43 percent in the GDP of the country during FY 2001/2002 (CBS 2002a). The salary and tax paid by the MHP manufacturers is contributing less than one percent in the country's GDP. However, the scenario would have been different if the total output of the MHP sector could have been included[166], i.e. income tax, productivity of manufacturing companies, etc. As about 8.43 percent of GDP of the country is being contributed by the manufacturing sector and whereas only the salary and tax paid by the MHP manufacturing sectors is about 0.0033% of the total GDP and only about 0.04% of the total manufacturing sector. Nevertheless, this scenario will be different once all aspects of MHP manufacturing facilities with detailed study are illustrated. The detailed future scenario will be discussed in Chapter Seven.

Similarly, the investment that has been done in MHP plant itself is also huge. Considering the total capacity of stand-alone systems to be about 4.6 MW, and the average cost of MHP about 108 thousand (in the year 2001, see **Annex 1.1 and Annex 6.7**), then Rs 483 million has already been invested in the stand-alone systems. The figure will be almost doubled, if we take into account the mechanical turbine and peltric set systems. Although it is not comparable with bigger hydro power plants but, from the perspective of RETs, it is a significant investment. So all these facts show that the MHP sector of Nepal is slowly coming as a sector that has future and sustainable foundation for future activities are being laid down.

#### 6.5.2.3 Cost of MHP Plants

The total cost of MHP electromechanical components is very much site specific but there must be some similarity in electromechanical components if they happen to be of the same standard, i.e. same flow, head, power generation and types of components. The investment cost also varies according to the sites (see Table 6.17 in next page and **Annex 6.7**). The average per kW cost of investment of cross-flow turbine and MPPU was about Rs. 14,432 and average additional cost for add-on system for electrification was Rs. 7,164 in the year

[166] Due to reliable data constraint, it could not be detailed, however, MHP could contribute, at least one percent of GDP of country's manufacturing sector. A detailed study is to be done for this sector.

1986/87 (ADB/N 1987). The combined cost per kW for mechanical and add-on electrification system would have been Rs. 21,596 per kW. Considering 12% discount rate or accounting rate of interest, after 15 years, the unit cost (per kW) of system seems to be the same (from calculation, it comes, on the average, around Rs. 105,552, nearly equal to most of the newly installed MHP's investment cost per kW in the year 2001 (see **Annex 6.7** and **Annex 1.1**)).

Nepal (2001) mentioned that the cost of the MHPs is relatively increasing - especially for the rural electrification projects. As a subsidy providing agency or authority qualifies only limited no. of manufactures and suppliers, sometimes there is the case of cartel. DeLucia et al (1997) has mentioned that the donors' involvement has not had a cost minimization approach and donor-funded projects have had considerably higher unit costs than privately funded projects. Nevertheless, some donor-supported programmes do not support only hardware but other aspects too, although the projects supported by donors are comparatively expensive. Therefore, the cost of MHP is high mainly because of non-standardization, oligopoly and the lack of consumer awareness and several other factors.

**Table 6.17 Cost of the some MHP projects**

| Name of MHP schemes, District | Power (kW) | Year of commission | Investment cost in ('000 Rs.) | Cost per kW ('000 Rs.) |
|---|---|---|---|---|
| Chhanna, Bajhang | 6.7 | 1986 | 209 | 31.19 |
| Barpak, Gorkha | 50 | 1990 | 2,483 | 49.66 |
| Ghandruk, Kaski | 50 | 1992 | 3,594 | 71.88 |
| Sima, Rukum | 16 | 1994 | 1,178 | 73.63 |
| Sikles, Kaski | 100 | 1994 | 9,041 | 90.41 |
| Haliya, Sankuwasabha | 15 | 1995 | 2,305 | 153.67 |
| Fakding, Solukhumbu | 18 | | 2,581 | 143.39 |
| Kanda, Bajura | 25 | 1997 | 2,910 | 116.40 |
| Galkot, Baglung | 50 | 1998 | 5,061 | 101.22 |
| Damek, Baglung | 20 | 1998 | 1,344 | 67.20 |
| Tipling, Dhading | 25 | 1999 | 2,877 | 115.08 |
| Talamarang, Sindhupalchowk[167] | 1.6 | 1999 | 107 | 53.5[166] |

Source: (Compiled from ICIMOD (1993),GTZ/CRT (2000), WECS (1995), CBS (2002a), ADB/N personally)

[167] Improved Ghatta

From quotations submitted by different MHP manufacturing companies, it has been found that the prices of electro-mechanical components are differing although the specification and quality seems similar. Table 6.18 shows the cost variation in different MHP components, based on quotation submitted by different companies for a MHP site in Rukum District of mid-western Nepal.

**Table: 6.18 Analyses of the costs of MHP components**

| Analysis of quotation submitted by manufacturers for a 16 kW MHP in Sima VDC/Rukum | | | | |
|---|---|---|---|---|
| Particulars | Company BYS | Company DCS | Company KMI | Company TEI |
| Turbine | Pelton | - | Pelton | Pelton |
| Capacity kW: | - | 16 | 20 | - |
| Turbine Cost: | Rs. 135,000 (incl. Gate valve) | Rs. 156,250 | Rs. 160,000 | Rs. 95,000 (incl. a runner) |
| Penstock cost | Rs. 285,000 | Rs. 289,700 | Rs. 500,000 | Rs. 180,000 |
| Generator type | 25 kVA (British) Synchronous | 25 kVA (Indian) Synchronous | 20 kVA Induction | 25 kVA Synchronous |
| Generator Cost | Rs. 225,000 | Rs. 116,000 | Rs. 225,000 | Rs. 125,000 |
| ELC Cost | Rs. 155,000 | Rs. 135,000 | Rs. 184,000 | Rs. 130,000 |
| ACSR Cost | Rs. 151,894 | Rs. 151,500 | Rs. 172,000 | Rs. 140,000 |
| Installation & Consultancy | Rs. 205,000 | Rs. 66, 480 | Rs. 122,400 | Rs. 40,000 |

(Source: Analysis based on information and quotations made available by Satish Gautam/ REDP, 1998)

Table 6.18 shows that the price of the turbine of almost similar quality differs with different manufacturers. The difference is about 68% from the lowest price. Although the Nepalese manufacturers use almost the similar design and technology, such large variation in price is because of lack of standardizations. Similarly, the price of penstock that is made of similar technology and material differs by 177% from the lowest price. The electronic load controller (ELC) is generally made by only one or two manufacturers and supplied to other MHP manufacturers in Nepal with similar technology and material but the price differs by 42% from the lowest one. The conductors (ACSR) needed for the transmission and distribution also vary even though the suppliers of such products to the MHP manufacturers are local companies with the same technology and materials. Even though the installation and service quality provided by the Nepalese companies does not differ that much, their charge differs by 413% from the lowest bidders. The main causes of the price differences in similar components with almost similar quality are because of the lack of norms of standardization of components and manufacturing processes in one side. While on the other side, the lack of customer awareness, monopoly of few pre-qualified manufacturers and the lack of quality control by the concerned authorities is also causing ad hoc pricing. Once intensive extension of MHP goes on, these monopolies and cost differences will be reduced because of awareness, competition, and if standardization of the components will be brought into the effect.

The average per kW cost of MHP is about 104 thousand Nepali rupees without local voluntary cost (see **Annex** 1.1). If the local voluntary labor is included in the total cost then the average per kW cost will be about 125 thousands[168]. The per-kW cost is also different in different regions. It can be concluded that the total costs of the MHP is also strongly dependent on sites and its distance from nearest road head and transportation costs and types of site. The current cost of MHP could be reduced significantly if,

- MHP electromechanical components are standardized so that customer can buy similar products from more than one supplier or manufacturer,
- local materials with appropriate technology is used for civil construction which has been done for several traditional irrigation canals in Nepal,
- local resources mobilized for investment, materials for the construction and transmission poles and enhanced participation in the community owned MHP for transportation and other non-skilled works, and
- enhancing transparency in manufacturing sector, market and subsidy distribution mechanism.

Regarding the operation and maintenance, the average costs of MHP also varies depending on the type of ownership, project site, types of turbine used, operating frequencies or duration, quality of water available and types of end-uses used. The operating and maintenance cost varies but normally assumed as 2 - 5% (e.g. Rijal 1997a and 1997b) excluding the exception of 30 - 40% of investment due to poor civil structure, i.e. canal and other natural calamities. The salary paid to the MHP operator or other employees also varies[169] and it depends upon the revenue generated and community's consensus in the

[168] Considering about 20% local voluntary contribution, but as per REDP (2000a) it varies from 5% to 20% and on the average is about 18% of total investment cost in 71 MHP demonstration schemes.
[169] The operators of stand-alone MHP facilitated by the REDP/UNDP get around Rs. 2,000 to Rs. 4,500 per month (see **Annex** of chapter five)

case of community owned system. Communities that are willing to pay higher tariff for the proper maintenance of plant are also paying good salary to the operators[170].

#### 6.5.2.4 Economic benefits

The sustainability issues at the project level (or in economic terms at the micro level) are consistent with the economic sustainability from broader perspectives too. In national perspective, the MHP projects are bringing sustainable benefits in economic sector as well as in the ecological sector. As sustainability has different levels and grades, MHP also promotes sustainability at different levels with different grades. The following sections will highlight the sustainability promoting aspects of the MHP projects at the macro level.

In terms of national output, Rs. 7.480 million tax (include VAT) has been paid by the MHP component manufacturers (based on the data of 14 manufacturers in Table 6.16 in page 197) in the year 2002. About 369 people are being employed by this sector paying 6.614 million Nepali Rupee as total salary (only by 14 companies), which, in some cases, does not include the salary of the owner. In addition, about 105 people are being employed in service centers and other small distributors, installers, and dealers engaged in MHP sector, which is not included in the above-mentioned figure. The mentioned figures are from known or the registered facilities, but there are certainly other inaccessible, informal facilities providing services to the MHP sectors that could not be counted here[171]. National benefits could be calculated estimating how much GDP has been contributed by this sector even in the traditional financial perspectives. Nepal's GDP of the year 2000/01 was Rs.376,433 million and the tax, salary paid by the companies is Rs. 14.094 million, which is less than one percent of the National GDP[172]. Looking at the manufacturing sectors' contribution to the GDP, this is also significant because the manufacturing sector contributes only about 8.43% to the GDP of the nation.

Economic development is achieved through MHP from two aspects: one because of investment in the manufacturing and service providing sectors and secondly from the

[170] Customers of Sanimkhola MHP in Bima VDC of Myagdi District are paying salary to the operator almost equivalent to the revenue collected from the lighting because of small capacity of the MHP plant.

[171] A detailed study of informal sector could reveal the more exact benefits of MHP technology in Nepal. However, to do such a study is beyond the scope of this work.

[172] The profit or yearly productivity, income tax of employees and the owners of the companies could not be collected, as most of the owners were not having such structured data. Considering the view of few manufacturing companies, there is a good margin of profit ranging from 10-30%. Therefore, the total national income from MHP manufacturing sector in the year 2002 could be more than 14.094 million Nepali Rupees.

availability of electricity for end-uses, i.e. for small scale local industries. As listed previously in Table 6.14 (page 196), the growth of invested capital in MHP sector is around 5% annually. This suggests that the industry is expanding. About Nepali Rupee 7.480 million is the tentative revenue through tax colleted by the government yearly from MHP manufacturres. Economic development process will also be induced or enhanced once small-scale technology based industries are installed in the periphery of MHP plants in the local villages. On the average, three to four enterprises (based on the REDP/UNDP' MHP sites) in each MHP project sites, there are several small-scale technology based enterprises in rural Nepal. These enterprises are providing job opportunities, better services to the local communities and adding the value on the local products thus enhancing the local economic activities and finally enhancing local development.

Tentatively, about Rs. 3,120 per year per kW subsidy that is given to kerosene will also be saved. Moreover, about Rs 13,000 equivalent of hard currency will be stopped from drainage in fossil fuel by an installed MHP per year per kW. The amount saved on dry cell battery, diesel is also significant (detail in the previous chapter).

The current production capacity of MHP in Nepal is about 3 MW per year, according to the opinion of manufacturers (see also Rijal 1997a, Pandey 1994, deLucia et al 1997). The maximum capacity of a turbine that can be manufactured is of mini hydro level, up to 500 kW. About 300-500 Peltric sets can be produced easily with currently available production facilities in different areas. Increased rural energy service centers in different parts of the country, would be able to provide prompt back-up services (e.g. ICIMOD 1993, Rijal 1997a & 1997b, REDP 2000a). It has been an issue that the failures or major problems of MHP projects are due to the lack of back-up services. However, at the end of 2002, there are about 18 well functioning and motivated service centers (formally registered only) from the eastern region to western Nepal. Their main objectives are to provide technical support, repair & maintenance services, do pre-feasibility surveys, sensitize the people and install the MHP and other renewable energy systems and components. From the national perspective, there could be a great leap forward in this aspect too.

#### 6.5.2.5 Population benefited

Till now, MHP has also served the Nepalese people from different aspects. From the exiting installed capacity of different MHP technology, the following Table summarizes the beneficiaries.

**Table 6.19 Exiting scenario of MHP**

| MHP technology | Capacity | | No. HH electrified /benefited | No. people getting service (tentative) | No. of person employed |
|---|---|---|---|---|---|
| | Nos | kW | | | |
| MHPe | 347 | 4,672.2 | 46,722 | 203,078 | 1,041 |
| MHPp | 810 | 1,326.8 | 7,961 | 43,386 | - |
| MHPm | 799 | 7,064.9 | 159,800 | - | 2,397 |
| MHPg[173] | 16,000 | 10,000 | 320,000 | - | 16,000 |
| Total | | | 534,483 | 2,887,361[174] | 19,438 |

Source: Author based on AEPC (2002), CBS (2002), REDP (2000, 2001) ( MHPe - stand alone electrical installation of MHP, MHPp- Peltric set, MHPm -mechanical milling turbine, MHPg - traditional as well as improved water wheel -ghatta)

The beneficieries and employment numbers in the future would include only MHP stand-alone system. While developing the future scenario, the stand alone types of MHP will be considered. The rationale behind this is that the existing ghatta would be replaced once there is electricity-producing plant or existing ghatta will be improved by including generator for electricity production.

### 6.5.3 Reduction of economic poverty

The World Bank Report of 2000/2001 discusses about a poverty attacking strategy in three ways: promoting opportunity, facilitating empowerment and enhancing security. From this perspective, promoting opportunity is mainly meant to enhance economic activity and to elevate economic status through jobs, employment and access to physical assets. Facilitating empowerment indicates access to decision-making and ownership to the resources of all types through participative institutions and reduction of biasness or hindrances to development process. Enhancing security means protecting against all social, health, economic and environmental or natural catastrophes. The poverty reduction impacts due to MHP are also related in the three ways. Nevertheless, in this section, the perspective of economic poverty will be discussed and other ways come implicitly or explicitly in other sections.

[173] Considering existing 16,000 ghatta and each ghatta provides service on the average to 10-30 HH and in the case of MHPm, on the average 200 HH (e.g. ICIMOD 2000, ITDG/CRT 1995).
[174] Considering average HH 5.45, a national average. Taking 1 kW for 8-10 HH in MHPe and 6 HH in MHPp because of technical realities as MHPp normally owned by a HH. MHPe stand alone electrical installation of MHP

It has been often discussed in the previous sections that MHP reduces several poverties (i.e. energy poverty, economic poverty, etc.) and enhances the livelihoods. MHP projects have forward and backward linkages, which are responsible for the creation of economic activities through end-use technologies. The enhancement of economic as well as social welfare is the main reason for the poverty reduction in MHP areas (e.g. REDP 2000a, 2000b). Fulford et al (1999) have highlighted that MHP can reduce the economic poverty of a few community members directly through employment and income generation in the remote areas of poor countries. However, Fulford et al (1999)'s data does not mention what types of employment opportunities and how they arrived in those numbers. Nevertheless, from the analysis in the previous sections of this chapter, it has been found that MHP has the following major benefits and employment opportunities from the perspective of economic gain and poverty reduction:

- creation of employment at macro as well as micro level directly by the MHP sector,
- savings on the use of energy in lighting thus money and household burden and
- creation of employment and income generating opportunities from the backward and forward linkages of MHP technology.

#### 6.5.3.1 Through the creation of employment at macro as well as micro level

The employment opportunities from the macro level perspective have been discussed in previous sections in this chapter. The macro level opportunities are scattered and are less in percentage compared to the economic activities in other sectors. In the micro level, the impact of job opportunities is more visible and contributing directly to alleviate the poverty of remote community. Table 6.20 (in next page) indicates the employment scenario of five MHP sites in Myagdi and Sindhupalchowk Districts of Nepal.

Number of non-skilled labor mentioned in Table 6.20 (in next page) is partially contributed by the community members as voluntary labor to reduce the cost of system. In other way round, such contributions also reduce the burden of cost sharing by households that would have been in cash. Even though the opportunity cost of such contribution is low because of large unemployment in the villages, these contributions could be counted as employment generation[175]. The mentioned total investment cost also includes so-called local cost

[175] Those households who are not contributing voluntary labor have to pay equivalent amount of money to hire a labor. From this perspective, voluntary labor is also an employment opportunity. In the case of privately owned system, such non-skilled labor is hired locally.

(voluntary contribution by the community members). Taking average of that data, after investing about two million Rupees in 20 kW[176] MHP plant, on the average, about 1761 unskilled person-day, 489 skilled person-day, 2-3 permanent employee in the MHP energy system itself, minimum of four in the electricity related end-uses technologies and 20 person-month in house wiring employment opportunities could be generated locally.

**Table 6.20 Employment after the MHP systems in five VDCs in Nepal**

| VDC | KW | Investment[177] (in '000 Rs.) | During implementation (person-day) | | Direct in the MHP system (all time job) | End-uses job (electricity related) | House-wiring, person-month |
|---|---|---|---|---|---|---|---|
| | | | Un-skilled[178] | Skilled laborer | | | |
| Okharbot | 30 | 3,524.42 | 1,857 | 1,164 | 3 | 8 | 30 |
| Muna | 50 | 4,748.82 | 5,564 | 1,644 | 3 | 8 | 50 |
| Chimkhola | 35 | 2,863.06 | 1,580 | 662 | 3 | 7 | 35 |
| Arman | 10 | 1,474.77 | 435 | 56 | 2 | 4 | 10 |
| Thampalkot (26+20 kw) | 46 | 4,276.38 | 5,617 | 655 | 5 | 8 | 46 |
| Total | 171 | | 15,053 | 4,181 | 16 | 35 | 171 |

Source: Author (compiled also from REDP (2000a) and Pokharel et al (2003b))

From these opportunities, people will either earn money to alleviate their poverty or save their expenses and financial burden, as about 42 percent of Nepalese are, economically, under absolute poverty, and most of them are living in the rural areas (e.g. Dahal 2000). With a small-scale investment, it has significant impact in alleviating economic poverty as well as other dimensions of poverty (e.g. poor living style with primitive kerosene lighting, etc.) and the rural people can be served in a better way. Rural people are subsistence farmers, their cash income is mainly from the remittances coming from urban areas or foreign countries. The received remittances are not being used for capital investment but rather buying daily consumption goods and used for operational expenses for energy, health, etc (e.g. Regmi and Tisdel 2002). Therefore, there is hardly any local entrepreneur

[176] 20 kW is taken the reference because the most suitable and manageable system size will be a 20-30 kW for a community of 200-300 families in the hilly and mountainous regions of Nepal. Bigger size could be cheaper but load factor will be low and may not be suitable from the financial point of view although in future, consumption may increase and community would need more power.
[177] Investment only to MHP, not in the end-use technology.
[178] Part of unskilled labor has been done voluntarily by the community members in the community owned system.

interested or capable to invest big capital in the infrastructure related development. With contribution from several families and support from concerned authority, implementations of such decentralized projects are the most plausible way of developing infrastructure. Moreover, these decentralized projects have the far-reaching impact from the perspective of investment and poverty reduction ratio[179].

The employment scenario shown already in Table 6.20 is for the MHP plant implementation, operation and its uses at the local level. The employment generated at the macro level, i.e. in the manufacturing sector and installation works done by the companies have been discussed already. In addition to that, the employment opportunity provided by the consultancies during design and survey, service centers providing repair and maintenance services are also already discussed in the previous sections of this chapter.

The economic analysis and evaluation must consider the employment benefits. "The additional employment generated is sometimes regarded as a social good to be evaluated and placed on the benefit side" (Mishan 1988:325). The traditional analysis puts opportunity cost of "idle" labor a zero value when there is the higher-level unemployment. Nevertheless, the investment of capital, generating employment benefits must be valuated giving higher value. The five MHP projects have generated local employment opportunities in the respective VDCs and such benefits are being generated to the local people after the MHP installation. From the local as well as the national perspectives, the traditional fuel like kerosene and dry cell batteries, were not producing that much of employment opportunities to the villagers and to the nation. Therefore, these types of benefits are the economic as well as social benefits to the community and for the nation.

In the previous calculations, the income generated by the few employed people inside the village is not accounted. In the case of Dajungkhola MHP in Myagdi, three people have been employed and earning altogether yearly about Rs. 100,800. Such benefits are not considered in any calculations. The local employment opportunity makes lots of sense

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[179] Taking the minimum wage of Rs 60 per day for non-skilled job (e.g. CBS 2002a), the income of local laborers would be significant. If the no. of skilled and non-skilled labor is converted to 300 days in a year and 20 years of plant life including house wiring job then a 20 kW system would need one half day employee for both the jobs, i.e. skilled and non-skilled. The average salary of an employee working in MHP system from the study is about 20.15 thousand per year, which is more than the average income of a Nepalese. Four employees or entrepreneurs in end use also get similar salary or get earning in the same range. House wiring job is also a skilled job and they, too, get good salary or benefits. In total, a 20 kW system provides permanently to 5-6 people a year round job directly, including end uses. The other backward and forward linkages are also more significant.

because of the higher level of unemployment[180] or underemployment. In the cost benefit analysis, the opportunity cost of such employment is nil because of 'idleness' of unemployed people (e.g. Mishan 1988). Nevertheless, employment opportunities would be the social benefits and could be accounted for as the community benefits.

The value of numeraire in the economic analysis of the local benefits is complex. The income earned through the local employment and resources generated by the local people through the decentralized system are also in the same monetary units as in industrial or urban rich areas but their value is far more than the resources generated in urban areas. When a person earns a specific amount in his village, he gives higher value to that than the similar amount in the urban areas. This could be controversial morally saying that the village poor value more for the same amount of money compared to urban rich but in the case of poverty and underemployment, this is the bitter truth in the villages. That is why, the income generated by local and remote people would have higher value than that by urban people. Moreover, even in the neoclassical sense, gained utility by the poor would be more compared to the urban rich.

From the perspective of either the gross national product (GDP), "environmentally adjusted net national account" (Munansinghe 1993: 11), "sustainability index" (Daly 1999) or "net national productivity" (Neumayer 1999), by using electricity for lighting, the indicator must improve because as it has been discussed in the previous sections that MHP projects are bringing net economic as well as ecological benefits. That is why, in this perspective, GDP[181] per capita must increase.

#### 6.5.3.2 Through the reduced household expenses on lighting energy

In Okharbot VDC, about Rs. 1,399 per year per household has been spent for lighting energy. The average amount of money spent by households in some of the REDP/UNDP programme implemented VDCs, is about Rs. 1,543 per year and used for lighting from kerosene and dry cell batteries. Whereas the maximum amount, on the average, that could be paid by each family after the electrification is about Rs. 960 to Rs. 1,200 per year and in Dajungkhola it is about Rs. 757 per year. In reality, families are not using 100 watt

[180] In Nepal, the official version of unemployment is low and underemployment is almost 50 percent among the economically active population. Generally, unemployed youths of the villages are tagged with a profession of farmer once he happened to be an unemployed member of a farmer. In this context, the local employment opportunity makes a big difference to the people of the village.
[181] The revised GDP is discussed by Daly (1996), Neumayer (1999), Pearce et al (1989) and others.

although several plants have been installed accordingly. In real terms, people are paying lower or same amount as the families of Dajungkhola are paying. That means there is almost 50% saving on their expenses on lighting energy. A part of that amount saved in buying kerosene and battery previously is now remaining within the community if they do not expense in other uses. Even if they use the saved amount to buy foodstuffs or medicine, there are other benefits to the family. In summary, people are being relieved from financial burden to some extent. Generally, the rural farmers are not having cash that is needed to buy kerosene and battery and people have to sell their products or go to urban areas to look for jobs to have cash. From these perspectives, relieving from cash expenses relieves the poor family from other burdens.

Additionally, the government had to provide about Rs. 243 subsidy per year per household in Okharbot for kerosene only and on the average Rs. 313 for each household in rural areas as mentioned in Table 5.4 (in page 147**)**, which is now being largely avoided after the installation of MHP. So, these are the economic benefits at the macro level, which is directly or indirectly goes to the people.

#### 6.5.3.3 Through employment, economic opportunities and backward & forward linkages

Exploration of the opportunities after electrification to establish cottage industries and economic activities are regarded as an important instrument for bringing about more equitable division of national resources and a fairer distribution of income, knowledge and power (e.g. van der Straaten 1992). Establishment of small-scale economic activities at the local level means creating local employments and the beginning of building an essential element of local industrial structure. After the community owned MHPs were implemented, there are several small-scale industrial as well as commercial activities started in the villages as shown in **Annex 6.8**.

As **Annex 6.8** shows that on the average four end use technology based economic activities are being created in each site of MHP projects and because of these four economic entities at least four people are earning their income and living better life than before. From these aspects, at least four people's poverty has been alleviated in the local context. Banskota et al (1997) has found that in the tourist industry, especially in the mountain regions of Nepal, marginal benefits of lodge owners in trekking route will be increased after electrification and will have small positive employment effects raising local people's income. Such spin-off benefits are significant but are still hard to say whether it is only because of MHP implementation or combined effects of several factors. Nevertheless, several studies, reports and publications (e.g. Banddyopadhyay et al. 1994, Pokharel 1999, Banskota et al 1997, ITDG 1997a, ITDG/SBPP 1995, Khenas et al 2001, Fulford et al 1999, Pokharel et al 2003b) have mentioned positive benefits of such small-scale inventions. Therefore, all in all, MHP would reduce the economic poverty of local people. The previous discussion under micro and macro economic aspects of MHP also revealed such opportunities in different sectors. As World Bank Report (2001) listed the several assets[182], lack of which causes poverty, electrification of villages with appropriate strategy would enhance the majority of such assets thereby reducing the poverty.

### 6.5.4 Economic analysis of MHP projects

In the previous sections under economic dimension, several aspects of MHP at micro and macro level have been discussed. More aspects from the perspective of externalities have been discussed in Chapter Five. In the following section, the economic analysis of MHP projects at the micro level, considering a case study of a selected plant in Myagdi District, will be done. In the analysis, the sustainability constraint will be the guiding factor. A project case will be taken and input economic capital and output economic capital will be discussed and analyzed to prove whether MHP projects are fulfilling the criteria of sustainability laid down in Chapter Two and discussed in Chapter Four.

At the macro level subsidy, the resource saving due to avoidance of fossil fuel import, creation of employment opportunities and revenue generated from the tax are the major issues to be considered. In the micro level, all types of invested and other economic capital are considered at the project level. To analyze the micro level sustainability issues from the perspective of economic component of complete sustainability, a few MHP systems of Myagdi District in Nepal will be taken as the reference example[183]. The rationale behind taking only a few MHP projects in the analysis has already been discussed in Chapter One.

[182] The assets are human, natural, physical, financial and social.

The detail of the few MHP projects in Myagdi District is given in the **Annex 6.9.** In the sustainability analysis, Dajungkhola MHP will be taken as the case. The micro economic discussion of the manufacturing sector could not be included in the analysis, which needs a further study. In our analysis of the MHP projects, economic capital as input to the MHP system are the financial capital, physical components and economic inputs given by the people. Sustainability condition of constant or increased economic capital, $dCc_t/dt \geq 0$, *(*from Figure 2.3 and 4.6, $Cc_2 - Cc_1 \geq 0$*)* must be fulfilled at project level. The detail of investment cost of Dajungkhola MHP is given in **Annex 6.9**. Capacity of the plant is 30 kW and beneficiary households are 264 (details in **Annex 6.9**). The investment of the project has been done by mobilizing resources from the different stakeholders and the government agencies, banks and donors. The community has also contributed about 19% of the total investment in cash as well as voluntary labor. The community contribution is not the investment for private profit but invested for the successful implementation of the project. Because of the community ownership, the voluntary contribution was possible. The financial status after the implementation of Dajungkhola MHP has also been shown in Table 6.21. The financial status indicates the cash flow of the project.

**Table 6.21 The financial status of the project**[184]

| Revenue in / Particulars | Lighting | End-uses | Total |
|---|---|---|---|
| Revenue collected Rs./year | 199,776 | 36,000 | 235,776 |
| Operation (salary) Rs./year | 100,800 | - | 100,800 |
| Maintenance and other Rs./year | 53,535 | - | 53,535 |
| Net income Rs./Year | | | 75,441 |

*Source: Author*

[183] However, the detailed analysis will be presented mainly of Dajungkhola MHP in Okharbot VDC of Myagdi District simultaneously analyzing other sites in the discussions. Investment and other details of Darakhola I MHP of Muna VDC and Darakhola II MHP of Lulang VDC and Dajungkhola MHP of Okharbot VDC of Myagdi district and few schemes of Kavre, Baglung and Tanahun districts are also given in the **Annex 6.9** and will be used in the analysis to illustrate the results more clearly. The data are from 1998 to 2002 because of the project implementation period. Socio- economic data are collected in the year 1997-98 when the author was the District Energy Advisor. The costs of projects were revised and there were some changes and these data were collected during the field study in 2002.

[184] All data are based on the first 24 months of operation of the plant as well as the rate of collection of the revenue currently. The maintenance amount included few new parts that were added to the plant at the beginning when plant started to generate electricity.

#### 6.5.4.1 Economic analysis of the Dajungkhola MHP

Based on the data in **Annex 6.9** and monetized externalities of kerosene and dry cell battery consumption per year as discussed in Chapter Five, an economic analysis of Dajungkhola MHP of Okharbot VDC Myagdi district can be done. There are several perspectives from which an economic analysis can be done. In this thesis, the community owned system has been given priority as households are the collectively the owner of the project. Therefore, the analysis will be done assuming that each household invests equally to the project and share the profit as well. The project is a community owned project therefore responsibility and authority will be equally distributed among the households. All investment costs, profits and any other financial parameters are analyzed, mainly taking household as a unit; however, a few analyses from the community perspective have also been done.

#### 6.5.4.2 Analysis from the household perspective

Table 6.22 (in next page) shows that the project is not profitable even if "subsidy externalities" are internalized. However, Table 6.23 (in page 214) indicates that if "pecuniary externalities" (term used only for those that could be monetized) are internalized and MHP is also provided equal benefits as other technologies then the project is financially viable even at the interest rate of 13%. This interest rate is plausible for commercial banks in Nepal (See **Annex 6.10** for more calculations of few other project sites in Nepal). The main question is that the households will have to invest money at the beginning. The amount is about 11.66% of the average GNP of a Nepalese family (considering the data of CBS 2002a). This amount is high if people's income is compared. Majority of the people are subsistence farmers, so collecting that much amount from all households will be difficult. If positive externalities are internalized then the contribution of families could be reduced as shown in the following table.

If people use 75% of the installed capacity (i.e. 21 kW out of 30 kW) for lighting paying Rs. 1 per watt[185] and, 8% of total energy that could be generated in a year would be utilized for the end use technology paying Rs 5.45/kWh[186], (see e.g. NEA 2003) then the project would be financially viable[187] at one percent interest rate on loan. In other words, if end use energy consumption is increased, the viability may be increased. For example, if

[185] The popular rate currently in Nepal.
[186] The tariff for the rural and cottage industry fixed by Nepal Electricity Authority.

15% of total generated energy in a year would be used for end uses then the project would be viable at 6% interest on loan per year for 20 years and tariff will be Rs. one per watt per month. In the other way round, in the case of Dajungkhola MHP, if community consumes energy as present for domestic lighting and pays Rs. 1.25/ watt per month and utilizes 10% of its total generated energy for end uses at same rate as NEA, then the project could be viable even if it pays 5% interest on loan. All these conditions are valid only if "subsidy "subsidy externalities" given to kerosene and diesel and has been provided to each rural household is internalized (i.e. given to MHP). The Box 6.1 (in page 215) considers a hypothetical condition based on our existing data and shows several possibilities.

**Table 6.22 Economic analysis internalising subsidy externalities[188]**

| Particulars per HH (average) | Without discount[189] | With 1% discount | With 6.5% discount | With 12% discount |
|---|---|---|---|---|
| Investment Rs. /year in 20 years[190] | 585 | 648 | 1,062 | 1,566 |
| Straight depreciation[191] Rs./year | 585 | 585 | 585 | 585 |
| Internalizing externalities of subsidy provided to kerosene, dry cells and diesel that could be replaced by MHP Rs./year[192] | 367 | 367 | 367 | 367 |
| Net investment of household Rs. per year | 218 | 282 | 695 | 1,200 |
| Net income per household per year (net income Rs. /HH) | - 299 | - 299 | - 299 | - 299 |
| Net profit Rs./year | - 517 | - 581 | -994 | - 1,499 |

Source: Author

From above discussions, it is clear that if load factor of MHP would be increased, the financial sustainability of MHP is possible (See **Annex 6.11** for several scenarios). Normally, several MHP projects are underutilized because people installed bigger plants considering future demands. Secondly, people are paying lesser than they were paying for

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187 See **Annex 6.10** for more and similar analysis.

188 By considering that there is no subsidy on MHP and subsidy provided to kerosene and diesel are a part of externality which could be avoided or given equally to MHP.

189 Discount is considered as an interest for investment, i.e. households are taking loan from the bank at the interest rate equal to discount rate.

190 The investment cost per family in the case of the case study project is about NRs. 11,699.74, whereas the average investment per family from 43 MHP as given in **Annex 1.1** is about NRs. 11,630. Therefore, analysis of Dajungkhola MHP as a case represents, in general, the MHP from the investment perspective.

191 Straight depreciation is total investment cost divided by 20 years and by no. of beneficiary households to get a share of each household.

192 As per calculation in Chapter Five.

kerosene and dry-cells, as per survey data. Thirdly, kerosene price has been increased by almost 183% since 1990 despite several subsidies (NOC 2002) whereas tariff of MHP has been hardly increased by 60% since 1987 (see ADB/N 1987 for old tariff). This clearly shows that in the case of MHP, lower tariff has been paid despite better facility. If people are willing to pay appropriate tariff then the MHP projects are financially sustainable.

**Table 6.23 Economic analysis internalising pecuniary externalities**

| Particulars per HH (average) | Without discount | With 6.5% discount | With 12% discount | With 14% discount |
|---|---|---|---|---|
| Investment Rs./year in 20 years | 585 | 1,062 | 1,566 | 1,767 |
| Straight depreciation Rs./ year | 585 | 585 | 585 | 585 |
| Internalizing pecuniary externalities of kerosene, dry cells and diesel that could be replaced by MHP Rs./year | 2,045 | 2,045 | 2,045 | 2,045 |
| Net investment of household Rs./ year | *- 1,460* | - 983 | - 479 | - 279 |
| Net income per household per year (net income Rs. /HH) | - 299 | - 299 | - 299 | - 299 |
| Net profit Rs./year | 1,161 | 684 | 180 | - 21 |

Source: Author

Looking at the Dajungkhola MHP, there are four end uses, like mills, running in the village. However, the revenue generated is less than what is required to be financially sustainable. Moreover, repair, maintenance and other costs are lower than 3% of investment cost. So if available capacity of plant is utilized optimally (ca 75%) in lighting and a significant percentage of energy is utilized for end-uses paying reasonable and payable tariff, MHP are financially sustainable if “subsidy externalities” are internalized. The voluntary labor contributed by the community members in their own system is also compensated by other qualitative gains. Therefore, from economic aspects, the project can be made financially sustainable if proper strategy and approaches are adopted. Government can also provide loan at lower interest rate because of several social profits. (More on financing of MHP is discussed in next chapter).

**Box 6.1 A hypothetical case based on field data**

The capacity of a plant is 20 kW. The investment cost, taking the average of 40 community-owned MHP, will be Rs. 2,200,000. Produced power would be utilized for evening lighting for 7 hours a day; people pay tariff as Rs 1.65 per watt per month; and, at least 10% of total generated energy per year is utilized for end uses at the rate of Rs 5.45 per unit, similar to government's rate for rural small and cottage industries. From the above assumptions, the load factor will be nearly about 0.32. Moreover, the MHP project gets subsidy equal to kerosene and diesel given by the government per household per year, on the average. This subsidy is provided yearly to MHP as revenue. Then the project will be financially sustainable even at 12% discount rate. The tariff of Rs. 1.65 for the poor would be acceptable because they divert their kerosene expenses into the bulb tariff. From the study, it is found that about 32% of households in Okharbot VDC use only one bulb of 25 watt. The average kerosene consumption before MHP was about 2.98 liter per month for a family (about Rs. 52.25). For a 25-watt bulb, people pay Rs. 41.25 per month. The expenses for the dry cells can be saved as electricity is used for radios and cassette players.

#### 6.5.4.3 Analysis from the community perspective

The following economic calculations that are based on primary data of the village indicate that the MHP projects could be easily economically as well as financially viable despite the perception of bad financial returns. Looking from the broader economic perspectives only, MHP fulfills economic sustainability criteria with subsidy and neglected (or at lower rate) discounting. From the community development perspectives and community as an owner for the benefits of the community members as a whole, the community enterprise, i.e. community owned MHP could be economically sustainable.

Table 6.24 (in next page) shows that the village is not in loss after the implementation of MHP in Okharbot VDC if the investment capital is discounted less than 1.5% and "subsidy externalities" is also provided to the MHP. The economic calculation assumes that the households are investing their capital at the rate of 1.5% interest (discount rate) per year and also paying the same amount of money they were paying previously for kerosene and dry cells. The operation maintenance expenses of MHP system is fixed aside, about 59,535 per year and salary for the working personal is allocated about 100,800 per year according to the current practice of the community.

**Table 6.24 Economic analysis from the perspective of community (with subsidy externalities)**

| Particulars | For community Rs./year |
|---|---|
| Net income from MHP/year (after reducing salary and O & M costs) | 75,441.00 |
| Depreciation (investment without subsidy divided by 20 years) | 154,436.60 |
| "subsidy externalities" internalized | 96,848.40 |
| Investment without discount | 154,436.60 |
| Investment @ 1.5% discount | 179,905.47 |
| Investment @ 6.5% discount | 280,332.18 |
| Investment @12 %discount | 413,515.67 |
| Savings due to switching to electricity for lighting | 169,548.72 |
| Net benefits without discount | 32,964.92 |
| ***Net benefits at 1.5% discount*** | ***7,496.05*** |
| Net benefits with 6.5% discount | -92,930.66 |
| Net benefits with 12% discount | -226,114.15 |

Source: Author

**Table 6.25 Economic analysis from the perspective of community (with pecuniary externalities)**

| Particulars | For community Rs./year |
|---|---|
| Net income from MHP/year (after reducing salary and O & M costs) | 75,441.00 |
| Depreciation (investment without subsidy divided by 20 year) | 154,436.60 |
| "Pecuniary externalities" internalized | 539,895.84 |
| Investment without discount | 154,436.60 |
| Investment @ 1.5% discount | 179,905.47 |
| Investment @ 6.5% discount | 280,332.18 |
| Investment @12 %discount | 413,515.67 |
| Net benefits without discount | 306,463.64 |
| ***Net benefits at 1.5% discount*** | ***280,994.77*** |
| Net benefits with 6.5% discount | 180,568.06 |
| Net benefits with 12% discount | 47,384.57 |

Source: Author

Table 6.25 (in previous page) indicates that if community members pay for electricity what they are paying now and "pecuniary externalities" is internalized, the project is financial viable even if they discount more than 12%. That means that the main obstacle is externalities that are making MHP not viable financially. In community perspective, total savings on expenses on lighting after the MHP installation is also considered profit. The rural people are adopting electrical appliances and new activities based on electrical energy are growing in the villages (see **Annex 6.8** for different end-uses in different villages). To increase the revenue collection, appliances or end use technology be used at off time hours. It will increase the load factor thus revenue and will make plant financially feasible.

#### 6.5.4.4 Economic benefits from electricity use in end-use technologies

The village has now few end-use technologies including existing mills[193]. If these had been run by diesel in the village then it would have needed about 3,863.9 liters of diesel and that would have cost about Rs. 115,917 per year. Similarly, subsidy burden to the government would have been about Rs. 23,183 or about Rs. 87.82 per household per year. Now because of the MHP, this subsidy and cost of diesel have been avoided. Moreover, local economic activities and employment opportunities by end use technology have been enhanced. Certainly, these are also economic benefits to the society from MHP, which could not be reflected in the traditional financial analysis.

**Table 6.26 Economic benefits due to saving of fossil fuels in the existing & potential end-uses sector[194]**

| Diesel mills | No. | Diesel (equivalent) liters per year | Cost[195] of diesel/year in Rs. | Subsidy saved /year in Rs. |
|---|---|---|---|---|
| Previously existing mills (now with electricity) | 1 | 1,500 | 45,000 | 9,000 |
| End-uses (mills) technology after MHP | 1 | 1,500 | 45,000 | 9,000 |
| Saw mill | 1 | 750 | 22,500 | 4,500 |
| Poultry farming | 1 | 113.9 | 3,417 | 683.4 |
| Total | 4 | 3,863.9 | 115,917 | 23,183 |
| Per HH | | 14.64 | 439.08 | 87.82 |

Source: Author

[193] Details of end-use technology in other MHP sites are shown in Table 6.32.

[194] Potential end uses sector means, the end-use technology or facilities set up after the installation of MHP and it is assumed that these end-uses would have been existed with fossil fuels even if MHP had not been installed.

[195] The cost is of 2001 and the current price of diesel could be more or different in the local areas.

On the average, draining of about Rs. 439.08 per family has been avoided from the village for diesel. If we look from the community perspective, this amount will remain within the community or used for other purposes. If it is utilized at local level then local economic activities would be enhanced.

### 6.5.5 Analysis of MHP from traditional financial approach

From the traditional financial analysis perspective, based on the obtained data (**in Annex 6.9,** see analysis example in **annex 6.15**) of the four MHPs in Myagdi District, the scenario as shown in the table below can be obtained. From the narrow financial analysis, it has been found that the MHP projects are not financially sustainable. When an individual decides to invest on such projects, he/ she will not do that. As discussed several times by several authors including Mackay (1990), the MHPs for a private entrepreneur are financially critical. Because of the low load factor, the revenue collected is not sufficient to have a 'profit' for an individual entrepreneur at the acceptable tariff rate. This is the case mainly with stand-alone systems. For add-on systems, because of major income from agroprocessing, the financial revenue collected is sufficient to have a 'profit' (e.g. Mackay 1990, ADB/N 1987) and for stand alone systems this modality could also help to sustain financially. The traditional financial analysis does not support the MHP projects at the existing conditions of rural economy in Nepal. Traditional financial analysis has limited space, time, system quality and boundary to analyze the impacts. Because of these narrow limitations, such analysis cannot reveal the true benefits of the renewable, appropriate and socially acceptable decentralized technologies.

Several studies including that of ITDG (Khennas et al 2001) has mentioned that financial recovery from the MHP system could be possible even without subsidies. The components of the system could be recycled partially after about 30-50 years and some economic capital will be recovered although most of the analyses of MHP designate zero salvage value. Apart from that, the employment benefits, revenues or tax collected by the government from the MHP manufacturers, reduced burden on the terms of trade due to the reduced import of fossil fuel. These are some of the economic benefits, which are also discussed in the previous sections and chapters. Therefore, the condition of constant or increased economic capital i.e. increased economic benefits laid down by the sustainability constraint is explicitly more than before the installation of MHP.

**Table 6.27 Financial indicators of MHPs in Myagdi district**

| Scheme | Investment Cost Rs. | Discount rate | With subsidy | | | Without subsidy | | |
|---|---|---|---|---|---|---|---|---|
| | | | NPV | BCR | IRR | NPV | BCR | IRR |
| Dajungkhola/ Okharbot | 3,088,732 | 0.00% | 687,912 | 1.18 | 6.66% | -1,579,912 | 0.74 | -6.03% |
| | | 5.37% | 90,445 | 1.03 | 6.66% | -2,177,379 | 0.56 | -6.03% |
| | | 12% | -257,406 | 0.87 | 6.66% | -2,525,230 | 0.40 | -6.03% |
| Bagarkhola/C himkhola | 3,700,657 | 0.00% | 429,144 | 1.10 | 2.46% | -1,726,637 | 0.74 | -5.36% |
| | | 5.37% | - 352,534 | 0.89 | 2.46% | -2,508,315 | 0.54 | -5.36% |
| | | 12% | - 807,634 | 0.69 | 2.46% | -2,963,415 | 0.38 | -5.36% |
| Darakhola II/Lulang | 3,256,939 | 0.00% | 82,090 | 1.02 | 0.62% | -1,931,659 | 0.66 | -7.37% |
| | | 5.37% | -442,697 | 0.84 | 0.62% | -2,456,447 | 0.48 | -7.37% |
| | | 12% | -748,234 | 0.65 | 0.62% | -2,761,924 | 0.34 | -7.37% |
| Darakhola I/ Muna | 5,137,024 | 0.00% | 1,742,675 | 1.14 | 11.58% | -2,309,824 | 0.74 | 5.12% |
| | | 5.37% | 623,153 | 1.18 | 11.58% | -3,429,347 | 0.54 | 5.12% |
| | | 12% | -28,643 | 0.99 | 11.58% | -4,081,143 | 0.38 | 5.12% |

Source: Author

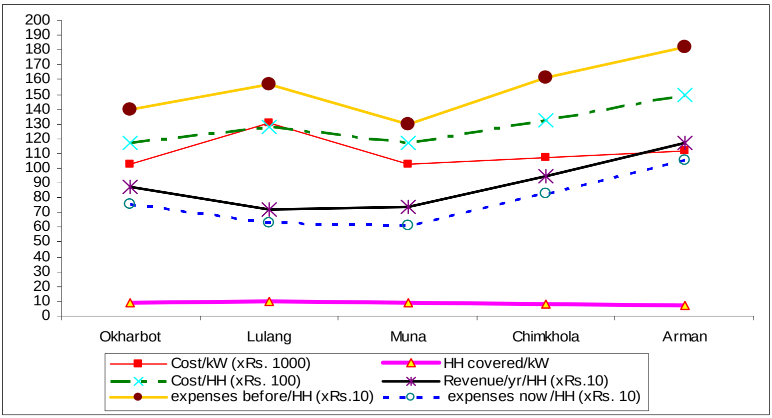


Figure 6.2 Comparative characteristics of five MHP sites in Myagdi.

Source: Author

The broad economic analysis from the sustainability perspective shows that the community owned stand-alone systems are economically sustainable. It has also been illustrated from the household perspective that the MHP projects could be economically feasible if appropriate subsidy is provided to internalize the positive externality. However, the traditional financial analysis cannot express such benefits in its calculations.

### 6.6 Social dimension of MHP

"Capital includes a broad range of assets which can be turned into desired goods and services" (ICIMOD 1999/1). Moreover, lack of these assets causes poverty (World Bank 2001). In traditional welfare economics, market price shall indicate the value of such capital or goods or services or relations. Nevertheless, the value of social capital is hardly indicated by the market because of the existence of hurdles, weaknesses and externalities. Externality, as it is discussed and defined in the previous chapter, is being tried to measure in terms of monetary units because of the popularity of cost-benefit analysis as a tool in decision making. More broadly, a "[social] capital is not a thing, but rather a definite set of social relations which belong to a definite historical period in human development" (Shaikh 1987: 333[196]). While discussing sustainability, social component has been neglected or marginalized in the operationalization because of the lack of quantitative indicators. Social components that are not being quantified or hard to quantify, sometimes, are being handled as an externality even in the sustainability discussions because, as per World Bank (2001), the income and consumption dimension has received most attention. Neglecting social components is equal to abandoning one component of the "means of production" of sustainability. Contrary to that, the fact is, it is still very hard to incorporate social component in sustainability without pecuniary methods and provide equal weight as other components of sustainability even today. Without economic value, no internalization is acceptable. For Pearce et al, "its importace lies in changing perception of 'economic' from meaning 'associated with cash flow' to meaning 'achieving human well-being" (Pearce et al 1993: 12). In the following paragraphs, it has been tried to quantify and illustrate the importance of a few social capital with the example of MHP projects in Nepal from the sustainability perspective. However, the analysis based on before and after can be done even with qualitative data and indicators.

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[196] Shaikh, Anawar (1987) in the New Palgrave, a Dictionary of Economics, London.

The sustainability condition of social analysis will be ***$dCst/dt \geq 0$, (from figure 4.15. $Cs_2 - Cs_1 \geq 0$)*** for defined time horizon and space. The invested social capital to the system must be outweighed by the social output and bring net social benefits. Under the social analysis, the reference parameter of equity and factors like compensation, compromise, accessibility, rights and resource distribution are to be reflected by the outputs. In the micro level resource distribution, en-gendered employment opportunities, access to fulfill the basic needs and existence of an institution managing and monitoring these activities are also evaluated. In the macro level sustainability analysis, this should include the decentralization, balanced regional development and other macro issues as well.

### 6.6.1 Analysis of social capital of community before MHP project implementation

Considering the social conditions from the perspective of energy used for lighting before the MHP has been installed, there were no employment opportunities in the villages, and households were paying for imported kerosene. Before MHP, on the average, women were normally using human labor for agroprocessing. The agroprocessing was done at home as well as nearby milling station run by water turbines or diesel mills, if available[197]. The time consumed for that was also not so less when they have to carry food grains to the mill site[198]. Not all family were using the facility available then, but after community owned MHP has been installed and electric mills happened to be in the centre of the villages, the situation has improved[199]. The tendency is towards the abandonment of traditional way of grinding and husking and using available facility of agroprocessing mills. On the average, women of the four VDCs in Myagdi were using about two hours per day for manual grinding and husking. Table 6.28 (in next page) indicates the different agroprocessing practices and technologies and the human labor used in Nepal.

Importing kerosene and battery was done either by using porters or mules. Depending on the places, people need few minutes to at least few hours per month to fetch kerosene and battery. The time consumed to buy kerosene or battery could have been combined with other shopping works like buying salt, sugar, stationary, etc. but subsistence farmer may not need these things from market frequently. From the questionnaires in the ten villages of

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[197] Out of 140 families interviewed, about 127 families of Okharbot VDC were using manual grinding and husking at home before the installation of MHP. Only oil expelling were done in the mills by most of the households.

[198] In Okharbot VDC, this duration, on the average, is about 3 hours 19 minutes.

[199] In Okharbot VDC, people say that almost all are using agroprocessing facility available after the implementation of MHP. However, in case of Muna and Lulang VDC in Myagdi a few households still use traditional way of grinding and husking.

Nepal, a pattern of time needed to fetch the kerosene and battery is found as shown in **Annex 6.12**.

**Table 6.28 Agroprocessing done by different methods and technologies in Nepal**

| Methods/Technology | Processing capacity ca. kg/hr | | | Human labor/ power needed | No. of HHs served (average) |
|---|---|---|---|---|---|
| | Grain grinding | Rice husking | Oil expelling | | |
| Janto (manual grinder) | 5 | | | At least -one person | Janto normally individual HH |
| Dhiki (manual husker) | | 9 | | At least 2 persons | Dhiki sometimes shared with neighbors |
| Kolu (manual expeller) | | | 3 | 3 person | Kolu is shared by at least 10-20 HHs |
| Ghatta (traditional) | 20 | - | - | 0.5 - 1 kW | 10-50 |

Source: Author (compilation based on ADB/N 1987, ITDG/CRT 1995, GTZ/CRT 2000, ICIMOD 2000 and discussion with the villagers)

The time consumed may not represent a pathetic scenario but the transportation of kerosene from motorable road head to the villages is, on one side not safe, while on the other side, needs lots of animated energy. The price of kerosene is also high because of the transportation. The question is that even being the owner of rich natural resources, the remote communities are bringing the kerosene, battery and the fossil energy to the villages without any extra benefits but with full of burden and uncertainty of availability.

### 6.6.2 Analysis of social capital output

The previous social conditions will be compared with the enhanced social conditions after the MHP installation. The social capital input to the MHP system will be the efforts, labor, participation and involvement in decision-making process. The communities of the four MHP sites in Myagdi District have contributed voluntarily the following (see Table 6.29 in next page) economic as well as social capital for the implementation of MHP system. Willingness to contribute voluntary capital is a part of the social capital because there is no private profit economically. Contributing some capital without any private profits is not economic investment but social investment.

**Table 6.29 Community voluntary contribution for the installation of MHP**

| VDC in Myagdi | MHP kW | Cash contribution Rs. | Labor contribution Rs. | Donation Rs. |
|---|---|---|---|---|
| Okharbot | 30 | 76,580 | 442,692 | 189,000 |
| Muna | 50 | 94,601 | 953,370 | 235,000 |
| Chimkhola | 35 | 762,374 | 444,617 | 189,000 |
| Lulang | 25 | 24,282 | 499,868 | 230,000 |
| Total | 140 | 957,837 | 234,0547 | 843,000 |

Source: Author (Compiled from the data obtained from DDC/REDS, Myagdi)

The labor contribution could be valuated in the monetary units according to the local wages and vise versa. The rich families and people earning cash have contributed voluntarily some amount. On the average, Rs. 3,295 per household has been contributed without any expectation of private/individual profit or returns, if the average is taken from the data of the four villages in Myagdi District. Such voluntary contribution came because of the implementation of MHP in the villages through community participation. If a big system or privately owned system had been implemented, there would have no such voluntary contributions. This indicates that the community members are ready to compromise and compensate for sustainability if development approaches are made consistent with their interest and needs.

The community or local villagers will invest their labor, time and other social capital to the decentralized MHP system. But in return they will get the benefits in different aspects (e.g. Pearce and Webb 1987, Hourcade et al 1990, Cecelski 1996, Aguado-monsonet et al 1997, Shrestha et al 1998, Rijal 1998, WB 1996, Banskota et al 1997, Broek 1997, and compare WB 1996, Meier 2001, Rijal 1998; Ramani et al 1993 and ICIMOD 1993)[200].

### 6.6.2.1 Enhanced living condition

Better lighting of houses will be achieved (see Table 6.30 in next page). People who were using one kerosene wick lamp are using at least one bulb[201]. Better lighting has also

[200] Also based on the discussions with the community people of the four villages of Myagdi district in Nepal and several unpublished reports of REDP/UNDP Nepal.
[201] The average numbers of bulbs used in Okharbot VDC in Myagdi is about 2.5 per family.

induced people to make better sanitation and hygienic conditions. Brighter light has exposed the corners, where cockroaches and other unhygienic things would have been before electricity came (e.g. see REDP 1998c). According to the local people, brighter light induced them to clean walls, floors and other parts of their houses making better hygienic condition than before.

**Table 6.30 Quality of lighting from electricity bulbs and kerosene lamps**

| | Before MHP (one kerosene wick lamp) | After MHP (one 25-watt incandescent bulb) | Remarks |
|---|---|---|---|
| Source of lighting | Kerosene | Electricity | Majority of cases |
| Type of lamp | Kerosene wick | Incandescent bulb | Majority of users |
| Nominal consumption | 400 watt | 25 watt | Energy content of kerosene is 37 MJ/l |
| Nominal output of luminous flux | 40 Lumen (lm) | 500 Lumen (lm) | Kerosene wick lamp 25% efficient |

Source: Compiled from Broek (1997)

Better and managed lighting also diminishes the likelihood of the fire accidents from kerosene at their homes. Although there is no such official record of kerosene causing the fire, it is well reported in Nepal in the daily newspapers. Electricity may also cause the accidents but the probability of fire is bigger in the case of kerosene lighting in rural hamlets and huts where hay is being used for roofing.

**FIRE DANGER**

Kerosene and candles cause countless fire catastrophes every year. There were 282,000 deaths from fire-related burns worldwide in 1998, and 96% of these fatalities were in developing countries. In India alone, 2.5 million people (350,000 of them children) suffer severe burns each year, primarily due to overturned kerosene lamps. Each year, many homes burn to the ground when a lamp is toppled. *(Quoted from SELF Newsletter, downloaded on 24.06.03 from http://www.lutw.org/environmentfuel.html)*

Reduced indoor pollution after avoiding kerosene lamps is another social output. As data showed, more than 10% people are suffering from bronchitis in Okharbot VDC as per household survey done by DDC Mygadi. There are several reasons and the indoor air pollution is, among others, causing chronic bronchitis. Brighter lighting from electricity has removed the smoke of kerosene wick lamp as well as induced the people to reduce the smoke of fuelwood[202]. This would result in reduced cases of chronic bronchitis among the people although long-term time series data are not available from the villages. Smoke from kerosene lamps and also inhaled kerosene fumes, that is equivalent to the smoke from two packs of cigarettes a day, are said to be responsible for respiratory infections, lung and throat cancers, serious eye infections, cataracts as well as low birth weight, and acute respiratory infections like influenza and pneumonia that kill nearly two million children in developing nations each year[203]. After installation of MHP in the villages, at least this threat from kerosene is avoided.

**Table 6.31 Comparison of pollutions from kerosene and electric bulb**

| Particulars | One kerosene wick lamp (before MHP) | One 25-watt incandescent bulb ( after MHP) | Remarks |
|---|---|---|---|
| Fuel consumption[204] per year | 86.4 liters (838 kWh) | 54 kWh | 1 Liter kerosene = 9.7 kWh |
| GHG[205] emission/year (CO2 equivalent) | $218.64 \times 10^{-3}$ ton from one wick- lamp | $0.5475 \times 10^{-3}$ ton from one 25-watt incandescent bulb | A 25-watt bulb emits about $218.0925 \times 10^{-3}$ ton less CO2/ year compared to wick lamp |
| Pollution gases in tonnes/year | TSP = 0.235<br>CO = 2.554<br>HCS = 0.013<br>NOX = 0.167<br>SOX = 0.285 | Negligible | Based on national average mentioned in CBS (2002b) |

Source: Compilation based on Broek (1997), Fritsche (1990) and (CBS 2002b)

Additionally, the dry cell batteries used in the rural areas are having poisonous substances. Poisonous ingredients in acidic dry cell batteries are manganese dioxide and ammonium

[202] People are induced to burn fuelwood in more organized way because electric light is brighter than kerosene lamps and electricity light shows clearly the smoke of fuelwood and make the family aware of more smoke than before. Electricity also shows the dark walls and ceilings of the houses more clearly. This also impels the people to reduce the fuelwood smoke so that the house can be made or seen clean. On the other hand, bringing electricity to the people makes them aware of energy related impact, as experiences show in the villages of community owned MHP system; people are adopting simultaneously fuelwood saving & efficient burning improved cook stoves. This will reduce the indoor smoke and reduce the health impact especially of women and children who normally do the cooking. The adoption of other fuels and energy efficient devices and technology is because of awareness after electrification. However, empirically such studies has to be conducted. The above statement is based on field experiences only.

[203] http://www.lutw.org/LEDtechnowhat.html down loaded on 25th June, 2003.

[204] Considering 6 hours of lighting in case of kerosene wick lamp and consumption of kerosene per wick lamp is about 0.041 liter/hr (e.g. Broek et al 1997). For electricity, 25-watt bulb is considered for 6 hours of lighting. Nevertheless, while calculating CO2 emission it is considered that the electric lamp lights whole year- as CO2/kWh emission of MHP is based on life cycle.

[205] CO2 emission of MHP-life cycle is 0.0025Kg/kWh, Kerosene is 0.0723 T/GJ.

chloride. In alkaline batteries, there are sodium hydroxide and potassium hydroxide. Symptoms of health effects of chronically ingesting and inhaling large amounts of the alkaline battery and acidic battery are: decreased mental ability, skin itching, irritation, muscle cramps, swelling of the lower legs, respiratory bronchitis, headache, severe pain in the throat, severe abdominal pain, diarrhea, vomiting, rapid drop in blood pressure, etc.[206]. After electrification, the above-mentioned possible health effects are reduced or avoided as batteries in radio and torchlight are no more used or drastically reduced. Although there is no time series data available on such impacts and health related expenses, after the reduction or abandonment of dry-cell use, households must have been benefited.

Moreover, lighting of roads and trails around the villages could enhance public security. Better preservation of medicines and availability of permanent and reliable energy supply in health centers would have positive impacts on the health system of the community because the most important output in the social capital is enhanced living condition by reducing vulnerabilities. " in the dimensions of income and health, vulnerability is the risk that a household or individual will experience an episode of income or health poverty over time" (World Bank 2001: 19), so reduced vulnerability enhance the living conditions of the poor.

#### 6.6.2.2 Drudgery and burden reduction

Improved social cohesion due to released work hours and available leisure time is a social benefit to the women although Cecelski (1996) opined in the other way round stating that electricity could have reduced the sleeping time of women as they do more work because of lights. Nevertheless, agroprocessing like grinding, hulling, husking, etc. would reduce the drudgery of people, especially women and children. From the field study in four sites of Myagdi District by the author and from the existing study (e.g. ITDG 1997a, ADB/N 1987), it is found that women have reduced load of agroprocessing by about one to four hours daily after the installation of MHP[207]. After mechanical grinding or husking technology is brought in the villages because of MHP, women have been relieved from such burdens[208]. On the average, about 60 hours of drudgery per month is saved per households. Although the opportunity cost of labor saved economically is nil, the benefit

[206] http://www.nlm.nih.gov/medlineplus/encyclopedia.html down loaded on 24 June, 2003.
[207] In Okharbot VDC, a woman, generally, spends on the average, two-hours of labor for grinding and husking everyday for a normal family (127 out of 140 interviewed family in Okharbot VDC).

from the relieved drudgery is there. According to a study in an area of the Himalayan region, women are said to be working more than 3,485 hours and men about 1,212 hours in a year (IFAD 1999) and for women in the rural Nepal it is said to be 4,000-5,000[209] hours per year (WECS 1995b). Especially in the hilly regions of Nepal, the tremendous labor intensity with the subsistence economy is evident and if labor use in other activities such as water collection, cooking, childrearing and other occasional domestic activities is also considered then the women and poor section of the hilly and mountain population are overworked (e.g. Bajracharya 1986). That is why, if she (or a child) saves, on the average, about 700 hours in a year avoiding agroprocessing labor works then the relief of drudgery is significant. As Dutta (2002) mentioned:

> *"As women work harder, they are faced with a variety of health problems. Firstly, growing food and processing it without any mechanized equipment is extremely tedious and time consuming. … Women experience other health hazards from cooking for long hours over poorly ventilated indoor fires. They, along with their young children, are exposed to large amount of smoke and incompletely burned particulates from indoor fires and [kerosene lamps], together with pollutants such as carbon monoxide and benzene. As a result they often suffer from respiratory infections, lung diseases, and eye problems" (Dutta 2002:16).*

**Table 6.32 Agroprocessing technologies in the villages after MHP projects**

| Methods/Technology | Tentative processing capacity kg/hr | | | Tentative power needed | No. of HHs served (average) |
|---|---|---|---|---|---|
| | Grain grinding | Rice husking | Oil expelling | | |
| Ghatta (Improved) | 40 | 150 | 10 | 1-5 kW | 50-200 |
| Mills (MHP mechanical/electrical) | 50-100 | 420 | 10-25 | 5-12 | 100-700 |

Source: Author (Compiled from ADB/N 1987, ITDG/CRT 1995, GTZ/CRT 2000, ICIMOD 2000 and data provided by the turbine manufacturers and mill owners

It could also be considered that the women and children were working extra hours[210] without pay and now they can, if they want, utilize these hours of labor for other works and get some 'earnings'. The saved time is about 90 working days, so, considering a local labor

[208] Grinding and husking were done normally early in the morning when it was still dark or during the night when other works in the fields or forest are not possible.

[209] Converting mentioned 11 to 14 hours per day in literature for 365 days (WECS 1995b)

[210] They were working additional hours because of unavailability of technology and/or their counterparts do not do that job even being idle.

rate of Rs. 60/ day[211], she can earn about 5,400 rupees if working opportunities are available. Whereas, the average family expenses for agroprocessing, as per field study, is hardly one thousand per year. The following text can be quoted to show the financial burden of a family:

*"lighting is generally achieved by the use of kerosene lamps, and amounts to around 1% of rural energy consumption – but this comes at high expense, since kerosene must be purchased from the cities, and carried (usually someone's back) to the village homes where it is consumed. For most villagers, kerosene for lighting is a significant expense, accounting for 10% to 20% of a typical family's earnings."*[212]

#### 6.6.2.3 Better education & information and awareness

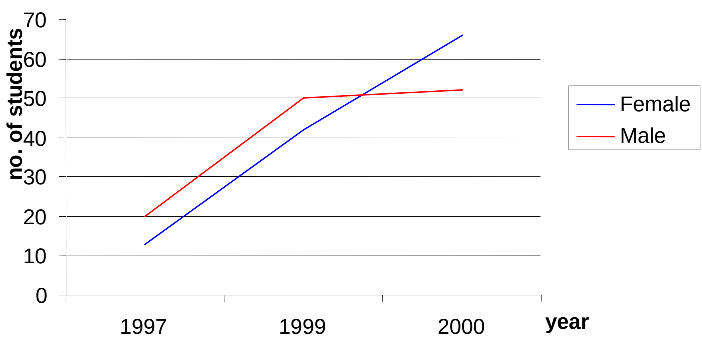
Enhanced access to audio-visual services (radio and television), which may play a role in developing the informational and educational level of the rural population, provides more ideas to the local people especially related to weather and agriculture based information. Lighting of schools and homes can improve the education of the children, schooling percentage has increased in a village after implementation of MHP through community mobilization and enhanced adult education program. Villagers themselves feel that after electrification more education and learning by children is perceived and awareness due to information through TV and radio is being better than before.

#### 6.6.2.4 En-gendering development

Small number of local employment opportunities for women could be noticed. Because of MHP installation, the employment opportunities were available to the village women in five VDCs (six MHP plants) as shown in Table 6.33 (in next page). This opportunity was not there before. If other technologies like grid and diesel mills were installed, it could have been business as usual scenario - operated and maintained by men only. Because of community owned system through participation, the development is being en-gendered providing employment opportunities to the women too. Providing equal opportunity to both men and women is the objective of en-gendering the development and thus sustainability.

[211] The wage rate is fixed by the government for unskilled labor; however, the normal wage rate is about Rs. 100 per day in most of the villages.
[212] Source: URL, www.hlf.org.np/energyintro.htm., down loaded on 14 July 2002

**Figure 6.3 Enrollment in primary school in Piughar**




Source: Based on data provided by Merina Pradhan/REDP (Piughar is a village in Tanahun District where a community owned MHP has been implemented)

**Table 6.33 Women's employment after the community MHP systems in few VDCs**

| VDC | During implementation (person-day) | | Direct in the MHP system (all time job) | End-uses job (electricity related) |
|---|---|---|---|---|
| | Un-skilled[213] | Skilled laborer | | |
| Dajungkhola/ Myagdi | 1857 | 1164 | 3 *(incl. one woman)* | 8 |
| Darakhola I/Myagdi | 5564 | 1644 | 3 *(incl. one woman)* | 8 |
| Bagarkhola/ Myagdi | 1580 | 662 | 3 *(incl. one woman)* | 7 *(incl. a women)* |
| Mahakhola/ Myagdi | 435 | 56 | 2 *(incl. one woman)* | 4*(incl. two women)* |
| Syankhukhola/ Dolakha | 2965 | 638 | 3 | 3 |
| Thampalkot (26+20 kw) | 5617 | 655 | 5 | 8 |

Source: Author (Compilation based on data from DDC/REDS Myagdi, REDP reports, interview with community mobilizers working in the villages of Myagdi district)

[213] Among the unskilled labors, there could have been women but the exact no. could not be found.

#### 6.6.2.5 Distribution of output and equity

In sustainability definition, equity is also one of the criteria. Equity on resource sharing, equity on accessibility and opportunity and equity in using individuals rights are to be ascertained if any sustainability activity or development process is carried out. Rural electrification may create a social change and feeling of 'modernity' (Cecelski 1996). To have the subsidized electricity by the rural people to feel 'developed' as the urban people is also a right of the rural people because the urban electricity has also been subsidized in one way or the other. According to Nash, "…a redistribution of legal rights is equivalent of real income; and it is well known that there may be a different Pareto optimal set of outputs corresponding to every possible distribution of real income" (Nash 1978:15). The legal right is also a right to have access to resources and its uses. Electricity generated from renewable resources in the remote villages could bring an equal access to the rural people as to the urban people.

Providing the rich families all and adequate amount of electricity through renewable resources and depriving poor families could not be justified from the sustainability aspects although the ecological sustainability constraint could be satisfied as renewable resources would not cross the carrying capacity of the ecology. However, in the case of community owned MHP, within one settlement, almost all villagers have access to electricity. The concept of project was so built up in REDP/UNDP supported community owned MHP that no households in a community will be left without access to electricity. This is one of the best aspects of the community owned MHP[214]. Certainly, other opportunities of getting jobs, developing enterprises cannot be distributed to all. Few among those who have schooling and training will get the job of management and operation and those who are risk taking and have some ideas as well as capital can start enterprises. In this aspect, one cannot give a dichotomized answer, whether there is equality or not. Nevertheless, accessibility to the electricity of minimum requirement of lighting is there. The revenue collected by the system as well as ownership of the system belongs to each household. This is the main achievement in the case of equity aspect.

[214] For example, the community of VDC Muna in Myagdi, with about 437 HHs, all are having access to electricity.

**Table 6.34 Distribution of bulbs according subscription in Okharbot VDC**

| No. of Bulbs/HH | 1 | 2 | 3 | 4 | 5 | 6 | 8 | Total |
|---|---|---|---|---|---|---|---|---|
| No. of HH | 85 | 81 | 37 | 31 | 9 | 8 | 3 | 254 |
| **No. of bulbs by watt used in Okharbot VDC** | | | | | | | | |
| 0 (5) watt[215] | 25 watt | 40 watt | 60 watt | 100 watt | Total Bulbs | | | |
| 4 | 580 | 117 | 28 | 12 | 741 | | | |

Source: Author

All people are having electricity in the community owned MHP whereas it could not be the case in the private owned MHP or centralized grid[216]. Therefore, the community owned MHP, in this aspect is more pertinent to the decentralized and remote isolated society like the hilly areas of Nepal. However, this depends on the types of ethnicity, homogeneity of the community and the local socio-political conditions. Being a local enterprise, a decentralized privately owned MHP could not easily deprive of local people electricity as water resources belong to the community. Indubitably, the community owned MHP projects have lesser conflicts than the private owned systems regarding access, resource use and tariff fixation and equality. Table 6.34 and 6.35 illustrate the distribution of electricity among the community members of Okharbot VDC in Myagdi district in Nepal.

The data in Table 6.34 illustrate that about 33.5% of families in Okharbot VDC are having only one electrical bulb, about 32% is having two bulbs and about 15% are having three bulbs. That shows that there is no large disparity although very few (about 1%) families are having eight bulbs. The scenario in Pinthali VDC of Kavre district is also similar as shown in Table 6.35. On the other side, almost all people are using 25 watt electrical bulbs (see **Annex 6.18** for details of bulbs used in few MHPs). Those who are using one bulb only are paying about Rs 20 per month, which is cheaper than one liter of kerosene. So, on the average, the poor families are benefiting from electrical lighting. One the other side, there is no large disparity among the families as most of them are using one or two bulbs and

[215] 'Zero watt' bulbs are actually five watt bulbs and these are being used in public places in Okharbot.

[216] There are also conflicts in some private owned MHPs and economically as well as politically influenced person, in general, are the owners of private MHPs. The conflicts on resources and its using rights are sometimes crushed with undemocratic ways, illegitimately utilizing owners' better ties with the local authorities. Nevertheless, there are also exceptions; few private MHPs are also serving people in a better way.

only a few families are using 5 - 8 bulbs[217]. From the equity and distribution aspect, community owned MHP are socially beneficial and fulfilling the constraint of equity and distribution.

**Table 6.35 Patterns of electricity consumption in Pinthali VDC of Kavre district**

| Power connected by families (in Watt) | 150 | 125 | 100 | 75 | 50 | 25 |
|---|---|---|---|---|---|---|
| No. of families | 3 | 4 | 2 | 19 | 58 | 30 |
| Percentage of family | 2.59% | 3.45% | 1.72% | 16.38% | 50.00% | 25.86% |

Source: Author

There have been many cases where poor families, who are economically weak, can pay tariff in kinds not only in cash. Sometimes local handicrafts, human labor or other products of the people are also being accepted as a tariff "charge of electricity"[218]. This is generally found in the community owned systems. These types of activities will provide opportunity to the poor people to have access to electricity even though they do not have cash at hand. This is not possible in the case of centralized grid system, where people have to bring their products into the markets first to have the cash for the payment of electricity tariff. Markets are not always there in the vicinity in the remote villages; people have to invest time and labor to reach to the market to sell their products. Accepting people's resources in any form (cash, kinds, products) will provide the opportunity to the people to have facility like electricity without extra burden of cash accumulation by selling their products.

The faster electrification[219] to the remote, mountain and hilly areas [220]can help to distribute the development benefits to the rural poor like electricity and electricity depending services - hospital, information disseminations, etc. Rural electrification has also helped to reduce minor urban migration[221]. The reason could be better facilities after electrification and for a

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[217] The large no. of bulbs using family would not be necessarily rich but with large family size, i.e. more family members.

[218] In Thampaldhap VDC of Sindhupalchowk district, community is also collecting poultry for tariff if families cannot pay cash. Similarly, in Lapilang VDC of Dolkha district,- they accept handicrafts like doko (bamboo basket) and naglo (bamboo tray used for disaggregating of grains), in Taman VDC of Baglung and in Thampalkot of Sindhupalchowk, they also employ labor if poor family does not have cash for electricity tariff (Source: Information received from REDP on request via email on 10 August, 2003).

[219] The REDP after its initiation in 1996, managed within five year to provide clean lighting to more than 10,000 families living in the remote hilly and mountain areas of Nepal (REDP 2000a)

[220] Most of the REDP and RADC's community owned systems are in remote areas of the country.

[221] Reluctances to migrate to urban areas have been noticed in few villages like Taman of Baglung district, Muna and Chimkhola of Myagdi district due to the availability of electricity thus the other facilities run by it, and this has been noticed especially among the pension receivers and remittance receivers. However, no time series study exist for a longer duration in these villages.

few, availability of local employment opportunities directly or indirectly. Normally, a large unbalanced development is among the reasons for creation of political conflicts, migration and backwardness in developing countries. Rural electrification through MHP may not avoid such problems but can ameliorate the situation. MHP is providing electricity to the rural and remote people thus bridging the gap between "developed" urban and "backward" rural at least in the electricity access and other electricity dependent facilities to some extent. Providing electricity to the rural people may not bring drastic change in narrowed development vision of income per capita (Pearce et al 1987). However, Pearce et al did not forget saying that social benefits are there and but still hard to quantify.

#### 6.6.2.6 Participation, empowerment and accessibility in decision making

The development activities or development projects are having the objectives of poverty alleviation, participation in the decision-making processes and the empowerment of target groups at the grass-root level. The concept of sustainable development has also emphasized the participation of people at the grass root level in decision-making process, in sustaining and maintaining socio-ecological balance (Dahal et al 1993). Poverty alleviation has several components (e.g. World Bank 2001). For van der Straaten et al (1992), poverty has three components: economic, social and political. Nevertheless, they have forgotten ecological components. The political and social components can be combined in one. Participation and empowerment belong to the social component of poverty alleviation objectives because empowerment means to enhance capability to affect the decision making in favor of empowered people.

For Holcombe, "participation represents action or being part of an action such as the decision making process" and "empowerment represents sharing control, the entitlement and the ability to participate, to influence decisions, as on the allocation of resources" (Holcombe 1995:17). As compared to alleviation of economic poverty, participation and empowerment cannot be measured in monetary quantitative units and have no borderline to specify that these objectives have been achieved adequately or not. Whereas, in economic poverty, one could define this much income is sufficient to alleviate the poverty. Social poverty is determined by relationships. "…it is often the result of repression, exploitation and feudal conditions…. This concept embraces not only income but also participation in social and economic processes" (van der Straaten et al 1992: 56).

**Social benefits from MHP: Expression of a village group from Okharbot VDC and Lulang VDC of Myagdi District in Nepal**

- manual agroprocessing is reduced or abandoned after MHP,
- less smoke inside the house, better lighting than before,
- children are happy in the evening, learning longer because of better living and learning environment,
- radio and TV thus knows all 'News' happening in the country,
- weaving is better now in the evening,
- bamboo working and other weaving activities are also done in the evening and small incomes are there for stationery expenses,
- more chicken because of better lighting and few attacks from fox,
- no leopard has 'attacked' in the village since light came,
- better adult education programme.

***Interviewed in November 2002***

World Bank Report (2001) state that the lack of institution at the community level induces vulnerability thus causing poverty. In that background, the development of local institutions and enhanced empowerment process due to decentralized MHP systems has been noticed in the community owned MHP. Each of these community owned MHP systems have management committees that look after overall matter of MHP management, operation, financial and repair & maintenance matters. Tariff rate fixing, rules and regulations for the overall management of MHP systems were also formulated and implemented by local people's committee. Empowerment cannot be measured but there are indicators like MHP functional group, management committee, operating bank account by the communities themselves, tariff fixing, public auditing, which illustrate that the people are empowered. Expansion of capability of an individual or a community will provide several means of development. Development objective is not to provide the ends but to expand the capability of the people or individual or a community (e.g. Sen 1989), because expanded or enhanced capability will drive the people or community to look freedom of survival. The local level planning, implementing and running decentralized systems in a sustainable manner are the indicators of enhanced capability of community.

The above-mentioned social capitals are hard to quantify and monetized but they are implicit as well as explicit benefits to the local communities. The existing social benefits of MHP are enough to argue that the condition of constant or increased social capital, a constraint laid down by complete sustainability, is excellently fulfilled by the MHP system.

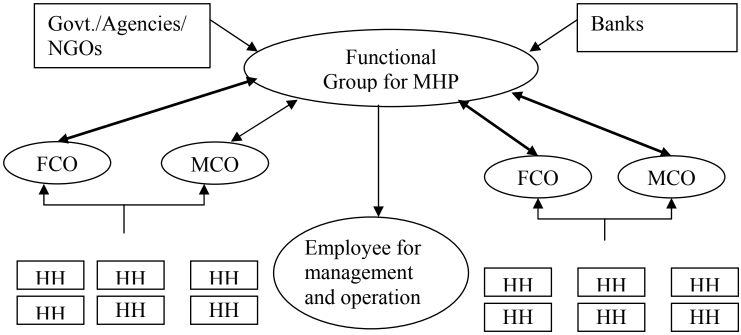


**Figure. 6.4 Structure of management committee in the community owned MHPs**

Source: Adapted from the existing pattern of institutional structure in community owned MHPs in REDP/UNDP program VDCs. (FCO = Female Community Organization, MCO= Male Community Organization, HH = Household)

## 6.7 Discussion and conclusion of the chapter

A project is a tiny unit of the development process. In reality, a development process that brings more social benefits is being implemented. The benefits are being evaluated normally in the monetary terms or, in most of the time, in the anthropocentric aspects only. These anthropocentric benefits, which are satisfying human beings, are termed as utility in economics. In the neo-classical economics, the society is interested in maximizing the weighted sum of utilities across its members; and the utilities depend upon, amongst other variables, consumption level of marketed and non-marketed goods (Hanley et al 1993). If the analysis of a project is limited to market goods and market price alone, then the price for service goods are unlikely to fully reflect their value to the poor people or to the country (e.g. Khennas et al).

Moreover, the facilities or, in the neoclassical sense, utilities gained by the poor from market goods or services sometimes could be more than that gained by the richer member of society, when one looks at satisfaction or utility. On the other side, providing more utility with fewer expenses will have more benefits from a project point of view. From that aspect, a government must support the projects that are helping poor communities because in ‘utils’ (in utility units), the benefits are more from such projects. In the aspect of providing the rural and remote communities of Nepal an access to electricity from MHP, the government will have more benefits even in the utilitarian aspect as outlined in this chapter.

MHP has been analyzed at macro and micro level in this chapter. The analysis has followed the framework developed in Chapter Two and Four. From that perspective, based on the holistic determinism, MHP technology in Nepal promotes sustainability in ecological dimension, social dimension and macro level economic dimension. However, at the project level, the financial sustainability could not be guaranteed if community's willingness and capacity to pay is not enough to sustain the plant financially, although there are also cases, where community has collected money proportionally and paid bank loan from their private capital[222]. It has been done so after realizing the monetary and non-monetary benefits from electricity as compared to kerosene lighting by the people. The micro level economic dimension to be sustainable, the positive externalities of MHP has to be internalized as discussed in previous section and Chapter Five.

The micro level economic analysis (as shown in Table 6.22 in page 213, Table 6.23 in page 214 and Table 6.24 & Table 6.25 in page 216) by including externalities shows that the project is financially sustainable from the perspective of households and community. Even if people take loan at the rate of 14%, the project will be beneficial if externalities calculated in Chapter Five are internalized. It is clear that if externalities are internalized, MHP projects are sustainable financially even with normal interest rate. It clearly shows that MHP are not financially feasible because of existing externalities. In fair conditions, where no externalities are present, the MHP project would be financially viable. Let us discuss a few possible scenarios (will also be discussed in Chapter Seven).

**Condition I**. The kerosene price has been increased by almost 183% since 1990 despite several subsidies (see NOC 2002), whereas tariff of MHP has been increased by 50- 100% since 1987 (see ADB/N 1987 for old tariff). If the current subsidy of Rs. 8 (NOC 2002) to kerosene will be avoided then the household expenses will be increased, at least by Rs. 25.92 (3.24 liter /month x Rs. 8 subsidy) per month and about Rs. 311.04 per year[223]. Then the household spending per year, in the case of Dajungkhola MHP, will be about Rs.

[222] In several community owned MHPs, such examples are found in Tangram of Baglung district, Chimkhola of Myagdi district and several sites in Kavre district.
[223] If household will continue to buy the subsistence amount of kerosene as previously even after subsidy is cut off, then this condition is true.

1708.81 (1397.77 + 311.04). If people pay this amount per year to the micro hydro system, and the condition exists as it is now in Dajungkhola MHP, then the scheme will be financially viable even in the traditional analysis with 8.5% discount rate (see **Annex 6.13).** Similarly, the MHP scheme of Darakhola II of Lulang VDC of Myagdi district will be financially viable if subsidy amount is added to their previous expense for lighting even at the discount rate of 10% (see **Annex 6.13**). Increment of the price of kerosene gradually helps MHP because electricity tariff fixed to sustain the system financially would become cheaper. However, the tariff of MHP has also to be increased gradually as per inflation or change in consumer price.

**Condition II**. If the price of kerosene will be increased more than the current boarder price[224] then automatically viability of MHP will be seen differently. The following analysis shown in the table can be seen in the case of MHP in Dajungkhola. There are two scenario assumed: firstly, with the increment of boarder price the rural people will have to pay equal amount of money to the MHP in addition to what they were paying for MHP, and secondly, if MHP had not been implemented, people would have paid the increment amount additionally to their regular lighting expenses. This is assumed because people are using very subsistence amount (minimum of basic requirement) of kerosene and even if price increases slightly, they will buy the same amount.

The first scenario indicates that if kerosene boarder price is increased by 100% by levying custom duty and MHP users are forced to pay the equal amount that has been increased to MHP tariff, then only MHP, at the present condition, is financially viable, as shown in the table, or if discount rate is decreased at 6.5% then at increment rate of 75%, the project is also viable (see **Annex 6.14** for analysis of more projects based on this condition). In the second scenario, if the villagers would pay the amount of money they were paying for kerosene and dry cells and increment amount of custom duty levying to the boarder price is also added to their expenses, then the project is financially viable even at 25% custom duty at 8.5% discount rate.

[224] Here border price means the price at the custom at the border, for the kerosene in Nov 2002, it was Rs 21.99 per liter (NOC 2002), certainly with negligible amount (Rs. 0.30 per liter) of custom duty. The retail price of kerosene is Rs. 17 per liter in the market (in remote areas transportation is included)

**Table 6.36 Financial indicators of Dajungkhola MHP with fluctuating kerosene price**

| Increment of kerosene boarder price (Rs. 21.99/liter) | Total revenue of MHP system = Revenue collected+ increment price (discount rate 8.5%) | | | Total revenue of MHP system = Expenses before+ increment price (discount rate 8.5%) | | |
|---|---|---|---|---|---|---|
| | NPV | BCR | IRR | NPV | BCR | IRR |
| by 25% | -1,356,837 | 0.7054 | 1.67% | 105,263 | 1.0229 | 8.96% |
| by 32%[225] | -1,207,249 | 0.7379 | 2.54% | 254,850 | 1.0553 | 9.62% |
| by 50% | -822,596 | 0.8214 | 4.60% | 639,503 | 1.1388 | 11.24% |
| by 100% | 244,915 | 1.0532 | 9.57% | 1,707,014 | 1.3706 | 15.49% |

Source: Author

**Condition III.** The impact of inflation of Nepalese currency, which is most likely because of current political situation, would have impacts on MHP cost but more impact on the price of kerosene. Kerosene is imported from India or other foreign countries whose currencies are stable compared to Nepalese currency. So due to the inflation, kerosene would be expensive. Most of the components of MHP are produced locally and in the case of MHP, the local price rise matters. Nevertheless, the local price rise depends also on inflation. However, the inflation is solely of devaluation of money whereas price index is the average of all products available in the markets. Individual component can have higher price index and a few are lower. When looked at the cost of MHP plant between 1998 and 2002 (different sites of REDP schemes), there is no such increment in the cost of MHP and tariff, whereas price of kerosene is increased by almost 50%. So, inflation of Nepalese currency would make kerosene expensive and MHP relatively cheaper. Nevertheless, the price of kerosene in the international markets also influences the boarder price of kerosene in Nepal.

In summary, it could be possible to analyze and quantify the major impacts of MHP in all components of sustainability, if long-term time series data are available. The sustainability analysis approach and its application itself would need more elaboration to include all issues raised. Any project could be analyzed with described methods but acquirement of data could be the hurdle. The biasness in obtaining, analyzing and interpretation could not be ruled out, as “most human structures are, ultimately, embodiments of beliefs and perceptions” (Clayton et al 1996) and “sustainability itself is a human vision that by definition is laced with human values (political and ethical)” (Bell et al 1999:32). With the

[225] 32% is equal to the custom duty levied to MHP imported components, based field study and interview with MHP component manufacturers.

help of short-term data, the analysis tried to justify the methodology and its outcomes. However, there is the space where a lot and accurate analysis could be done in the future. Analyzing a part of a system only cannot be term as a sustainability analysis. Sustainability encompasses all dimensions of a system and any analysis that claims to be in the perspective sustainability must incorporate all dimensions. Therefore, analysis of project with holistic determinism as discussed in Chapter Two and Four, the condition of the projects and their output can be revealed. Based on the output, the best project from the sustainability perspective can be chosen to increase the efficiency of resource allocation. The micro hydro projects in Nepal are satisfying the sustainability conditions laid down in Chapter Two and Four.

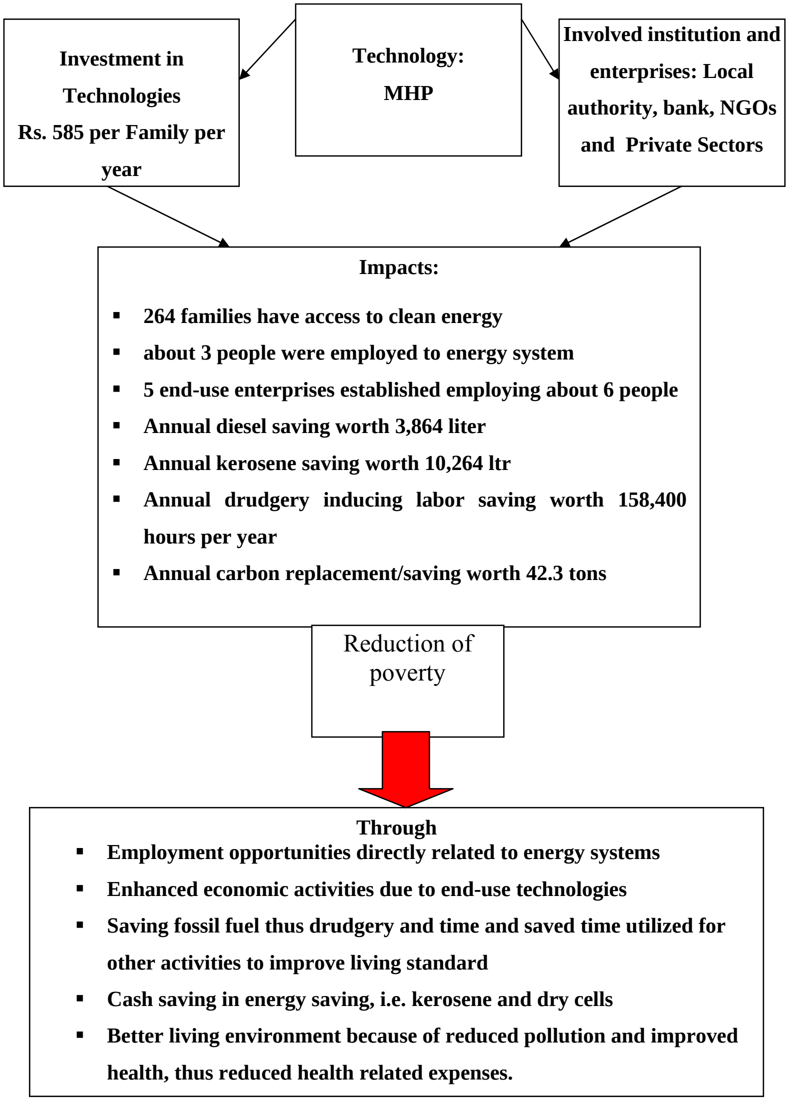


Figure. 6.5 Impacts of Dajungkhola MHP

## Chapter Seven

# A Way Forward: Realizing Sustainable MHP Projects for Promoting Sustainability in the Rural Energy Sector in Nepal

### 7.1 Background

Sustainability has several dimensions and levels as well as ranking. In the previous chapters, the different aspects of rural energy projects, especially of MHP, were discussed and analyzed from the perspective of sustainability. It has also been illustrated that MHP fulfills the sustainability constraints. The issues of externalities in the rural energy sector and comparisons with MHP projects also brought some positive prospects. This chapter shows how far MHP in Nepal can provide the increased socio-ecological as well as economic benefits that are consistent with sustainability, in the future too, to promote sustainability.

Sustainability is not only an economic issue or only an ecological issue. "Sustainable development involves strategies and investments that enhance human resources and technological know-how and remove institutional weaknesses so that the productivity of available resource base is sufficiently augmented" (Dahal et al 1993: 150). So while promoting sustainability of the society or the nation, all factors are to be considered. From the energy development perspective, especially in poor countries like Nepal, socio-ecological constraints are also bound with economic constraints. The large energy systems are costly or need bulk of investment whereas decentralized systems are scattered and scattered resources could be mobilized. Once scattered resources are mobilized for the scattered systems, it relieves the economic burden of the limited financial resources. Therefore, while highlighting the sustainability approach in the MHP sector, decentralization would be one of the prerequisite conditions. That is "because the resources themselves are naturally decentralized, water management and water development must be brought under control of local government and monitored by civil society" (Ahmed et al 1999: 118). The decentralization of decision-making, resource rights and responsibilities are the fundamentals of sustainability.

From the social perspective too, decentralized systems increase harmony and cohesiveness among the beneficiaries as these systems are transparent to the communities. The investment of different nature (cash, kinds and labor) that are needed for the systems can be mobilized locally to some extent. The local investments are not tied with narrow financial profits. "If someone invests in a project in their own community, however, they get a return on their money in many ways besides interest they receive. Indeed, these non-interest returns could be so important that those financing the project would be prepared to charge no interest at all in order to be sure it went ahead" Douthwaite (1999:174). Charging no interest rate means abandoning discounting principle, which is also a controversial issue in sustainability discussions. Such non-interest invests on community projects are also being found in the several community owned MHP projects in Nepal (see Chapter Six).

The decentralized systems, normally, are being neglected in the mainstream economic decision-making because of narrow financial tools, which presumes decentralized systems as expensive in its calculation. Referring to such stereotype decision-making, Hourcade has expressed, "the mechanisms by which financing costs for traditional solutions are assumed raises the propensity to ignore decentralized supply options" (Hourcade 1990:868). The revised tool and method of sustainability analysis that are devised to include several of such issues and factors, has been used in the analysis of sustainability in the previous chapter.

Therefore, in the future prospects of MHP, a decentralized and community owned system would be a reference in the different MHP development scenario. The second assumption is that the community owned system could provide electrical as well as motive power to significant numbers of the hilly and mountain households within the next 20 years. Initially, because of the existing externalities MHP need support from the government in the form of subsidy, which has already been illustrated in previous chapters.

### 7.2 Future scenarios of MHP

The available potential of MHP in Nepal could serve a large part of families living in the hilly and mountain regions. The Copenhagen Declaration in 1995 states that the family has to be focused as a basic unit of society in sustainable development. In this dissertation too, benefits and costs are looked upon from the perspective of family as a unit of sustainable development. In the following scenarios too, all future prospects are discussed and the family is considered as a smaller unit or the basic unit of development.

### 7.2.1 Transportation sector

Till now, the transportation sector is dominated by the fossil fuels in Nepal if one excludes the animated power contributed by the people and animals. The targeted areas where MHP will be developed within the next 20 years will hardly get black topped roads. Till the year 2001, there were only 4,577 km of black topped roads in Nepal (HMG 2001). Most of the road development and extension works are in the plain areas or are only connecting district headquarters. Extension of black topped or even graveled roads to the remote villages will still take a few more decades. The most plausible and real assumption will be to envisage the paved seasonal roads for the rural areas. So using electrical energy for the transportation sector in earthen roads is still premature in these areas. Nevertheless, ropeways could be built if they are economically viable. Except for an isolated case[226] of using ropeway, there still exist no detail economic study and plan to run ropeway in MHP areas in Nepal. The ropeway could be the potential option.

Moreover, if the production technology of hydrogen becomes cheaper and popular within the next 20 years, MHP may contribute to the need of energy in the transport sector replacing imported fossil fuels (e.g. Pokharel 2001). However, such development in the present context of Nepal is still premature and technology transfer from the developed countries needs still a longer time because hydrogen in transport sector is still new to the developed countries, too. The next option will be charging battery and running local small transport vehicles. Nevertheless, it will not take place in the near future because of technical as well as managerial problems. Battery run vehicles are, generally, of small capacity and cannot run in the rough roads. All in all, MHP will not be used in the transport sector within the coming two decades.

### 7.2.2 Agriculture sector

The energy needed for the agriculture sector in the hilly and mountainous areas is for agroprocessing and irrigation. For the processing, i.e. mainly grinding, husking and expelling of the local products, energy from MHP could be sufficient. The production of crops will not be increased drastically because the present crop-producing practice is already an intensive one. The scenario would change but not drastically because of the

[226]A ropeway was built in Barpak, Gorkha district by a private entrepreneur with the financial as well as technical support from ITDG/Nepal and others. However, later after an accident, it is not being operated.

existing soil erosion. The yield[227] cannot increase forever and will either stabilize or reduce because of ecological reasons, i.e. soil erosion, land losses, floods, etc. The quantity that has to be grinded, husked or expelled will more or less remain the same[228]. Therefore, the capacity of agroprocessing mills installed through MHP will be sufficient with 60 MW assuming 15 kW plant can run mills of 8 kW and each mill will run about 8 hours per day[229].

**Table 7.1 Production of crops in the hilly and mountainous areas of Nepal**

| Crops | **Paddy** | **Wheat** | **Maize** | **Millet** | **Barley** | **Oilseed** |
|---|---|---|---|---|---|---|
| Metric Ton (MT)/ Year | 897,890 | 416,600 | 1,031,980 | 270,020 | 35,370 | 23,970 |
| For MHP areas i.e. share of about 36%[230] of HH living in hills and mountains in 2001 | 325,575 | 151,059 | 374,196 | 97,909 | 12,825 | 8,692 |

Source: Compiled from CBS (1999)

**Table 7.2 Agroprocessing energy required to the hills & mountains MHP areas**

| **Procesing methods** | **Husking** | **Grinding** | **Expelling** | **Remarks** |
|---|---|---|---|---|
| Metric Ton/Year | 325,575 | 635,990 | 8,692 | Wheat, maize, millet and barley need grinding, paddy husking and oil expelling |
| Processing capacity of MHP Kg/hr | 420 | 75 | 15 | Mill capacity ca. 8 kW[231] |
| Mills of 8 kW required nos./year | 323 | 3533 | 241 | Assuming 8 hrs/day and 10 months/year operation |
| Capacity required in kW | 4,854 | 52,999 | 3,622 | Assuming minimum of 15 kW plant can run 8 kW mill |

Source: Author (based on data of CBS 1999, ITDG 1997, ADB/N 1987)

227 The yield rate of paddy, wheat, maize, millet, barley and oilseed in the year 1984/85 was 1.96, 1.15, 1.40, 0.86, 0.92, 0.66 MT/Hectare respectively and similarly it was 2.70, 1.81, 1.80, 1.10, 1.10 and 0.70 MT/Hectare respectively in the year 1999/2000 (CBS 2002a).

228 The quantitative change is less than 5% in 15 years (HMG/N 2001) and there were negative changes in wheat, barley and millet. Normally, barley and millet are produced in the hilly and mountainous regions only. Change is population also affects the amount to grinded or husked, however, the deficit amount would be brought in the villages are partially ready-made one, i.e. already husked or grinded. So change in grain amount due to the change in population is neglected.

229 However, not all produced crops will be grinded or husked; some are used without doing so. Moreover, a plant can have different capacities and either can run husking, grinding or expeller only or all together or only two facilities depending upon the site and the community. Grinder may need lower capacity and husker may run by 3-4 kW motor. Therefore, the assumption behind the calculation could not reflect exactly the real situation that can arise but tentatively, the proposed capacity of 60-80 MW would be more than enough.

230 This is about 36% of the households living in the hills and mountains and is equal to 20% of the total households in Nepal based on the population census of 2001.

231 The average capacity of mills is taken as 8 kW in a 15 kW plant, but for husking about 5 kW and for grinder about 3.5 kW and expeller 4 kW could be sufficient (e.g. ICIMOD 1993).

The next sector that needs energy could be the irrigation sector. Until the fiscal year 1999/2000, only 6% and 8% of total cultivated land has the facility of year round irrigation in the hills and mountains respectively. The maximum that could be possible to irrigate is about 67% of the total cultivated land in Nepal and the water resources strategy of HMG/N targets to irrigate 90% of the irrigable land by 2027 (WECS 2002). The remaining land cannot be irrigated through natural flow of water or gravity flow irrigation system. The remaining options will be to use electrical pumps or other pumping devices.

However, in the hills and mountains, there is no data available exactly of how much land could be irrigated with electrical pumps or other means because of the varying altitude of the cultivated land from the water source. It would not be technically feasible to lift the water from sources to irrigate all hilly lands. Only a part of the remaining land could be irrigated through lifted water technically. On the other side, lifted water cannot irrigate paddy fields. Irrigating paddy fields through electricity will not be economical and is not done anywhere in the hills and mountains of Nepal at present. The only technically as well as economically feasible estimates could be to irrigate a part of the non-irrigable lands during the off-season period for off-season products. That could be managed with existing power with proper time scheduling and organized utilization in MHP areas. Moreover, MHP could provide the water from its tailrace for irrigation but not for year round irrigation using electric pumps.

Therefore, from these perspectives, energy from MHP would be sufficient for the selected villagers in the vicinity of MHP areas if they use for off-season irrigation for cash crops only but not for regular crops irrigation like paddy. However, to estimate such a scenario, an in-depth study has to be done.

### 7.2.3 Industrial and commercial sector

In the case of MHP, the industrial sector consumption will have to be promoted on one side through the end-use technologies, while on the other side, there is limited flexibility in supplying energy for the industrial activities. However, looking at the current socio-economic condition of the country, there will hardly be any large increment of industries in the remote areas that are based on electrical power. If any, then such industrial activities will be related to the agriculture sectors. Energy required for the agriculture sector industry, except mills, especially in food processing could be received from other technologies such as biomass and solar thermal if they need heat or thermal energy because electricity will be expensive compared to heat energy from biomass and solar. Therefore, for the major needs of the industry based on agriculture, there will be no shortage of power in the remote villages unless new energy intensive industries come up in more numbers like electric dryer for the herbs, cardamom, and other such local products, etc.

However, there are chances of development of the market centers, which are providing buying & selling facilities to the villagers. These centers may need electricity for small-scale industries and commercial activities. Initially the produced electricity may supply the demand but later that would not be sufficient. Therefore, there will be the need of either local network, which may combine the decentralized systems together so that energy can be supplied needed to the market centers nearby, or other power plants have to be added either from the additional MHP or other resources whichever is feasible or possible. One extra factor is the tourist destinations where energy needs will be higher. In such places, the combined energy resources or "energy mixes" are to be used (see Banskota et al 1987).

### 7.2.4 Domestic or household sector

The primary purpose of MHP in Nepal is to provide electricity for domestic use especially for the domestic lighting, household appliances and agroprocessing especially grinding, husking and expelling. For the domestic use of electricity, there will be two scenarios as explained in the following sections.

**Scenario A: the rate of increment of both the per capita income of the people and the energy price remains the same**

The expenses for lighting energy (kerosene and dry cell battery) will be about 2 - 3% of yearly income of the family. In the background of the current level of per capita income and availability of 'free fuelwood', there would be hardly any use of electricity for cooking in rural areas, in general. The average growth rate of real PCI from 1986 to 1997 was about 2%[232] whereas inflation on consumer price was not less than 7.8 % during the same period[233] (e.g. Dahal 2000, WECS 2002). The real expenses of households on the traditional form of energy is increasing even without an increment in the PCI. A study from the five electrified villages shows that at the present rate of expenses on lighting, is a

[232] "For the period of 1965-90 the average annual growth rate of GNP per capita has been confined to 0.5 percent" (Dahal et al 1993:152)

maximum of Rs. 1,200[234] against the expenses on traditional energy, which is about Rs. 1,543 per year. The current expense on electricity, on the average, is less than 2% of a family's income. Currently, there is no cooking in the villages using electricity from MHP. The present energy consumption pattern of a MHP plant, on the average (average of the four VDC in Myagdi, one in Sindhupalchowk and four in Kavre district), is low. From Table 7.3, it is found that, on the average, the plant's load factor[235] is about 34%. That means only 34% of produced energy has been utilized.

**Table 7.3 Utilization of plant capacity in the community owned MHP plant**

| Activities | Energy use in % of the plant's production capacity |
|---|---|
| For lighting | 22 |
| For agroprocessing and industrial use | 9 |
| For Radio,TV and other home-appliances | 2 |
| Commercial activities | 1 |
| Total | 34 % of plant capacity |

(Source: Author)

If the electricity price increases at the same rate, as that of the inflation rate then there will be no use of electricity in cooking in the future, if PCI does not increase drastically. Therefore, the use of electricity will be mainly for lighting and household appliances in a business as usual scenario. However, there will be a slight increase in the demand of electricity because of the increased household appliances use. Such increase in the demand could be managed through time schedule of energy consumption and energy conservation measures like using CFL. If household consumption in the lighting increases by 2% yearly (equal to the rate of increment of family's income), then only about 33% energy will be consumed by households in the lighting after 20 years. If about 56% increase per year (equal to GDP) in the consumption on household appliances is assumed, then hardly 5% of the total energy produced will be consumed after 20 years.

[233] However, according to HMG/N (2001), the overall consumer price index in FY 2000/2001 was 134.8 compared to base year (in 1995/96 = 100). Similarly, it was 140.6 for the hilly areas in FY 2000/2001.

[234] Most of the community owned MHP systems are subscribing on the average 100 watt per family. The tariff is about Rs. 0.80 to Rs. 1.00 per watt per month. Therefore, the maximum annual expenses will be about Rs. 1200 per family. Nevertheless, in four VDCs of Myagdi district, people are paying lower than that, as discussed in previous chapter.

[235] There is a difference between load factor and plant factor.

The remaining energy will not be utilized largely by the households because they cannot switch to cooking which consumes a large amount of energy. Therefore, the household demand will not increase drastically. The current energy demand could be easily doubled if other activities, that consumed electricity, are enhanced. The remaining energy could be utilized for other uses in the small and cottage industries, social and commercial activities. Such utilization could enhance the economic activities and employment opportunities at the local level. The remaining energy must be utilized for two reasons: for the financial sustainability of the plant itself and to enhance the people's income.

Technically, the future MHP projects are to be implemented by considering on the average 100 watts per rural household. The locally available energy from MHP (assuming 20 - 30 KW range) could be sufficient, if planned and implemented considering 100 watts per household although that would be about 150 watt after 20 years but later energy saving lamps would adjust the increasing demands in lighting. All in all, MHP can fulfill the demand of electricity needed by the rural areas for lighting, agroprocessing and limited number of small - scale cottage industry in remote villages until the next two decades.

**Table 7.4 Utilization of plant capacity in community owned MHP in scenario I**

| Activities | Consumption (in 2005[236]) in % | Growth per year in % consumption[237] | Energy use in % of the plant's production capacity in 2025 |
|---|---|---|---|
| For Lighting | 22 | 2 | 33 |
| For agroprocessing, Industrial use | 9 | 2 | 14 |
| For radio, TV and other home-appliances | 2 | 5 | 6 |
| Commercial activities | 1 | 5 | 3 |
| Total | 34% of plant capacity | | 56% of plant capacity |

Source: Author

[236] Although this is for 2002, in the scenario, development 2005 is assumed as the base year.

[237] The growth in lighting energy consumption is taken as tentatively equal to average GDP per capita growth rate (see **Annex 7.1**). In agroprocessing similar trends are assumed, however there could be, if technically possible, addition of new systems needed for processing, value addition or for other activities. For HH appliances and commercial activities, a realistic growth of 5% is assumed because as per Human Development Report of Nepal (HDR 2001), the economic growth of Nepal during the last 15 years is increased by, on the average, 5% per year. However, the actual growth of energy consumption, because of the increased use of household appliances, cannot be forecasted exactly because of unknown and complex reasons of increased use. Nevertheless, household will increase appliances because of increased income, "modernity and status feeling", "neighbor's envy", etc.

**Scenario B: The per capita income of people will increase at a level that promotes people to use electricity for cooking and other household appliances**

The specific electricity consumption of a family when they use 100 watts connection, like in the community owned MHP, is about 216 KWh per year[238]. For cooking, at least at the rate of 2 hours a day with one 1000 watt cooking appliance, people need about 720 KWh per year[239]. Assuming a small amount of energy consumption in other activities like TV, radio and other household appliances, a family need about 1000 KWh per year (216 kWh for lighting and 720 kWh for cooking and remaining to other minor uses).

From chapter four we know that there is a strong relationship between the electricity consumption and GDP. The average per capita GDP of Nepal is about 1,219 PPP$ and per capita electricity consumption is about 40 kWh per year (WB 2000), that is about 216 KWh per family, which is exactly equivalent to a family's normal consumption in the community owned MHP. To switch towards the use of electrical energy in cooking, the ability of the people to pay must be raised, at least in the economic perspective. Even if we assume that with the increase in income of family, people will spend part of their increased income to energy, the present income of the people must be drastically increased. People may use electrical energy for cooking in the case, fuelwood would be as expensive[240] as electricity and the same rule applies to other energy, too. In that case, the demand of a household will increase almost five times to the current consumption. In such case, either intensive energy conservation measures has to be taken that could partially manage the demand or other options like additional MHP system, solar for lighting only or biogas for cooking etc are to combined.

Nevertheless, the doubling of the per capita income (in terms of GDP) needs at least 15 years if Nepalese will have 5% increase in their PCI per year. Such chances are very meager in the context of the current development scenario of Nepal because since many years, as per Dahal (2000) and WECS (2002), the average PCI of Nepalese is increasing at the rate 2% only with average inflation rate of about 5.37%. Equally, switching to the

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238 Assuming 6 hours of lighting per day.

239 There are also development of low wattage cooking devices, popularly known as "Bijuli Dekchi" but these devices are not used everywhere although such devices could have good future, if socially accepted. Such development may affect the scenario in favor of MHP.

240 Expensive not only in the sense of market price but also time needed for the collection, poor availability and accessibility could hinder the people to use fuelwood on one side and on the other side, people may look at the opportunity cost of fuelwood collection before switching to other energy for cooking. Moreover, the comfort in cooking, "status feeling" or "modern way of living" factor can also drive the people towards the electric cooking, especially use of rice cookers among the cash receiving or comparatively richer families.

electrical energy based cooking, is also hypothetical in the near future, because people in urban areas, who has been using subsidized electricity for few decades[241] still have to switch to electricity for cooking. According to the study carried out by Baskota et al (1997) in a tourist destination in Nepal, only rich lodge owners are using electricity in cooking whereas middle level and lower level lodge owners are still burn fuelwood for cooking. The reasons of switching to electricity by rich lodge owners could be several but noticeable is that the fuelwood in the hilly and mountainous tourist destinations are more expensive than in normal villages or small market centers.

Therefore, the scenario of electrical cooking is difficult to realize and generalize unless proper rural economy and its dynamics are studied. However, the electrical energy for cooking, at least part of their cooking energy can be envisioned among the remittance receiving families or government employees because of “comfort cooking”.

However, as “modernization” of a few families can be expected among the cash or remittance receiving families, it would increase the number of household appliances like refrigerator, TV, video, music systems and need more energy. In such case, even if not all families are expected to do so, energy demand will increase. Such demand could be managed only through time schedule management, “energy mix” and conservation measures and in the extreme case, with additional energy systems or increasing capacity if technically and financially possible. Nevertheless, such fast modernization depends upon the type of community, location of village, trend of existing migration of rich people to urban areas and possible socio-economic progress.

Moreover, MHP has to be combined with family biogas, solar thermal heaters, even solar cookers in high mountains and trekking routes to meet the future demand sustainably. These options are the better solutions than extending the grid to these places for a sustainable energy solution.

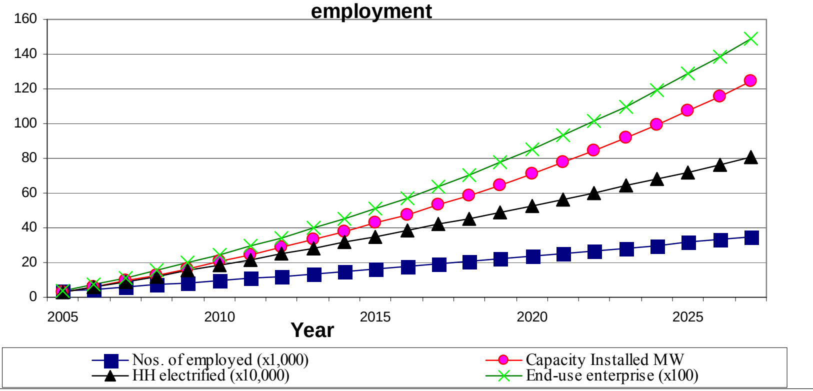
### 7.2.5 Employment

One of the main benefits of MHP in Nepal will be the employment benefit in the local as well as national level. The decentralized job opportunities will have more distributional

[241] However, few families in the urban areas are using only electric rice cookers to cook rice because of “cooking comfort”. One of the reasons of not switching towards the electrical cooking could be cheaper fossil fuel like kerosene and gas. The electricity is said to be subsidized although the tariff is among the highest in Asia (WECS 2002).

effects than centralized one because of enhanced accessibility of more people even in the remote hills and mountains to employment. As most of the existing plants will be of, on the average, 20 - 30 KW[242] and if trends continues in similar size, then about 3,000 new direct employment opportunities would be created every year through the installation of a total of 3 MW MHP projects. And 25% of those getting employment will be engaged in the sector as they are needed for the operation, management and maintenance sector (see Table 6.13 in previous chapter). Therefore, after the year 2025, in the business as usual case, the employment scenario from MHP will be about 31,510 directly in the MHP sector (considering annual productivity about 2%).

**Fig 7. 1 Future scenario of MHP with benefited HH and employment**




Source: Author[243]

From scenario 'A' discussed in the previous section, there is no need of extending grid or other energy supplying systems in the remote and isolated regions of Nepal where potential

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[242] For future implementation of MHP projects, the new potential MHP sites may not be available everywhere. For that, currently existing water turbines could be replaced by stand-alone systems or add-on systems. There are about 900 mechanical water turbines currently existing in Nepal and these could be replaced by stand-alone system when they became disposable or need big overhauling. It is also possible to generate more power than existing system generation after the existing canals and mechanical systems are improved when replacement and overhauling is needed. Moreover, it may not be possible to install all 20-30kW systems but few 10 kW or 60-80 kW could be installed. The bigger system would have more employees, more end-uses and more beneficiary households and the average of small and bigger MHP makes assumption roughly plausible in scenario development.

[243] 10 HH per kW is initially and 2% growth of HH demand per year is equal to growth in PCI, manufacturing and installing capacity of MHP sector's growth is 5% equal to current average GDP growth (see **Annex 7.1**), productivity growth is assumed about 2% and 3 end-use services per MHP plant of 20-25 kW is assumed.

of MHP is available to generate this number of employments in the MHP sector[244]. Assuming, on the average of 25 KW MHP plant and 3 end-use per plant, then about 12,900 end-use services or enterprises will be developed in the rural and remote areas of Nepal by the year 2025 based on business as usual scenario. Moreover, the backward and forward linkages of industrial and commercial activities, other social activities will also have significant employment generation impacts (see Fulford et al 1999). Employment at macro level in the manufacturing sector of electrical component could not be included in the figure but if these products are produced in the country (as most of the components are produced in Nepal at present), the figure must be significant.

#### 7.2.6 Economic benefits and development

The economic benefits and economic development to the nation from the MHP sector come mainly from the following sources:

- revenue collected from the manufacturer,
- salary, tax paid by the people involved in that sector,
- infrastructure development,
- economic activities in industrial as well as commercial sector,
- saved import of fossil fuels and dry cell batteries and
- avoided socio-ecological damages that would have incurred economic costs.

Economic development is achieved through MHP from two aspects: firstly, because of investment in manufacturing and service providing sectors and secondly, from availability of electricity for end-uses, i.e. for small-scale local industries. As discussed in the previous chapter, the growth of invested capital in MHP sector is around 5% annually. This suggests in neo-classical perspective that the MHP industry is expanding. The tentative revenue through tax collected by the government yearly from the MHP manufactures is about Nepali Rupee 7.480 million, which, in some cases, does not include the salary of the owner in the year 2002. This scenario, at least, will continue or increase in the future, if implementation activities go on. Economic development process will also be induced or enhanced in the local villages once technology based small-scale industries are installed in the periphery of MHP plants. Even while considering on the average three to four

[244] Taking the average of the existing plants in four VDCs of Myagdi and one VDC of Sindhupalchowk, four VDCs of Kavre and one in Baglung district, at least four local people are being employment as an employee or became entrepreneur in the end uses sector at each MHP sites and using electricity (**See Annex 6.8**).

enterprises[245] in each site and the capacity of MHP on the average 20 - 30 kW, then there will be at least about 360 - 480 new technology based small-scale enterprises in rural Nepal per year. These enterprises will provide job opportunities, provide better services to the local community and add value on the local products thus enhancing the local economic activities. More importantly, these enterprises are not concentrated in urban areas but in the remote and rural communities of Nepal.

From the perspective of industrial production and its capacity, most of the important components of MHP are locally manufactured and have a good potential for export in some Asian countries. It is reported that Indian manufacturers do not manufacture small turbines and "in India, manufacturers would never be interested in producing turbines below 100 kW, or may be even 500 kW, in capacity" (Rijal 1997b:27). India is dominating the markets of Hindu-Kush Himalayas excluding Chinese territory; if India does not or is not interested in this business, Nepal has, at least, a benefit of not requiring to compete with the giant neighbor. According to few manufacturers[246] , they have exported a few turbines to India and other Asian countries. Despite the good chances of producing and exporting MHP components, one can not discard that there could be chances of import as well if the policy is not made plausible to local producers and several aspects are not brought into effect, i.e. quality improvements, standardization etc.

**Table 7.5 MHP components: locally manufactured and export/imported**

| Locally manufactured | Export potential | Imported |
|---|---|---|
| **Turbine**: propeller, pelton, cross-flow, MPPU, improved *ghatta, peltic* | Cross-flow turbines and small turbine of other types, Peltric sets | Driving systems like belt and bearing |
| Penstock and accessories | - | Couplings and valve |
| Transmission and distribution poles, transformers, cables, other electrical components | - | Switch-gears and insulators |
| Electronic load controller (ELC) | ELC/in some Asian countries | Generators |

Source: Author

[245] based on the numbers of end-uses technology and electricity using enterprises in REDP/UNDP supported and facilitated community owned MHP sites

[246] Kathmandu Metal Industry (KMI), Nepal Yentra Shala Engineering (NYSE), Nepal Machine and Steel Structure (NMSS) and Thapa Engineering Industry (TEI).

The current production capacity of MHP in Nepal is about 3 MW per year[247] (e.g. Rijal 1997a, Rijal 1999, deLucia 1997, Pandey 1994). The maximum capacity of turbine that can be manufactured is of mini hydro level, up to 500 kW. About 300 - 500 Peltric sets can be produced easily with the currently available production facilities in different areas. Excluding these small peltric sets, which is very popular and useful for small community of up to 1 - 35 households, MHP plants with total capacity of more than 100 MW can be manufactured and installed by the local companies during the next twenty years in the business as usual technical scenario, i.e. at the current available technical facility. Such endeavor will enhance the energy and industry infrastructure of the country.

Installation of MHP will save about 390 liters of kerosene per kW per year only for lighting, about 310 pairs of dry-cell battery used for torchlight, radio and cassette players per kW (see details of average kerosene consumed by a HH of rural Nepal in chapter five and six). A significant amount of diesel will be saved by avoiding agroprocessing through diesel mills, running diesel based sawmills. About Rs. 3,120 per year per kW subsidy that is given to kerosene will also be saved. Moreover, Rs. 9,750 equivalent of hard currency will be stopped from drainage in fossil fuel by an installed MHP per year per kW. In addition to that, a significant amount of hard currency drainage could be saved by avoiding the import of dry-cells battery and kerosene. The scenario in 20 years, will show a huge amount of such savings thus enriching economic status of the country, community and individual.

Based on the field experiences, this study and highlights of several studies on MHP and rural electrification (e.g. Rijal 1997a, 1997b, Baskota et al 1997, ICIMOD 1993 and 1998b, ITDG 1997a, WECS 1995, REDP 2000a, Bajracharya 1986, BPC/SADC 1999, Jha 1995), the following macro level advantages can be listed:

- decentralized electricity is the only sustainable option left for isolated communities in Nepal to have required heat, mechanical energy and lighting energy,
- for the balanced development of the country's regions and development of remote and rural centers for different facilities based on energy and power,
- utilization of local resources so that there is no need to buy or import fossil fuels,
- more importantly, for energy security so that there are no impacts due to political conflicts and embargoes on socio-economic life of the country, and

[247] According to the MHP manufacturers, the tentative production, manufacturing and installation capacity is more than 3 MW per year.

- development and utilization of local natural as well as human resources through increased opportunities of employment.

The benefits on avoided costs on socio-economic damages are reduced, health expenses due to marginal reduction in indoor pollution, fire damages due to kerosene and drudgery induced impacts. Sustainability can only be achieved if local environmental, social and economic life is enhanced. MHP in this perspective realizes the dream of “Small is Beautiful”.

### 7.2.7 Reduction of GHG and other pollution

Based on the calculation in previous chapters, about 1.376 tons of CO2 emission will be reduced by one kW per year by MHP in business as usual (BAU) case, i.e. assuming rural people could have used the same amount of kerosene they were using if electricity were not available and MHP is being utilized at about 30 - 35% load factor. Pollution and poisonous gases or substances causing soil and water pollution will be saved after avoiding the use of dry-cell batteries. About 4,128 tons of CO2 emission could be avoided per year if 3 MW of MHP is installed yearly, in BAU case. Moreover, lots of indoor air pollution and GHG that would occur due to the use of dry cell battery could also be saved.

### 7.2.8 Electricity supply, demand and beneficiaries in the national scenario

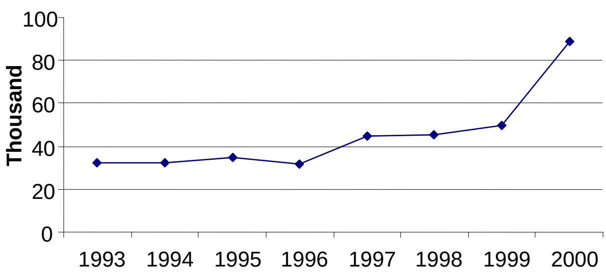
By the end of 2001, there were about 731,990 domestic customers of Nepal Electricity Authority (NEA), a state-owned public sector for the generation, distribution and management of national grid system (NEA 2001) and this figure does not include the MHP customers of decentralized systems or private and community MHP systems. Considering one domestic customer as one household, only about 17.54% of the total households are having access to the electricity from the national grid until the end of 2001. Current installed capacity of MHP of about 6 MW (Stand-alone and add-on electrification system of MHP and peltric sets[248]) is used mainly for rural electrification in Nepal. Considering average subscription rate of 120 Watts[249] per household, about 50,000 household have been getting electricity from MHP, which is about 1.2% of the total households in Nepal and 6.53% of what NEA is providing through the national grid. Taking average HH size of

[248] AEPC 2002, and summing up only up to mid-July 2002 from REDP, RADC and other projects.

5.45 in Nepal (CBS 2002a), about 272,500 people of Nepal are getting electricity from MHP that is about 2.5% of the rural hilly and mountain people in Nepal (the total hilly and mountain population is about 10.9 million in 2001). This is a significant achievement if we compare total investment given to rural electrification based on the grid system to MHP for the same purposes.

NEA's plan to add about 30,000 households into its customer list per year may depend on the development of bigger hydropower plants that would need financial loans or grants for its generation, distribution and transmission networks. NEA has managed to achieve more than its target of adding 30,000 customers per year by adding, on the average, about 45,000 customers per year since 1992 as shown in figure 7.2.

**Figure 7.2 NEA's yearly customer increment**




Source: Compiled from NEA (1998, 2000, 2001)

If NEA's expansion of domestic customer is covering one household per customer, then the current pace of covering 45,000 households per year will need around 66 years to provide the access of electricity to more than 3 million households who do not have electricity[250]. Therefore, with NEA's current pace of extension and even with improved distribution rate it will hardly cover all Nepalese households within next 50 years even if socio-economic situation of the country remains same, which seems unlikely in the existing socio-political situation. The rate of extension will be easier in the plains, valleys and densely populated

[249] By assuming 8 HH per kW because most of the existing plants are not yet been fully utilized and there are also losses. After taking the average of 24 REDP supported community MHP projects, the consumption comes about 105 watts per family based on the installed capacity divided beneficiaries HH. However, our main assumption in scenario building at the beginning (for base year) would be about 100 watt per household.
[250] Neglecting population growth and growth of NEA's capacity in the future.

regions but the rest of the country will have to wait a few decades due to geographic, economic, socio-political as well as ecological reasons if the grid has to be extended.

According to WECS (2002), the target of HMG/N Nepal, until 2027 is to provide 60% of its people with electricity. The population forecasted by WECS (2002) for 2027 is about 38.832 million and 31% will live in urban areas by then. If so, then the remaining 69% are living in the rural areas. That means those who will not have electricity will be 40% of the total population and almost all of them will live in the remote hills and mountains because plain areas will get the grid due to the ease ness in transmission, distribution and dense settlements. In other words, about 58% of the rural people living in the hills and mountains[251] will still have to wait for electricity even after 2027, even if government's optimistic plan are realized (which is very much unlikely because of the socio-economic condition of the country). That means the majority of the rural people will be deprived of this facility even after two decades if the grid extension policy is taken as the future strategy.

Among the alternatives, MHP will be suitable in most of the hilly and mountainous communities; if the current potential of technical capacity of the MHP manufacturing sector would be utilized, then about 3 MW can be installed per year. If one kW serves, on the average, about 10 families in the beginning and family's demand increases by 2%, then about 721,140 families will be served by the year 2025[252]. Considering the family size of 5 people[253] about 3.61 million people will be benefited by 2025. That is about 13.5% of the rural population in the year 2027. The energy ladder (discussed by Thapa et al 2003) indicates such possibilities in a very long period. Certainly, not all population will have access to electricity from MHP because of the site-specific condition but a major part of the rural population would have sufficient electricity from MHP at least for the lighting needs and for end-use technologies needed for day-to-day life. Therefore, MHP can increase the number of people having electricity in the rural areas. Most of the people who will be getting electricity would be from the remote villages. This will provide the people

[251] However, if hydropower plants were built in the hilly and mountain regions, which is true in the case of Nepal, normally the settlements in the vicinity will get electricity connected to their houses and such population endeavor may also increase the nos. of family in hills getting electricity.

[252] About 100 watt per family as per REDP supported projects for the base year 2005 and growth consumption is assumed equivalent to the growth of PCI that is 2% (not the GDP which is about 5%).

[253] The current family size is about 5.45 as per CBS (2002a) which would reduce by then as trends show such scenario.

with the development benefits as well as an opportunity to enhance their livelihoods through electricity.

The people who are getting electricity through MHP are mostly those who would have waited for a few decades. If more number of MHP is installed per year and then a few thousand remote and rural families will get electricity every year. Therefore MHP is indispensable to provide people of hilly and mountain regions with electricity for the balanced development and development of infrastructure that could help them to live better than before.

### 7.3 Implementation modalities of MHP projects

A sustainable project has several dimensions. Accomplishment of sustainability also depends on how a decision to implement a project or a set of developmental activities is made. Referring to decision-making in the governance for sustainability, Adger et al (2003) have highlighted the issue of interdisciplinarism mentioning that any decision making that are concerned with environment and sustainability depend on institutions, scale and context. Such decisions are examined "by paying simultaneous attention to efficiency, effectiveness, equity and legitimacy" (Adger et al 2003: 1098). The decision-making that includes implementation modalities and strategy of a project also influences sustainability of the project. As Panday (1999) mentioned, "concepts do not function in isolation and concept in certain cases can often inhibit ideas together" (Panday 1999: xi - xii). The implementation modalities depend on institutions existing in the country, scale of the project impacts and context of the project being implemented. Now, the question is how future MHP projects in Nepal could be implemented so that they promote sustainability in the best way by incorporating existing issues. The issues of efficiency, effectiveness, equity and legitimacy are the criteria on which modalities in the context of MHP are to be made consistent with sustainability principles.

A country's sustainable energy strategy is satisfying basic human needs by direct allocation of energy resource and creating fair economic comparison between all energy sources. In that context, the sustainable future of MHP, there-by promoting sustainable development, also depends on the country's policy. Helcombe (1995) mentioned that policy and planning directs the poverty alleviation activities and modes of implementation whereas participation is required in implementation, operation and control. Moreover, because of the several political and economic hurdles and bottlenecks, the government cannot distribute the country's existing resources equitably to current as well as the future generations and renewable energy resources are no exceptions. However, the planned or upcoming project's benefits could assist to acquire the goal of benefit distribution if the government's policies are formulated accordingly (e.g. Squire et al 1975). Without equity, the development benefit is not socially efficient and does not fulfill the sustainability constraint. Therefore, the existing policies related to energy and MHP are to be analyzed and modifications are to be suggested to make the macro as well as micro level policies and planning consistent with the objectives of promoting sustainability.

It is often quoted that the rural people are poor, renewable energies are expensive and poverty is hindering the development of renewable energy technologies. Nevertheless, in the context of Nepal, renewable energy technology such as micro hydro would be the solution to alleviate poverty to some extent. Micro hydro development strategy must be integrated with the objective of poverty reduction. As poverty has several dimensions and facets, MHP with holistic approach improves one or the other dimensions and facets of poverty. There have been different objectives and approaches of MHP implementation in Nepal. Therefore, accomplishment of the objectives of poverty reduction will depend on the approach on which MHP is being implemented. In the following paragraphs, a few modalities that could enhance the implementation of MHP projects to promote sustainability in Nepal will be discussed.

### 7.3.1 Financing of MHP projects in Nepal

For the financing of bigger hydropower projects in Nepal, a policy of attracting foreign investors is formulated providing several facilities and benefits (see Hydropower Development Policy of Nepal 1992 and 2001). However, the facilities and benefits in the name of economic efficiency and liberalization alone cannot guarantee the flow of investment, as socio-economic as well as political situation of the country is not in favor, and past policies have not performed well (e.g. Acharya 2000, Sharma et al 2000). "Foreign private capital has not flowed into Nepal despite the sweeping measures taken to attract it" (Acharya 2000:52). The policies that are formulate to have more economic efficiency and economic growth could not perform well because of other non-economical factors. In setting efficiency goal, i.e. operating functions, the ecological as well as social factors are also to be considered. Dominated by dreams of gigantism until now, the simple alternatives of “micro-level development options have received only limited options” (Bandyopadhyay et al 1994:12). Until now, excluding ad-hoc subsidy policy, there is no concrete policy to finance the MHP projects in Nepal. The following paragraphs will discuss some of the financing and incentive providing issues related to MHP projects in Nepal.

#### 7.3.1.1 Incentives, promotion and subsidy

It has been formulated and discussed in previous chapters about the methods of economic analysis for the decentralized energy projects and externalities existing in the rural energy sector. The competing technologies and energy resources are not being equally favored and a few are protected through either regulations or policies. Different technologies and resources are having either positive or negative externalities (benefits or loss). Therefore, to internalize these externalities either an equal level playing field be provided through proper pricing and tax mechanism or those technology or resources, that are bringing more socio-economic and ecological benefits but could not compete in the existing markets, must be supported through proper policies. To support such policies plausible methodologies are to be developed. As Munasinghe (1993) mentioned that the income distribution and other social issues related to the economic analysis are addressed with ad hoc approaches, it would be advantageous to have at least a plausible methodology to incorporate such issues.

From the traditional approach of financial analysis, in the existing conditions of unfair market due to subsidized fossil fuel, hardly a few MHP projects are viable, although many MHP projects could be economically sustainable, if externalities are internalized. To implement such projects to promote sustainability, two approaches would be adopted: firstly, abandoning the biasness and internalizing the externalities in the energy market and secondly, bringing MHP in an equal level playing field by providing justifiable subsidy (e.g. Pokharel 2002). Internalizing the externalities needs strong policy and such policy is not likely to be brought into effect in Nepal in the near future although the eighth five-year development plan (1992 - 1997) of the country has already proposed to include social costs in the energy pricing (NPC 1992). In the long-term, internalizing externalities through policies is the sustainable solution to provide an equal level playing field to all types of energy resources and technologies until market fails to do so. On the other hand, the equal level playing field could be managed through justified subsidies. However, providing ad-hoc subsidy is also a controversial issue because, firstly, sometimes subsidy has been utilized by richer group who may not need such support[254] (e.g. Schramm 1993, WB 1996, Nepal 2000). Secondly, sustainability of such approach is questionable because poor countries are lacking resources to provide continuous subsidies For example for the implementation of 80 MW of MHP projects, Nepal could need about 80 million US$ to provide subsidy at the current rate of about 1,000 $ per kW, which is a huge amount.

However, until externalities are internalized, a justifiable optimum subsidy has to be provided to enhance the sustainability promoting project implementation activities. Subsidy providing policy is mainly of two types: firstly, to support poor people or communities because they cannot pay the full cost of technology. These subsidies are being provided, in general, with the technology that cannot be competitive in the markets[255]. Secondly, subsidy is being provided to the technology, which is not competitive in the market, no matter who gets the subsidy. The technology is not competitive because of market failures or in other words, because of existence of externalities. In the case of MHP in Nepal, subsidy policy would be a combination of both strategies because both issues are existing i.e. poor communities and externalities. That is why among the rationales to provide such incentives or subsidy, in the case of decentralized electrification system that enhances the living standard of the people, the following two approaches could be adopted:

- Social development (equity issues) approach:
    - Based on differences in the human development index and
    - Based on capability to pay and price from sustainable energy system.
- Economic approach:
    - internalization of existing externalities and
    - providing an equal level playing field to all technologies.

#### 7.3.1.1.1 Human development index and expenses on lighting

The Human Development Index (HDI) could be taken as a base to formulate incentives or subsidy approaches. HDI approach has also been discussed in chapter four with justifiable reasons. The Table 7.6 (page 262) and Table 7.7 (page 264) are justifying the consideration

[254] If the subsidy is only meant for the support of poor people's access to energy technology but not for the technology and for the market correction.

[255] However, sometimes to reduce the burden on the poor people, subsidy is also provided like subsidy in water pumps, subsidy in kerosene used for rural lighting, etc.

of HDI in providing facility to the rural poor under the cover of distribution of development benefits[256]. Considering the example of the Okharbot village in Myagdi District, the HDI is calculated 0.300. This value is lower than the national average HDI. The expense on lighting (for kerosene and battery) is about 3 - 3.5% of yearly income of a family, which is more than the national average. Had the 'monetary value' of fuelwood and other resources needed for other energy consumption included, the expenses on energy would have been more. There is no strong causal relationship between average per capita income and average kerosene expenses as people are using for the subsistence level. The fuel price is different in different places and depends on the remoteness of the villages. However, the richer group in the community uses relatively more kerosene than the poor family. The relation between HDI and expenses for lighting could have some causal relationship although it is minor (also see Koirala 2001). That means if the lighting energy would be made available at a cheaper rate, the living standard of the people in remote villages can be improved through saving on expenses. Moreover, to reduce the disparity among the people it can be balanced to some extend if HDI is brought to the same level through development activities, which are to be supported through subsidies, etc.

**Table 7.6 Per capita income, HDI and lighting expenses[257]**

| VDC in Myagdi District | Adult education | Combined enrolment | Income PPP $ | % of National average PPP | Lighting expenses in Rs | % of PCI of family used for lighting | HDI |
|---|---|---|---|---|---|---|---|
| Okharbot | 7.49% | 40.80% | 779.12 | 67.93% | 1,397.77 | 3 | 0.300 |
| Marang | 0.14% | 7.20% | 699.66 | 61.00% | 1,608 | 3.5 | 0.221 |
| Lulang | 6.28% | 26.40% | 640.05 | 55.80% | 1,567.68 | 3.4 | 0.256 |
| *Average of three villages* | | | *706.28* | *61.58%* | *1,524.48* | *3.2* | *0.259* |
| *National* | *39.2%* | *61%* | *1,219* | - | *1,543.18* | *2.0* | *0.471* |

Source: Author (based on UNDP 2002, DDC Myagdi (n.d.))

[256] Because in the hills and mountains households are spending 23 to 29% of their yearly income for non-food consumption (CBS 2002c) and three villages in Myagdi spending about 3.5% of their yearly income only for lighting energy. Comparing their income and expenses for lighting energy and non-food items, then they are spending more than 10% of non-food expense only for the lighting energy, which could be higher even if we compare with developed countries.

According to the consumption survey of CBS (2002c), a significant part of non-food consumption of households goes to the energy needed only for lighting. The average non-food consumption is about 23 to 30 percent of total consumption and households' consumption for lighting is about 3 to 3.5% of the total income. The total consumption and per capita income is around the same because the majority of rural people are living at the subsistence level. Therefore, if the household expenses in lighting could be reduced there would be relief to the poor and rural households. Moreover, to reduce the disparity among the people, the rural people must be supported with some incentives. The HDI of Okharbot VDC in Myagdi district is 36.13% less than the HDI of the national average. Therefore, the project that would enhance this indicator could be entitled to get at least about 36.13% subsidies if the project is not financially bearable to the people of the region.

From the perspective of social equity, which covers basic need and distribution factor, the Human Development Index and energy tariff calculated as per traditional project analysis methods have to be considered in the project analysis. Human Development Index of Nepal, according to UNDP (2002) is 0.471. The MHP project in Okharbot VDC, which is for the betterment of the living conditions of the people, should be supported looking at the HDI of the local people. Electricity helps people to manage for better learning environment, adult education, reduces the smoke of kerosene and induces people to make house clean because of brighter light of the electricity. So, evening adult education, longer hours of learning for the children, reduced health problems[258] and increased opportunity for income generating activities are the benefits that could enhance the HDI value of the local people. According to Goldemberg (1996) and Rijal (1997) too, there exist the causal relationship between energy use and HDI. So MHP project could be supported taking HDI of the people as a reference as well as other factors that are having causal relationship with amount as well as types of the energy (electricity) uses.

[257] The national average consumption in lighting is based on ten villages from the middle, western, and far-western regions of Nepal. At least 10 HH to maximum of 200 HH from each village were asked for their expenses and consumption in REDP/UNDP programme VDCs and lighting consumption includes dry cell battery and kerosene, which is possible to replace with electricity. The data for the calculations are also taken from DDC/Myagdi and questionnaires collected through DDC/REDS Myagdi and national data are from CBS (1999), CBS (2002a), UNDP (2000)).

[258] Before the project, there were more than 10% people suffering from bronchitis in Okharbot VDC where Dajungkhola MHP has been implemented. One of the reasons of higher level of Bronchitis could be the smoke of kerosene although there is no long time series study after the project

#### 7.3.1.1.2 Capacity to pay and price of sustainable energy system

The traditional financial analysis[259] of the MHP project of Dajungkhola in Okharbot VDC in Myagdi, by excluding local voluntary contribution of the people[260], shows that each household must pay Rs. 2,037.30 per year for the financial sustainability of the project. This is about 45.63% more than what people were paying previously for kerosene and dry cells. The sustainable resources, from the financial perspective are not competitive compared to traditional resources because of the imperfect market conditions. Due to existing lower paying capacity, people cannot afford electricity at the price obtained from traditional analysis. The lower paying capacity is because of the poverty. Poverty is caused by existing inequity and inequalities in distribution of resources and opportunities (e.g. UNDP 2002). To enhance the capacity to pay, initially, some incentives are to be provided for the basic social needs. Therefore, difference in the price of energy for lighting before and after MHP justifies the subsidy because people are to be provided basic lighting from sustainable resources.

**Table 7.7 Average HH expenses on lighting before and after MHP/year**

| Amount paid for lighting before MHP (Kerosene & Battery) in NRs. (a) | Actual amount paid for lighting after MHP in NRs. (b) | Amount needed to pay as per pure financial analysis subtracting subsidies in NRs. (c ) | Amount to be paid from traditional financial analysis without any subsidies in NRs. (d) |
|---|---|---|---|
| 1,398.96 | 756.73 | 1,380.82 | 2,320.23[261] |
| Factor comparing lighting energy expenses before[262] | 0.5409 (b/a) | 0.9870 (c/a) | 1.6585 (d/a) |

Source: Author (based on MHP of Okharbot VDC of Myagdi District in Nepal)

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[259] Interest rate 16% and discount rate at 12%, as used in Nepal for MHP analysis.

[260] If the community's voluntary contribution is included into the cost of project then the investment will be about NRs. 3,720,422, and each HH has to pay about Rs 2,365.50 per year. If we assume subsidy of 50% each HH has to pay Rs. 1,414,77 per year to make project financially sustainable (see **Annex 6.15** the traditional financial analysis of Dajungkhola MHP). However, HH is paying only Rs. 756.73 per year. On the average Rs. 756.73 could be the current willingness to pay of the HH although they had paid, on the average, more (Rs. 1,398.96 per year) than previously. Using the consideration that has been brought up in Chapter Four there is also some justification. The traditional financial analysis without subsidy shows that each HH must pay Rs. 2,365.50 per year that is again about 69.09% higher than what people were paying previously.

[261] This amount is about 5% of PCI of an average Family in Nepal.

[262] In practice, while calculating and selecting the conductors for transmission and distribution, if transmission loss is more than 17% then that type of conductor is rejected and alternative is chosen. Assuming as per general practices in Nepal, households will use all energy except assumed 17% losses in transmission on watt basis, however that could not be the case in the reality. The tariff from the traditional financial analysis would be higher if current consumption amount (that is less than 83%) in watt is taken. It is also assumed that after MHP the use of kerosene and dry-cell battery is abandoned and the total cost of the project excludes the local voluntary contribution

#### 7.3.1.2 Internalization of existing externalities in the rural energy sector

As discussed in Chapter Five, there exist externalities in the rural energy sector in Nepal. Looking at the currently used energy technologies and resources for the lighting, household appliances and small-scale industries, MHP has positive externalities whereas kerosene has negative externalities. To internalize these positive externalities either the market has to be leveled equally or positive externalities have to be accounted. As externalities have not been internalized, the positive externalities of MHP must be accounted in policy and subsidy policy will be the easiest way of doing it until externalities are internalized. Politically, at policy level and even from social aspects taxing fossil fuel exactly equal to peculiar externalities will be difficult. The internalization of externalities is the market approach of bringing 'equity issues[263]' of technology and resources into the pricing mechanism. Nevertheless, from the perspective of externalities, MHP project should also get the subsidy equal to the externalities it internalizes if implemented (as discussed in chapter five). Moreover, from the social equity aspects too, MHP serves the poor and remote community. From the externalities perspective, the following scenarios can be seen in the future:

(1) The government does not internalize the pecuniary externalities but provides subsidy on ad hoc basis to RETs,
(2) The government internalizes the pecuniary externalities of fossil fuels but does not provide subsidy and
(3) The government neither provides subsidy nor internalizes the pecuniary externalities.

(1) If the government does not internalizes the pecuniary externalities, however continues to provide subsidy to renewable energy technologies, then there will be lack of resources and needs external grants or loan as the country without foreign aid cannot sustain such expenses (see also **Annex 7.2**) and will be forced to change the subsidy policy. In the past because of changing subsidy policy, the development of MHP was discouraging (e.g. Junejo 1997, DeLucia et al 1997). This scenario does not support the long-term development of MHP and other renewable energy technologies. However, because of the social equity issue that drives the idea of providing facilities to the remote people, the government would continue to provide some sorts of subsidy, but in a limited

[263] In other words, it is providing equal level playing environment to all technology.

quota system as before 1999[264] because of lack of funds. RADC is the example of such an endeavor in Nepal (see **Annex 3.2**).

(2) The second scenario would be that the government internalizes the pecuniary externalities of fossil fuels but does not provide subsidy to RETs. In this case, in the long term, accessible areas, economically interesting areas like tourist destinations or routes, herbs processing areas, market centers will get electricity from MHP or other renewable technologies because fossil fuel will be expensive. However, the remote and poor areas where there are no market potentials of electricity (that is low load factor in technical sense), no individual can manage to invest money and no external private entrepreneur will go there to invest. Community alone may not be able to mobilize all the investment needed. In the energy sector, especially in rural areas, "…it is unlikely that the market mechanism can supply what is needed" (Barnett 1992: 332). Even internalizing externalities is not sufficient because "policies to deregulate markets and get 'price right' ignores the poor. Even the best functioning energy market will not reach those who cannot pay" (Nakicenovic et al 1998:246). Internalizing the externalities would also not serve the remote and rural poor because of lack of investment capital in the beginning. On the other side, internalization of externalities through tax system, in general, is unjust to the remote poor people because they are not using fossil fuel beyond the carrying capacity of the local ecology (e.g. Bhattacharyya 1996). However, internalization policy induces them to switch towards RETs. Therefore, the government has to provide a part of the investment capital as a subsidy from the social equity aspect to the people.

(3) The third scenario will not enhance the development of MHP or renewable energy until fossil fuels are expensive because of several reasons, i.e. shortage in supply, etc. Becoming aware of ecology and environment and investing in renewable technologies like MHP, in the context of Nepal, still takes a few decades. Therefore, this scenario is not supporting MHP development. However, modernization, status feeling factor among the rich community can persuade the people to implement MHP without looking at any narrow financial benefits or supports from the outside. A few cases are also there in Nepal.

264 There were limited quota systems in SHS and MHP subsidy programme.

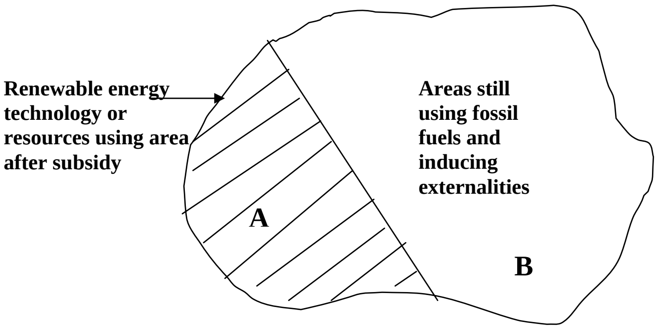


Figure. 7.3 Process of internalizing externalities and abandoning subsidies

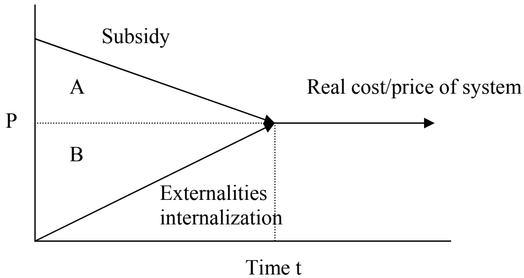


Figure 7.4 Process of internalizing externalities and abandoning subsidies

Internalization of externalities at a point of time is not possible. This is a gradual process. Looking at the figure 7.3, ‘A’ and ‘B’ together represent the “period” of rural energy development process in Nepal where externalities are making energy market unfair. In the beginning, the government has to provide subsidy up to the area ‘A’ gradually and let internalize the externalities partially in the area ‘B’ (area means not physical areas but could be a part of technology or part of target group or duration of a period). This has to be done because government cannot internalize externalities and or provide subsidy at a point of time. If externalities, especially pecuniary one, be internalized area ‘B’ will suffer as an alternative will not be available immediately. When there will be an appropriate ratio between ‘A’ and ‘B’ then the government can internalize the externalities through available means or policies. Once externalities will be internalized, subsidy policy can be abandoned that is given in the area ‘A’. The price of the energy will be a real price at P as shown in figure 7.4.

### 7.3.1.3 Mobilization of resources locally to implement the MHP projects

Most of the MHP projects in Nepal are generally analyzed financially before they are being implemented (e.g. ITDG 1997, AEPC/ESAP 2001). The analyses are adopting purely traditional approach. Once projects are viable financially, investments are allocated. Nevertheless, the lack of financial resources puts very hard constraint on developing countries to look for the best alternatives. Energy and power supplying projects are heavily depending on foreign loans or aids. Such aids are taken for the infrastructure development and other activities. Nevertheless, the question is how such investments or financial resources are allocated on one side and on the other side, how the sustainable financing modalities are to be adopted or formulated so that investment needed could be mobilized locally reducing the debt burden and other impacts.

Therefore, for the project to be implemented sustainably from the economic as well as financial perspective too, participatory investment is needed[265]. The participatory investment provides the collective community ownership and attention of all stakeholders to maintain the system without being an altruistic social worker. The development of infrastructure needed for the day-to-day life of the people is being maintained sustainably if such infrastructures are built through participation from the beginning. The good examples are well functioning irrigational canals, which are constructed and managed by people themselves in Nepal (e.g. Joshi et al 2000, WECS 2002). Success behind the community forestry is also a good example. Electricity is necessary to all, every household is eager to have electricity connected. By developing a modality that enables and convinces the rural families to invest partially in the system, a large amount of local resources could be mobilized.

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[265]. A possible modality of participative investment: MHP potential that is needed for 800,000 families of Nepalese mountains and hills is, at current level considering 100 watts per family, about 80,000 kW. Investment needed assuming current tentative cost of Rs 125,000/kW (including local voluntary cost, although it could be lower or higher than this, see **Annex 1.1**), about NRs. 9,000 million or €112.5 million is needed. If 50% subsidy is to be provided then about NRs 4,500 million or € 56.25 million is needed. If each household invests the amount of money equal to their expenses for kerosene and battery in five years (from a survey in 10 villages in Nepal, on the average about NRs. 1,543 are being paid by each household per year for kerosene and dry cell batteries) to the MHP project initially then NRs. 6,172 million local resources could be mobilized. Considering the example of MHP of Okharbot VDC, where Rs. 585.00 would have to be invested by a family per year until 20 years, if investment is not discounted and Rs. 1,061.82 if discounted at 6.5% more than the average inflation rate (5.37%) of the country. It is important to mention here that the households who are getting electricity through national grid have to pay initially, at least Rs. 2,200 as a connection charge. Excluding other expenses like administrative, training and other soft work the investment needed can be mobilized locally provided that an appropriate ownership mechanism is implemented (see also Enzensburger et al 2003, for the financing of renewable energy projects in Germany via closed end funds.).

In the micro level or in the remote areas or villages, hardly any investment will be expected from outside as MHP projects may not bring financial profits as expected by a private entrepreneur. It is also not certain that the private local entrepreneurs are available everywhere to invest their own capital in MHP projects alone. At least 2.1 million US $ per year is needed as investment with current investment cost and subsidy rate to implement 3 MW of MHP every year. Theoretically, for a household that is using only 100 watts connection, the initial investment will be about US$ 70 with the current level of subsidy of US $ 1,000 per kW, and about US $ 170[266] without subsidy.

As foreign donation declining and share of loan is increasing in the country's development plan, providing subsidy would not be continue. Getting financial aid is possible only in the name of rural development (*but not guaranteed*!) and is being done because through participatory approach of investment and ownership, MHP could be linked with several other rural development activities. Once foreign aid is invested into the decentralized systems of a community owned MHP, there would be no vicious cycle of debt burden and pressure to oblige external guidelines against the interest of own people as in the bigger power plants implemented with loan (e.g. Bhadra 2002). That is because, in small scale decentralized system higher percentages of utilization is possible on one side, on the other side, while such aid mostly come as a donation or help. Not only cash but also financing mechanisms of donors like "Food for Work" is more effective in some cases where intensive labor force is required.

None of the MHP projects installed after the nineties is owned by the government in Nepal but by the communities or private entrepreneurs. This indicates that there is a willingness to invest on MHP from local resources. Hydropower Development Policy (2001) of Nepal has also proposed to create a rural electrification development fund for the development of MHP and rural electrification. The fund will be generated from the royalty received from bigger hydropower and could be utilized for RETs for poverty reduction. However, due to the ever-changing policies - sometimes on ad-hoc basis - the objectives of MHP implementation programs are also different. Sometimes it is for poverty reduction, regional equity and productive demand (DANIDA/HMG 2000) and sometimes it is for the

[266] Considering tentative cost of US$ 1,700 per kW of investment, as most of the REDP project's total cost including voluntary labor, on the average, comes around to this figure (average per kW cost is Rs. 108,115 without voluntary cost, assuming 20% voluntary cost and exchange rate of US$ 1 equal to Rs. 75 (CBS 2002a), then the total cost comes around US$ 1685). Operation and maintenance will be paid by collected revenue.

enhancement of rural livelihoods based on holistic approach (REDP 2000a). However, with the holistic approach of MHP development, mobilization of local investment is more sustainable and realizable.

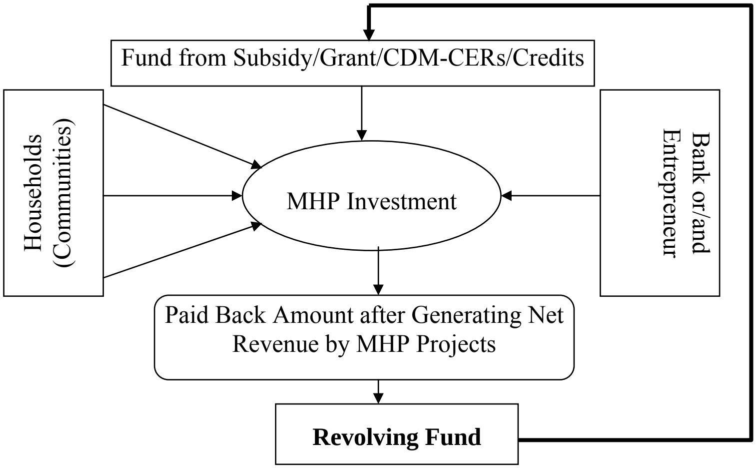


Figure 7.5: Financing mechanism of community owned MHP

Other modalities of financing MHP projects could by creating a revolving fund. As Nepal received frequent development aid (like Global Environment Fund (GEF), from WB, etc.) for the renewable energy sector development, a fund could be created to finance the successive MHP projects. Communities or entrepreneurs take soft loan credits and later will return the credit partly or completely to that fund to finance future projects..

Therefore, the modality as shown in figure 7.5 could be adopted in the case of community owned systems. If the investment amount would not be sufficient even after the contribution of the community members' investment and grant from government or organizations then a third source has to be found. A bank loan or/and involvement of an entrepreneur as a partner of the community is to be envisaged. Taking the average investment cost of 24 community owned MHP that are being implemented between 1998 to 2001, each family, on the average, has to invest about Rs 11,323 to have access to electricity from MHP and contribute voluntary labor, which is, on the average, about 15% of their investment depending upon the sites (e.g. REDP 2002). That means without subsidy and without voluntary labor contribution, a family has to invest, depending on the site about 154 - 176 US$ or 12 - 14% of average income of a family in a year[267]. In this perspective, if decentralized modalities and community ownership approach is adopted, MHP could easily be financed by the local community members and the government can relieve their burden through subsidy or grants. However, not all communities of remote villages can invest that much amount initially at once.

### 7.3.2 MHP as a CDM project

The third session of the Conference of the Parties (COP) to the UN Framework Convention on Climate Change (UNFCCC) has put forward a protocol in December 1997, known as the Kyoto Protocol, to limit and reduce the GHG emission in order to promote sustainable development. Under the Article 12 of Kyoto Protocol, a provision of emission trading between developed countries as mentioned in Annex I[268] of the Protocol and Non-Annex I developing countries is proposed. The aim of the emission trading mechanism, known as Clean Development Mechanism (CDM), is to assist the parties in Annex I to achieve the compliance with their quantified emission limitation and reduction commitments under Article 3 and assist non-Annex I developing countries to achieve sustainable development as well as contribution to the objective of the convention.

As **Annex 7.2** illustrates that the foreign aid is decreasing in Nepal, the CDM would be one of the possibilities of getting financial support to the renewable energy technologies investment and transferring new technologies from developed countries. The CDM will create markets for certified emission reduction units (CERs) which are to be obtained by implementing the CDM registered projects in developing countries either by developing countries themselves or by entities of developed countries. The condition of CDM is that the projects would not have been viable if they had not been registered as the CDM projects, on one side, on the other side, they must reduce the emission compared to the business as usual projects. However, it is still to be seen how far poor developing countries will be benefiting by selling carbons in the competitive international market.

As mentioned in decision 21/CP[269].8 ANNEX II of UNFCCC (2002) for simplified modalities and procedures for small–scale clean development mechanism project activities,

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[267] Considering average PCI of Nepalese US$ 236 per year and family size 5.45 (CBS 2002a).
[268] Annex I is the list of countries mentioned in the Annex B of Kyoto Protocol plus Turkey and Belarus.
[269] Conference of Parties.

renewable energy project activities with a maximum output capacity equivalent to up to 15 megawatts (or an appropriate equivalent) are to be defined as CDM projects. These projects should reduce the anthropogenic emissions of greenhouse gases by sources below those (baseline) that would have occurred in the absence of the registered CDM projects activities. A baseline shall cover emissions from all gases, sectors and source categories within the project boundary. As per Executive Board (EB) “the definition of maximum output is defined “output” as installed/rated capacity, as indicated by the manufacturer of the equipment or plant, disregarding the actual load factor of the plant”. However, the conflicting issue is about baseline and 15 MW capacity. It is still not clear whether carbon reduction by 15 MW small - scale projects is handled as done by bigger power project and CERs are issued only based on carbon reduction. If CERs are issued only based on carbon reduction then the benefit of categorizing small-scale is only the reduction of transaction costs and short CERs issuing process. Unfortunately, the small-scale renewable energy projects would not be benefiting as compared to low cost alternatives like energy efficiency improvement projects (e.g. Shrestha et al 2002). Additionally, looking at the volume of CO2e reduced, it is hard to say that categorizing ‘small-scale project’ benefits renewable energy. One has to look at the economic scale. Nevertheless, for poor countries it is still useful if value of CERs is attractive in the international market.

Micro hydro projects in Nepal, in this regard, could be brought under the CDM projects because several MHPs in the existing conditions are not financially viable and however, in the absence of MHP in rural areas consumption of kerosene, diesel and dry cells will be continuously increasing. As discussed in previous chapters, one electric bulb could reduce about 0.0964 ton of CO2e every year if a family gets access to electricity from MHP (dry cell is neglected in the calculation). The methodologies suggested by UNFCCC for small-scale CDM project activities are not exactly suitable in the Nepalese MHP context because of two reasons: firstly, electricity from MHP is consumed in wattage (in power unit) and charged according to connected wattage and secondly, electricity replaces not only fossil fuels but also a significant amount of dry cells. So the following methodology to calculate the avoided amount of CO2e could be suggested:

*CO2e avoided by RET = (Nos. of Bulbs could be used in the system x CO2e emitted by a kerosene lamp in a year) + (Nos. of HH x average CO2e avoided in end-use technologies/HH) + (Nos. of HH x CO2e emitted by a HH because of dry cells in a year)*

In most of the MHP projects, normally one bulb is of 25 watt and there are, theoretically, about 40 bulbs in one kW installed capacity. From the study of sites in Myagdi district and Sindhupalchowk district, tentative CO2e avoided in end-use technologies is about 0.041 ton per year per HH and one bulb replaces one kerosene lamp avoiding about 0.0964 ton of CO2e per year. Considering an ideal site of 20 kW MHP, the following figure could be obtained:

CO2e avoided = (20 kW x 40 * 0.0964) + (200* 0.041) + (200 * 0.005[270] * 31) ≈ 100 tons/ year of CO2e will be avoided by 20 kW MHP plant[271].

However, as per Fritsche (1990), in the calculation of CO2e emission of MHP, about 5,000 hours of operation per year is to be considered (after subtracting operation, maintenance and idle period). If we consider this data then 20 kW of MHP will also avoid only about 100 tons of CO2e per year[272]. Accepting this figure, if Nepal implements 3 MW of MHP projects per year the CO2e avoided is : 3,000 * 5,000 * 0.0009[273] = 13,500 tons.

If CERs are obtained at the rate of US$ 3.5[274] per ton per year then about 21% of the investment needed could be mobilized through CDM if CERs are paid initially and the project life is assumed 20 years[275]. However, the avoidance cost of CO2e due to the implementation of renewable energy technologies depends on several factors and considerations[276]. One kW of MHP, on the average, avoids about one ton of CO2e per year, if we take the existing practices and figures. It does not include the CO2e figure that would have been emitted by fossil fuels if households replace one bulb with one kerosene

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270 Assuming that one pair of dry cell emits about 5 kg of CO2E.
271 If default value of distribution losses is assumed as 20% (e.g. UNFCC 2003), then the reduction would be nearly about 81 tons/year.
272 However, in a small decentralized community system, the connections are on watt basis and losses are neglected while charging the bills.
273 The IPCC default value is 0.9 kg CO2e/kWh (or 0.0009 ton CO2e/kWh), which is derived from diesel generation units (see UNFCC 2003).
274 Jotzo and Michaelowa (2002) estimated the value of CERs at US$ 3.78 per ton of CO2E including all transaction costs. Chen (2003) has considered about 1US$/tC for CDM whereas Jotzo and Michaelowa themselves assume about 0.75US$/tCO2e.
275 CDM project's baseline is valid up to maximum of 21 years only.
276 The marginal cost of CO2e emission with zero rate of pure time preference and equity consideration was calculated to be 260 US$ minimum by Azar and Sterner (1996). Similarly, as per Sims et al (2003), the cost of alternative mitigation technologies in the power generation sector, compared to gas fired combined cycle gas turbine (CCGT) power station and the potential reductions in carbon (C) emissions to 2010 and 2020 for non-Annex I countries for hydro, is about 66-400 US$/t of C avoided. In the case of Nepal, as per Pokharel et al 2003, the real CO2e avoidance cost of renewable energy technology is ranging from NRs. 1,187 for biogas to NRs. 8,543 for solar PV per ton of GHG emission, and similarly, the CO2e avoidance cost through MHP projects is about NRs. 1,777 and one US $ is equivalent to NRs. 75 in October 2003.

lamp and for the same duration. The households, those who were using one lamp, are using more than one bulb in the project implemented areas (also see **Annex 6.18**).

#### 7.3.2.1 Possibilities of getting MHP as CDM project

The requirement to be a CDM project host country will be fulfilled by Nepal after signing the Kyoto protocol, establishing designated national authority (DNA)[277] and obligating the criteria put forwarded by Marrakesh Accord. On the other side, the major criteria of CDM project would be fulfilled by MHP because of their poor financial viability in the BAU case. From the perspective of market of CDM[278], as per Jotzo and Michaelowa (2002), the global market of CDM non- sink project is about 305 Mt CO2e per year and 29 Mt will be shared by Asian countries excluding China, India and Indonesia. Whereas Chen (2003) estimates about 70 - 160 MtC (*not CO2e*!) of CDM market with USA participation in the Protocol. Similarly, Zhang et al (2001) has estimated about 132 - 358 MtC of CDM market in 2010 and only 13.41% of this would be available for poor least developing countries. According to Shrestha et al (2002), China can design energy efficiency improvement CDM projects of about 12,000 million tons of CO2e mitigation at lower cost; similarly, India can also attract CERs for nearly about 900 million tons CO2e only in energy efficiency projects. In these backgrounds, if Nepal, despite this competitive market, could manage to mobilize CERs for maximum of 1 Mt CO2e per year[279]. at the market rate, then the amount would be plausible for additional financial investment needed for RETs in Nepal.

**Table 7.8 CDM/CERs value needed for the projects to be financially feasible**

| Scheme | Plant capacity kW | CO2e reduction ton/Year | Current revenue Rs./Year | Current expenditure Rs./Year | **CERs in US$** (1 US $ = Rs.75**)**) | |
|---|---|---|---|---|---|---|
| | | | | | at 5.37% discount rate | at 12% discount rate |
| Darakhola I | 50 | 225.0 | 331,560 | 190,200 | 10.71 | 13.55 |
| Bagarkhola | 35 | 157.5 | 243,090 | 144,389 | 11.30 | 14.05 |
| Darakhola II | 25 | 112.5 | 186,684 | 120,420 | 15.34 | 18.34 |
| Dajungkhola | 30 | 135.0 | 235,776 | 154,335 | 11.35 | 14.00 |

Source: Author

[277] Nepal currently does not have a parliament, signing of protocol is uncertain

[278] Speculations and modeling of CDM market is enormous in literature. However, what will happen in reality, from the perspective of poor country is not know. Policies of UNFCC are based on liberalized markets, i.e. rules of demand and supply through cost effectiveness. In addition to the risk of grasping the CDM markets by the countries like China, India, Brazil, Indonesia, etc. there is also an additional risk of successful R & D of CO2 injection (see also UNDP 2004). If the cost of injection comes down making that is profitable, then a developed country will have economic benefits of doing that because of job creation for example. So, CDM market for a poor country is still too far.

[279] Unit of a CER is equal to one metric ton of CO2e-equivalent,

The currently propagated international rate of CER of US$ 3.5/ton will not be sufficient to make most of the MHP projects financially feasible, considering the examples as shown in table 7.8 (previous page)[280]. For the existing cases, the minimum value of CER is US$ 10.71 - 15.34/ton of CO2e, taking discount rate equal to the average inflation rate of Nepal. If discount rate equal to normal practices in Nepal is taken, the value of CERs should be about US$13.55 - 18.34/ton of CO2e to make MHP projects viable in the real existing conditions of revenue and expenses scenario of the projects.

**Table 7.9 Sensitivity analysis with different scenarios and CDM/CERs values**

| VDC | Scheme | CO2 Reduction ton/year | Tariff Rs./ watt/ month | % of energy consumed in End-uses | Value of CER US $ | NPV (Rs) | BCR | IRR% |
|---|---|---|---|---|---|---|---|---|
| ***With 5.37% discount factor equal to average inflation in Nepal (1998-2003)*** | | | | | | | | |
| Muna | Darakhola I | 225.0 | 1.00 | 10 | 3.50 | 1,449,112 | 1.20 | 8.45 |
| Chimkhola | Bagarkhola | 157.5 | 1.00 | 10 | 3.50 | 550,967 | 1.10 | 7.03 |
| Lulang | Darakhola II | 112.5 | 1.00 | 10 | 3.50 | 18,046 | 0.89 | 3.41 |
| Okharbot | Dajungkhola | 135.0 | 1.00 | 10 | 3.50 | 113,703 | 1.02 | 5.79 |
| Hypothetical scheme of 20 kW with average cost of Rs. 125,000/kW (including local voluntary costs, other condition remains as in the real sites) –case I | | 90.0 | 1.00 | 10 | 3.50 | - 1,030,791 | 0.77 | 0.01 |
| | | 90.0 | ***1.25*** | 10 | 3.50 | - 450,935 | 0.91 | 3.19 |
| | | 90.0 | 1.00 | ***15*** | 3.50 | - 701,602 | 0.84 | 1.88 |
| | | 90.0 | 1.00 | 10 | ***11.55*** | 574 | 1.00 | 5.37 |
| | | 90.0 | ***1.25*** | ***15*** | ***4.45*** | 6,374 | 1.00 | 5.40 |
| Considering average cost as in Annex 1.1 (ca. Rs.108030/kw)- case II | | 90.0 | 1.00 | 10 | ***7.55*** | 4,993 | 1.00 | 5.40 |
| | | 90.0 | ***1.25*** | 10 | 3.50 | 65,964 | 1.02 | 5.73 |
| | | 90.0 | 1.00 | **18** | 3.50 | 12,820 | 1.00 | 5.44 |
| ***With 12% discount factor equal to normal practice in Nepal, other conditions remain same*** | | | | | | | | |
| Muna | Darakhola I | 225.0 | 1.0 | 10 | ***5.90*** | 20,017 | 1.0 | 12.05 |
| Chimkhola | Bagarkhola | 157.5 | 1.0 | 10 | ***7.50*** | 25,000 | 1.0 | 12.09 |
| Lulang | Darakhola II | 112.5 | 1.0 | 10 | ***12.32*** | 1,363 | 1.0 | 12.01 |
| Okharbot | Dajungkhola | 135.0 | 1.0 | 10 | ***8.50*** | 12,312 | 1.0 | 12.02 |
| Hypothetical I | | 90.0 | 1.0 | 10 | ***15.55*** | 5,498 | 1.0 | 2.03 |
| Hypothetical II | | 90.0 | 1.0 | 10 | ***11.75*** | 11,880 | 1.0 | 12.07 |

Source: Author

[280] In the case of CERs, one US $ is taken equal to NRs. 75. The CERs value has to be paid to the project to add in their project revenue yearly taking into account the equivalent rate of discount, which is used for projects' financial analysis, i.e. revenue of CERs in Nepalese currency must be added to cash flow adding discounted value (for n year the revenue paid to the project must be (CER value per year x $(1+\text{discount rate})^{n-1}$)). Although the payment of CERs has different modalities as per Marrakesh accord. However, due to the inflation of Nepali currency, normally, the entity in developed country would not be in negative position because the project's financial analysis has been done in Nepalese currency.

Nevertheless, if families of community connect the 80% of power generated in lighting paying Rs. 1.00/watt/month and utilize 10% of energy generated[281] in end-uses and pay equal to the national grid tariff for rural cottage industry then the scenario will be different. The projects are generally sustainable, in this case, if we take discount rate of 5.37%, equivalent to average inflation of the country. However, when the discount rate is increased to 12%, then the values of CER have to be increased to more than US$ 5.9 to make projects financially feasible. The scenario is shown in Table 7.9 (previous page).

Considering a hypothetical case, taking average data from the study of several sites (see **Annex in 1.1**), the scenario also shows the same patterns. Therefore, from the above figures, it is clear that the projects are not financially viable with the value of CERs of US$ 3.5, in the current scenario. However, if the discount rate is lowered at equal to the inflation rate (that means providing the loan for investment at that rate) and with the conditions of at least minimum power utilization, the projects would be feasible. The tariff of electricity is also to be increased to make project sustainable (see Table 7.10) and load factor has also to be increased. However, not in all projects the load factor can be increased immediately, this is a slow process and depends on the community and the nature of site.

**Table 7.10 Increment of electricity tariff to make project feasible**

| ***Village*** | ***Scheme*** | ***CO2 avoided*** | ***% of energy used for end-uses*** | **Tariff (in Rs./watt /month) needed to make scheme viable at CER 3.5 $ and 12% discount rate** |
|---|---|---|---|---|
| Muna | Darakhola I | 225.0 | 10 | 1.20 |
| Chimkhola | Bagarkhola | 157.5 | 10 | 1.33 |
| Lulang | Darakhola II | 112.5 | 10 | 1.78 |
| Okharbot | Dajungkhola | 135.0 | 10 | 1.42 |
| Hypothetical case I | | 90.0 | 10 | 2.01 |
| Hypothetical case II | | 90.0 | 10 | 1.69 |

Source: Author

However, the scenario would be favourable once tariff of electricity is increased by the community. All in all, to make MHP projects financially viable through CDM CERs, the

[281] The power generated is calculated for 5,000 hours per year (i.e. 208.33 days in a year), as per Fritsch et al (1990), considering all losses and breakdowns. AEPC/Nepal has put the condition for subsidy to MHP that 10% energy must be utilized in end-uses, at least to be mentioned in the proposal while applying for subsidy.

value of CERs must be higher than the propagated rate, tariff of electricity must be increased at least at the rate of inflation. Nepal can, theoretically, wait if in the future the value of CERs will be increased, to sell its carbon. If the value of CERs becomes higher than currently propagated then the MHP projects could be designed as CDM projects.

#### 7.3.2.2 Implementing MHP as the CDM projects

MHP projects are of below 100 kW, to register them as CDM projects, several MHP would have to be bundled. Not only MHPs but also biogas projects could be bundled with MHP because in many cases biogas is the complementary technology of MHP. The entities in Annex –I countries may not be interested to deal with small projects of few kW or few nos. of biogas plants. For this case an instrument with a comprehensive mechanism in developing countries is needed which is responsible for the bundling of the projects and deal with entities in developed nations. In case of Nepal, the following modalities would be useful. However, to reduce the transaction cost of the process, a decentralized independent authority capable of bundling such RET projects could be given direct access to deal with the entities in developed nations to get an optimum value of CERs.

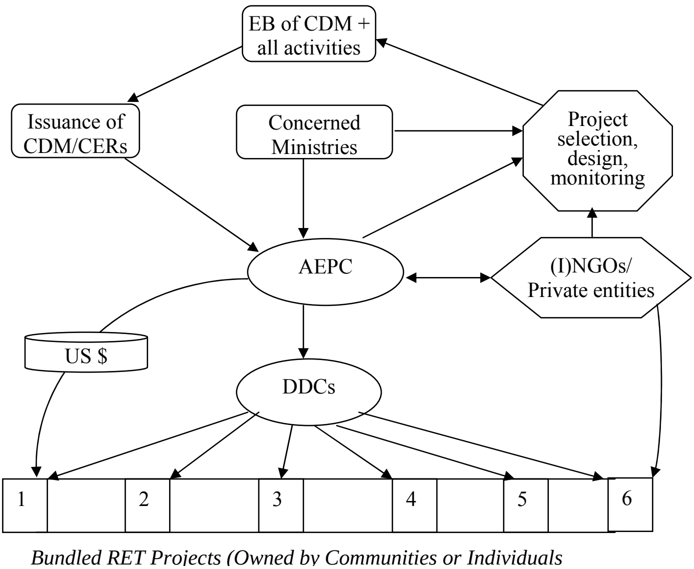


Figure 7.6 CDM mechanisms within Nepalese context

However, only through propagated value (US $ 3.5) of CERs, MHP projects are not financially viable at present scenario. Table 7.11 shows that the traditional financial indicators are not drastically improved to make the projects financially sustainable. Therefore, the propagated value of CER at the rate of US $ 3.5 per ton is not attractive for the Nepalese MHP sector. That is why Nepal must wait until market value of CERs increases. However, government can invest its own resources in the beginning to acquire CERs and can sell later on at higher price. Such possibilities would be high once the USA and other developed countries sign the Kyoto Protocol.

Even if people pay what they were paying for fossil fuels before MHP projects were implemented, the projects are not financially feasible at lower CERs. Table 7.12 shows that the financial indicators are improved slightly.

**Table 7.11 Financial indicators of few MHPs after CDM/CERs**

| Scheme | Investment Cost Rs. ('000) | Discount rate | Without subsidy | | | With CDM/CERs @ US $ 3.5 | | |
|---|---|---|---|---|---|---|---|---|
| | | | NPV | BCR | IRR | NPV | BCR | IRR |
| Dajungkhola/ Okharbot | 3,088.73 | 12% | -2,525,230 | 0.40 | -6.03% | -1,847,601 | 0.56 | 2.51% |
| Bagarkhola/ Chimkhola | 3,700.66 | 12% | -2,963,415 | 0.38 | -5.36% | -2,225,134 | 0.53 | 2.42% |
| Darakhola II/ Lulang | 3,256.94 | 12% | -2,761,924 | 0.34 | -7.37% | -2,234,640 | 0.46 | 0.47% |
| Darakhola I/ Muna | 5,137.03 | 12% | -4,081,143 | 0.38 | -5.12% | -3,026,456 | 0.54 | 2.68% |

Source: Author

**Table 7.12 Financial indicators of few MHPs after CDM/CERs (If people pay what they were paying)**

| Scheme | Expenses of a family Rs./yr before MHP | With CDM/CERs @ US $ 3.5 & 12% discount rate | | | | | |
|---|---|---|---|---|---|---|---|
| | | In real scenario of revenue & expenses | | | If people pay what they were paying before | | |
| | | NPV | BCR | IRR | NPV | BCR | IRR |
| Dajungkhola/ Okharbot | 1,398 | -1,847,601 | 0.56 | 2.51% | - 583,507 | 0.86 | 9.21% |
| Darakhola II/ Lulang | 1,568 | -2,234,640 | 0.46 | 0.47% | - 363,494 | 0.91 | 10.33% |

Source: Author

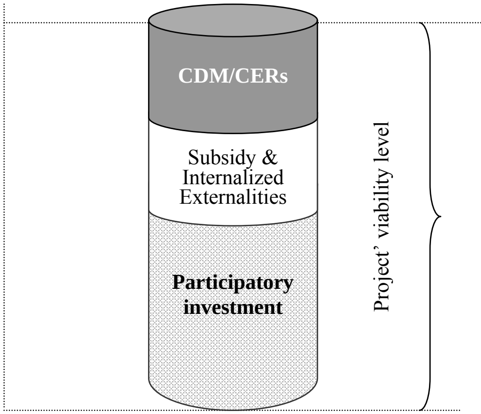


Figure 7.7 Project's resource mobilization and its sharing.

Therefore, current implementation of MHP may not be based on CERs as a part of investment. However, the first task would be to internalize the pecuniary externalities, implement the project, and accumulate the CERs. Later on, these CERs could be sold at higher value when demand increases. The following figure shows the modalities of investment cost mobilizations to implement the MHP projects in Nepal. The CDM/CERs portion of investment can be done by the government to stockpile the CERs for future sell when the market value is appropriate.

The figure 7.7 can be interpreted as

Investment required to a RET Project = [Local investment + Subsidy] (***Non CDM/CER investment*** ) + [CDM/CERs]

Provided that, the project is not financially viable with *non CDM/CER* investment and CDM/CER is needed as a financial "additionality".

Dutschke et al (2003) and Zhang et al (2001) have discussed about few possibilities of providing oversees development aid (ODA) and other funds to CDM projects without diversion as envisaged by the Marrakesh accord. In case of MHP in Nepal, this is also possible if Annex-I countries will not reduce ODA fund. Figure 7.7 shows that only through CDM/CERs RET projects could not be financially sustainable. As per Kyoto

Protocol, "*the purpose of the clean development mechanism shall be to assist Parties not included in Annex I in achieving sustainable development*". Sustainable development incorporates various objectives. So providing CERs based only on competitive market value, the projects in poor developing countries can not be implemented although such projects can have multifaceted impacts as illustrated in Chapter Six. So while providing CERs to such multifaceted projects (those bringing more social benefits) in least developing countries, a priority has to be given. Otherwise, CDM projects based on additionality criteria only, hinder the sustainable development (e.g. Shrestha et al 2002).

Table 7.13 shows that if a subsidy is added to the MHP project's investment as illustrated by figure 7.7 (see previous page), the projects are feasible. The "additionality" criteria required for the CDM projects could be fulfilled. After including participatory investment and subsidy, a part is left to be financed by the CERs values. In this case, the projects are financially sustainable even if discount rate is taken at 12% (see Table 7.13). So, subsidy could be provided for the part of investment after getting CERs, so that sustainable development could be achieved. Otherwise, CERs value should be increased to a level of "*solidarity value*" (*higher value to support poor nations based on quota*), so that with the solidarity of Annex I countries, poor countries can get higher value for CERs and develop renewable energy projects for sustainable development. In developing and poor countries, incentives of CERs (*giving solidarity value*) should also be seen as a means of both to support carbon emission reduction and support equity or distribution aspects of development aid.

**Table 7.13 Financial indicators of few MHPs after CDM/CERs and Subsidy**

| Scheme | Expenses before MHP Rs/HH./year | Subsidy in non local cost | With CDM/CERs @ US$ 3.5 and discount rate 12% | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | If people pay as before | | | In real scenario of expenses | | |
| | | | *NPV* | *BCR* | *IRR* | *NPV* | *BCR* | *IRR* |
| Dajungkhola/ Okharbot | 1,398 | 21% | *26,141* | *1.01* | *12.15%* | -1,198,967 | 0.67 | 4.64% |
| Darakhola II/Lulang | 1,568 | 12% | *27,946* | *1.01* | *12.14%* | -1,843,807 | 0.51 | 1.51% |

Source: Author

### 7.3.3 Institutional modalities

"Strengthening the ability of local communities and groups with common concerns to develop their own organizations and resources" was the commitment of the Copenhagen Declaration on Social Development in 1995 and UNFCCC for sustainable development. Institutions have different scales depending on the scope of development activities and context. For Adger et al (2003), the institutional arrangements, which are arguably capable of protecting the legitimate rights and interests of local actors within a larger governance structure aimed at addressing higher scale environmental problems, are capable to govern sustainability taking legitimate decisions. A macro level institution can formulate policies and guidelines whereas micro level institutions are responsible for implementation and monitoring. Decentralized institution can also formulate policies in line with the macro level policy without confliction in a broader sense. Nevertheless, the micro level institution must be flexible to adopt sustainability constraints in their context.

The Nepalese experiences especially of irrigation systems have shown that the community-managed systems are working better than authority managed irrigation systems (e.g. Joshi et al 2000, WECS 2002). The MHP projects are closely linked with the community managed irrigation systems because both of them are interlinked and most of the times both are using combined canal or water sources. According to Joshi et al (2000), Nepal has more than 20,000 irrigation systems managed by the communities of farmers. There were also more than 7,041 forest user groups in Nepal in 1998 which increased to 8,877 in 1999 and 9,930 in the year 2000 (CBS 1999, CBS 2002b ). These user groups are managing community forest better than the government authority. Therefore, the grass-root level institutions can manage energy matters once rights of decision-making and authority to implement the energy projects are given. The local level institutions could be sustainable like community irrigation and forestry systems in Nepal. Nonetheless, influencing, lobbying and providing feedback to formulate appropriate policies at macro level is the additional task of micro level institutions.

It is important to note that in the remote and easily inaccessible areas the common infrastructures or public facilities are to be implemented by the community's own institutions so that operation and maintenance cost will be lower and any benefits earned will be invested locally making system sustainable. In this regard, the rights to implement and control the water, energy, irrigation, education, etc., social and infrastructural development works be given to local institution that are established through people's participations. Moreover, looking at the communities living in the hilly regions of Nepal, and from the experiences of a few implemented projects, the community approach seems more suitable to have better linkage with all local political, institutional and social components.

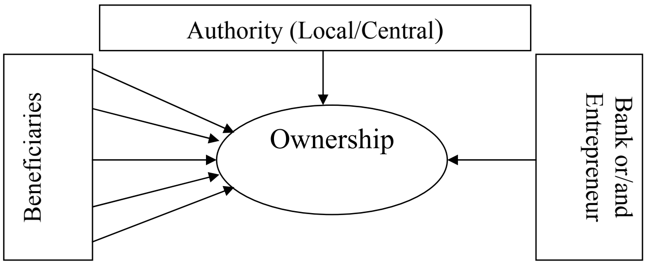


Figure 7.8 Ownership and institution modalities in MHP projects

### 7.3.4 Ownership

The question of ownership has been raised in several sustainability discussions including WCED (1987). From the sustainability perspective, it has been proposed that the resources should belong to the communities because communities have to have the right to decide, protect and use their belongings. Many discussions on property rights and sustainability brought several opinions. Pezzey (1992) opined that traditional organizations existing at the community level have managed resources sustainably. Enhancing such organizations wherever it exists and replicating the concepts at the different levels, (i.e. regional or national level) can help in achieving sustainability, especially in the aspect of resource utilization. Providing access to the technology and development activities, thus enhancing equity in opportunity, can also reduce the intra-generational gap in all aspects of development at the micro level.

The decentralized institutions, which are handled by several communities making them busy, creative and owning the system as well. The ideas and creations would be versatile and independent in vulnerability. When one system fails, others may still work. Similarly, when one owner creates one idea, another may bring different visions. "Since a local unsustainability cannot cancel local sustainability elsewhere, a sustainable world would consist of a number of territories, each of which would be sustainable independently of others" (Douthwaite (1999: 171). With the ownership at local communities, the developed technology systems could be adapted locally and will be brought up by individual community management style that is sustainable from the community's perspectives. A MHP in the eastern hills of Nepal would be managed differently than that of western hills but both would be sustainable. Later, even if one community in the eastern region fails, it would try to replicate the ideas from the western region adapting in its specificities. This will be the sustainable way of owning the systems. So, if community members own the MHP system in the name of community, through their own investment, the system would be sustainable as compared to that managed by the central government undertaking with stereotype bureaucracy and top-down inflexible rules. The main hurdle and bottleneck is that the centralized lobby does not loosen the grip blaming the grass-root community of being incapable and inefficient. Although the vision of sustainability in the social aspect is to enhance the capability of individual, society or nation to have equal access and opportunity to the developmental activities.

On the ownership aspects, most of the MHPs in Nepal are owned by either individual or community (co-operative type). The type of ownership depends upon the community, supporting donors' approach and potential or existing conflicts on water right issues. A private owner may get obstruction from the community if water had been used for multiple purposes. The water resource policy of HMG Nepal (1992), clause 7, has placed hydroelectricity on the fourth priority and it is clearly mentioned in sub-clause 2 that any disputes on water should be solved as per given priority. This clearly indicates that a private ownership on community water resources may get many hassles from community members. The community ownership has managed water resources even for multiple uses like drinking, irrigation and power generation[282] on consensus. Therefore, developing MHP through private entrepreneurship or community owned "co-operative" type enterprise solely depends upon the type of site, community and water resource use potential.

Which ownership modality is better - the answer depends upon the site and its specificities as well as the objectives of implementation. The national public utility - NEA has also realized that the community-based organizations will be the sustainable partners in rural electrification. Since mid 2003, a community organization can buy electricity in bulk, sell it to the community households, and take all responsibilities of financial, operation and maintenance of such systems of electricity distribution in their community (see NEA 2003b). Ownership also depends on the objectives of implementation of MHP, i.e. for social equity, regional equity and basic needs or for more economic activities, more end-uses or industrial as well as commercial activities. However, the community owned systems approach promotes the sustainability in several facets as discussed in previous chapters.

Community choices and individual choices differ in the preference because an individual, if given the choices, would try to cut down all trees from the community forest for his own benefit, whereas a community realizes that cutting the community forests increases the chances of washing out the village by landslides. Then the individual would therefore act and decide differently from the perspective of the community (e.g. Douthwaite 1999). In community activities, rules are consistent with local living styles, not biased, not short sighted and not marginalized as compared to a centralized system of decision-making. If communities are given the rights to decide, these vulnerabilities are also taken into consideration. For O'Riordan, "sustainable development ought to mean the creation of a society and an economy that can come to terms with the life support limits of the planet in a way that enables the most vulnerable people to survive with dignity in a self reliant manner" (O'Riordan (1998: 97).

### 7.3.5 End-use development

On the aspect of utilization of power, basically, there are two approaches on which MHP has been or could be developed: firstly, for the fulfillment of basic needs, i.e. electricity for lighting and mechanical power that is needed for the agroprocessing for subsistence farmers; secondly, in addition to the first objective, the development of electricity supply as a catalyst for the rural development, thereby enhancement of non-farm activities, cottage industries, tourism etc. The first objective may be looked at differently and given different consideration in the analysis than the second one because the first objective could be considered as the social development issue required for living in the rural and remote

[282] A best example is in Pakhu village of Arman VDC in Myagdi district. In this village, about 82 HH are having electricity, irrigation and drinking water from the same stream of a nearby village

areas. It may induce the spin-off effects thus bringing more backward community and society forward and into the mainstream of the development process.

The second case could only need equal level playing opportunities and “priming pump” like incentives and can be financially sustainable after economic activities are enhanced. Nevertheless, the second objective may bring more economic activity if such potential exists. From the second objective, more economic returns to the system can be expected. However, the end-use development objective comes under both the objectives to bring more benefits to the community members. As Cecelski (1996) mentioned the following regarding rural electrification:

> *" So far electricity, to have a real development impact, either access to electricity has to reach further down the income scale to lower income levels; or electricity must be used for more end uses, especially those that relate to basic needs and productivity; and /or these uses of electricity must have some special role in leveraging other development somehow" (Cecelski 1996: 11)*

Rural electrification schemes or systems have low load factor because electricity is used mainly for evening lighting (e.g. Pearce 1987, Munasinghe 1990, Schramm 1993). The low load factor is also the problem in the case of decentralized systems, as daytime use is negligible. To increase load factor, daytime energy has to be utilized for the beneficial activities. In the case of MHP of 20 - 30 KW system, there are also technical restrictions to use end-use technologies[283].

The load factor of a MHP is very low because of low utilization in the daytime[284]. Using power for other purposes than lighting only may increase the load factor and thus the revenue collected. Demand of energy, for a short duration, is already constant, as villagers have subscribed fixed nos. of bulbs. Except evening lighting, in addition to radio and cassette player that need very low amount of energy, there is no use of energy especially at

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[283] An electrical motor needs higher power to start than given power rating of motor. That means existing capacity of plant in kW does not mean that electrical motor of nearly same power can be driven by the system. Normally, nearly 50% more power than rated power is needed to start electrical motor. However, if geographically suitable site is available, end-use equipment that need mechanical power can be directly coupled to the shaft of turbine through driving system thereby providing the possibilities of utilizing more shaft power. Moreover, end-use activities that need thermal heat or electrical lights can be used to optimize the use of power. Nevertheless, such possibilities are not always realizable because of technical as well as non-technical factors.

[284] The load factor of MHP is found to be around 0.30 - 0.35 in the four MHP plants in Myagdi district of Nepal.

the household level. Nevertheless, this scenario could be different in the future as experiences show that the people with external remittances would like to have ironing, cooking with rice-cooker, color TV etc. Such scenario will change the demand scenario. However, initially the demand is more or less fixed. So to generate more revenue in one side and on the other side to utilize produced power for other socio-economic goals the end-use technologies are to be extended.

End-use approaches and technology should be of different types[285] to utilize maximum power so that the load factor can be increased. An increased load factor has two benefits: firstly, financial recovery of system would be enhanced through increased revenue; secondly, utilized energy in end-uses could create employments and enhance the income of the entrepreneurs. From sustainability aspect, both impacts are important because they will enhance local livelihoods. More use of power to run small-scale machines would reduce the drudgery in food processing and agriculture related manual works, like grinding, husking, etc. Secondly, local products could be processed locally thus increasing the value of their products in the market and reduction of drudgery in transporting unprocessed products to the market centers, which are sometimes far from the villages. Moreover, there are also cases where the local products are not being utilized properly because of lack of energy and technology[286]. Such products could be processed to gain more income of the local people by utilizing locally produced resources and preventing resource drain from the region. However, there are several hurdles in developing end-use technologies because of lack of markets, ability to buy products or competition from other products that are produced in mass and injected into the rural areas. Nevertheless, opportunities are also there once power is available.

The demand of electricity and development of end-uses also depends on the people's income. From the field study, the Nepalese rural households could be divided into three types of consumers as generally available in the rural areas of Nepal as shown in Figure

[285] Not only to drive mechanical power through motor but also thermal heat consuming end-uses like bakery, electricity consuming enterprises like small-scale chicken farm, etc. Moreover, timing of running motor can also be optimized by allocating time to such systems.

[286] In Arman VDC of Myagdi district, there is a local production of tomato for seed. About 15 tonnes of tomato are used to extract seeds. The rest of the tomatos, i.e. juice after extracting seeds are simply thrown. If some technology is introduced to convert this juice into tomato products like tomato ketchup, etc, the import of tomato ketchup in nearby market could be avoided, The market is about 20 minutes away from the village where tomato ketchup from India are imported. More interesting is that this market center is 4 hours walk from nearest bus station and ketchup are transported either by human labor or by mules.

7.9 (see **Annex 6.3** also). When one looks at the poverty alleviation through the development of rural energy systems, one has to concentrate especially on group I so that the benefits of electricity will be utilized by all. The group I is paying tariff with financial burden but once his/her import of some food stuffs (like vegetable, milk, meat, eggs, etc) will be produced by himself making partially self sufficient, his/her burden of tariff payment will reduce. His/her expenses on electricity can be earned through the savings on these small-scale products like eggs, chicken, goat meat, etc. which were imported through the household expenditure. This only needs a small-intervention simultaneously with the electrification, asking and making people aware of these benefits and giving short trainings and orientations.

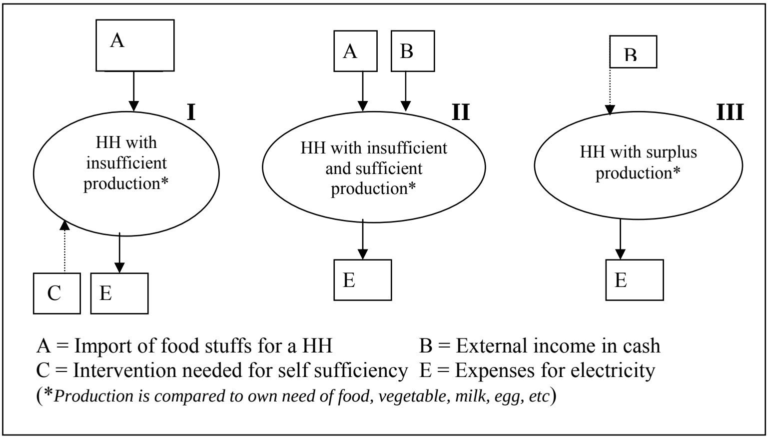


Figure. 7.9 Classification of households and their income status in rural Nepal

Source: Author

The group II and III can be promoted as an entrepreneur to utilize daytime electricity to have productive end-uses or processes. They have the capital and can take risks to start enterprises by utilizing electricity. The group II is the highest energy-consuming group because of cash income. They are government employees, or school teachers or (I)NGO employees, or foreign remittance or pension receivers. They also have more energy consuming appliances like radios, TVs, cassette players and similar things and some times rice cookers as well. The group III is self-sufficient farmers and producing enough for their use and using their products for other expenses also by selling surplus foodstuffs. Within this group, a few may have cash income as well but such families are less in numbers (*See **Annex 6.3** for details from a village*). This group can be the potential suppliers of the local inputs for the value addition business.

Therefore, in case of community owned systems, development of end-use technologies depend upon socio-economic structures, geographical location of sites (remoteness or tourist spots, etc) and local production (see ITDG/SBBP 1995). However, the introduction of electricity via community system also impel the community to utilize electricity to make the system sustainable.

### 7.3.6 Technological development and back-up services

The rural and renewable energy system must be (e.g. Hourcade 1990, Huacuz 1995):

- less capital intensive,
- give priority to short and medium term needs of poor,
- offer some degree of flexibility in the face of unexpected changes in the demand, condition of sites, etc.,
- easy to adopt, operate and maintain and
- standardized to fit accessories available in the market.

These are the main issues while developing the decentralized system for rural people. MHP, the locally developed technology in Nepal since a long-time, offers some of the above-mentioned advantages but still more has to be done for the betterment of the system. Development of cheaper means of controlling the electrical load system, treatment of locally available wooden poles locally for a longer life, increasing the efficiency, quality and reliability of the turbine and its components and introducing the low cost technology in canal construction are the areas of future technological development and research in MHP systems. Moreover, more focus has to be given to develop end-use technologies especially meant for MHP in rural areas that are portable, simple in maintenance and need low start load. The end-use technologies should be focused on the processing or value addition to the rural products and drudgery reducing activities that are to be borne by women and children. Such technologies could be popular in the villages.

For the sustainability of the system, developing only technology does not mean that job is done. The back-up services provided constitute more than half of its share in sustainability of the system. Technological back-up facilities are in the rise in Nepal. MHP could be sustainable only when cheaper and faster back-up supports are available. Technical training to the people within the community and nearby market centers is useful as done by the REDP/UNDP. Such targeted people are to be selected considering their personal interest, social background (as few ethnic groups are having their traditional occupation in the related fields) and sustainability of their future profession in that sector. Such back-up service providing people must be trained in multiple skills so that they can provide services to several rural technologies like RETs, end-use technologies, etc and can earned their livings sufficiently.

### 7.4 Alternative to MHP

The question can be raised why only the MHP for rural lighting. To clarify this, in this section, brief comparison of energy technologies or carriers used in the rural areas of the hilly and mountainous regions will be made. Apart from MHP, a few technologies or energy resources can serve the community. The following section will analyze other complementary or substitutable technologies and their possibilities:

(1) maintaining status quo with kerosene, diesel and dry cell battery,
(2) providing grid,
(3) solar PV systems,
(4) biogas (can be complementary technology) and
(5) other new renewable energy options (solar thermal, wind, etc).

#### (1) Maintaining status quo with kerosene, diesel and dry cell battery

The economic as well social disadvantages of using kerosene, diesel and dry cell battery for energy needed for lighting and communication equipment has been discussed in several perspectives in the previous chapters and sections. The summary of negative impacts of maintaining status quo of lighting energy in the rural sector for 20% population of Nepal living the hilly and mountainous regions. Table 7.14 (in next page) illustrates the impacts from the macro point of view.

#### (2) Extending grid to remote rural areas

Another alternative of decentralized MHP system is extending the national grid. But “since rural households are by definition widely dispersed, this leads to higher distribution costs and higher unit costs per connection and per kWh than urban households” (Cecelski 1996: 11). There are several reasons that the grid is not economically and technically viable.

Firstly, the transmission and distribution cost is expensive as discussed in externality issues. Secondly, the intensity of electricity consumption is low, i.e. electricity consumption per km of transmission and distribution line is low. Moreover, those grid based rural electrification projects are being highly subsidized. To provide grid to the rural and remote areas is to provide them continuous subsidy because of costly maintenances and operations, revenue collections etc works. Whereas in the case of decentralized system, one time subsidy is enough to provide the facility to the people.

**Table 7.14 Impacts of maintaining status quo of kerosene, diesel and battery use**

| Perspective | Disadvantages | Quantitative | Qualitative |
|---|---|---|---|
| Economic | Drainage of hard currency and financial resources regularly | About 28,181 kiloliter of kerosene per year has to be imported to the families who could have got electricity from MHP and about 4,000 employment opportunity, directly related to MHP, and about 640 in the end-use sector will be lost. | Backward and forward linkages of MHP would not be realized. |
| Social | Drudgery, health impacts will not be avoided | Women have to work about 500 - 700 hours more for agroprocessing if status quo is maintained | Women and children will suffer further, people suffer physically as well psychologically |
| Ecological | GHG, soil, air and water pollution. | 4,090 ton of CO2 emission will be emitted and 1.24 million pairs of dry-cell battery will be thrown in soil and water | Indoor air pollution, health impacts due to toxic & chemicals of dry-cell battery |

Source: Author

From the financial perspective, larger energy systems need huge financial resources and huge financial resources cannot be mobilized locally. Foreign aid or loans are needed. Using foreign loan has several impacts. Foreign loans are in hard currency and electricity sold in the local markets generates local currency. For a poor nation that does not earn hard currency through export, another loan has to be taken to pay old loans thus making a cycle of debt. On the other side, utilities financed through debt will have to follow the guidelines of the lenders. “There is a growing support for the view among some elements within donor agencies that electricity should be supplied only to those consumers that can afford to pay its full cost (regardless of its social or other benefits)” (Barnett 1992: 329). Moreover, “there is widespread pressure to shift the balance of funding further towards the direct support of poor people and rural development” (Barnett 1992: 329), not for power projects. In the case of Nepal, the opportunity cost of big hydropower is more than what country gets in return from the plant (e.g. Thapa 1997). However, contrary to that, MHP need and can manage local investment and are linked with other rural development activities.

The next impact of the grid on the local economy is the resource drain from the villages and resources are collected centrally beyond the access to the rural people. The money paid for the electricity bill goes to the centralized utility. Whereas in the case of community owned decentralized system, such money could be used for the local developmental activities, which would generate employment opportunities or economic activities. Moreover, extending grid means supporting, in general, the bigger systems like large dam based big hydropower projects in Nepal. For the grid, technically and economically, a bigger system is advantageous. In such case, energy system will be monopolized and put beyond the reach of the poor people. From sustainability perspective, in the case of monopoly or oligopoly, there is no fair dealing with the common people. The poor who do not oblige to the rules of utility are not permitted to have access whereas in the community owned systems a compromising, plausible, or amicable solution would be found locally giving the best possible opportunity to every-member of the community to have the access to the system, because providing equity in the opportunity is one of the basic requirements of sustainable use of any resources or development endeavors. The bigger hydro systems are also being criticized for being unsustainable from several perspectives in the Nepalese context[287] (e.g. Bandyopadhyay et al 1994, Pandey 1994, Thompson 1994, Thapa 1997, Dahal 1998). Not only that, the grid extension to remote and rural areas inhibits the promotion of local resources like small water steams for multipurposes: irrigation, drinking water and power (e.g. Hourcade 1990). Therefore, comparing with MHP, bigger and centralized grid systems are not consistent with sustainability rules.

### (3) Solar PV systems

Solar home systems (SHS) are popular among the rural people in Nepal and used by more than ten thousand families. If MHP, biogas, grid, and other renewable energy technologies are not possible economically and technically in the near future, the SHS would be the only alternative to avoid the use of fossil fuel. However, solar PV is economically expensive

[287] See **Annex 7.3** for detailed unsustainability issues of Big Hydro in Nepal.

and imported technology. From the macro-economic point of view, solar will bring similar burdens as kerosene but in the small scale. Where MHP potential exists, SHS cannot be the alternative because it is expensive, has to be imported and cannot induce other industrial and commercial activities as compared to MHP. Centralized solar PV plants, financially as well as technically have not brought positive results from experiences in Nepal. Nevertheless, in future, if cost comes down, solar PV could be the alternative where other renewable energy resources and technologies are not feasible technically as well as socio-economically, i.e. biogas in high mountains, micro hydro where there are no streams, etc.

**(4) Biogas**

More than 100 thousand families are using biogas for lighting and cooking in Nepal. There is a potential of about 1.3 million family size (4 - 10 $m^3$) biogas plants in Nepal (NPC 1995). Especially the plain and hilly regions are profiting from this technology. Biogas is sufficient for lighting and cooking depending upon the size of the family and cattle holdings. Biogas is still not being used to drive any mechanical machines and for other motive powers and electronic appliances. The function of biogas and MHP is in a broader sense not substitutive but complimentary, i.e. biogas is for cooking, MHP is for lights, and other need of electrical energy could be a sustainable option for a family in rural areas. Therefore, biogas is a complementary part in supplying sustainable energy to the families of hills. Nevertheless, because of climatic conditions, mountain regions still cannot do that, as biogas, in general, cannot function well in the cold climate.

**(5) Other new and renewable energy options**

Wind energy utilization is still far from reality because no wind mapping and detail feasibilities of regions have still been done. Therefore, discussing about wind energy is still premature in the context of Nepal, although potential of wind energy exists (e.g. CES 2000). The potential of geothermal energy is still not well known. Other renewable energy technologies to replace the MHP in hills and mountains are not known as of yet. Therefore, from above discussions, it can be proved that MHP seems the potential technology for the hills and mountain region where such potential exists and especially biogas could be the complementary form of energy technology to provide sustainable energy to the rural households. Moreover, solar thermal, improved cook stoves and other RET can be combined together from the perspective of energy mix, as discussed already, for sustainable rural energy supply.

**Chapter Eight**

## 8.1 Discussions on Findings and Set Hypothesis

Operationalization of sustainability envisioned systematically mainly after the Rio-Summit in 1992, bringing in several perspectives, approaches and methodologies. Especially at the project level, in broader perspective, there are two different approaches adopted. From the literature review, mainly two approaches can be listed: holistic determinism and ecological determinism. Some even restricted to environmental determinism. Nevertheless, this dissertation argues that the holistic determinism only could analyze the complete sustainability and if a project fulfills the criteria laid down by each component of sustainability, then the project promotes sustainability.

Energy projects, especially renewable energy technology based projects, are needed to avoid the unsustainability caused by the energy production, exploitation and consumption processes. New approaches based on complete sustainability are to be developed to analyze such projects. This dissertation has tried to bring the issues and suggested a methodology with examples. However, the main target of the study was to concentrate on the micro hydro technology with its relevant issues.

It is frequently mentioned that the MHP utilization in traditional art was already in Nepal since centuries. It was mainly meant to serve farmers. Its linkages with other services were hardly realized and the state of the art technology was not brought out among the people even after falling water impinged on turbine producing electricity in 1911 in Nepal. However, the development after the sixties broadened the pace and a few people are being served better. The findings from the study show that the technology has several facets. Because of these facets, MHP is being considered the best tool among the other development efforts to promote sustainable development in rural Nepal.

However, including several other known and unknown factors, and existence of externalities in the rural energy sector is hindering the sustainability of micro hydropower technology in rural Nepal. It was tried to find out the amount of externalities in Chapter Five. Most of the externalities are still qualitative and need in-depth study, however, a few pecuniary values of externalities compared with non-subsidized MHP has been listed. Among the easily internalizable externalities are “subsidy externalities” which are found to be about NRs 366 per household per year at the current situation. However, about NRs 2,045 per year per household is the pecuniary externality (only that has been quantified based on the existing data). If internalized, certainly after further rigorously studying the findings and correcting, MHP projects could be easily financially viable.

From the existing condition of MHP technology in Nepal, the following are the findings as listed below:

***Economically,*** MHP is bringing benefits at the micro as well as macro level. The following are the findings related to economic aspects:

- Employment generation, about one-person year per year per kW and 0.25-person year per year will be additional for operation and maintenance of the existing MHP systems. If productivity factor is considered, the amount of job opportunities would be slightly lower than the obtained figure in the future. A main impact of employment creation is decentralized form of income distribution. People earn money even in remote areas and this will enhance the process of balanced development, a goal of regional development endeavors. Not only would that but in an economy of subsistence farming, employment generation alleviate the poverty.
- About Rs. 366 per year of subsidy that is given to them by the government in diesel and kerosene is being saved by each household. In other words, tentatively, about Rs. 3,121 per year per kW subsidy will also be saved that is given to kerosene and Rs. 537.30 for diesel. It would help to save unnecessary expenses and this fund could be diverted to promote the technologies that contribute more socio-economic and ecological development.
- Moreover, about Rs. 13,000 equivalent of hard currency will be stopped from drainage in fossil fuel by an installed MHP per year per kW. All these are the figures considering current actual situation, i.e. families are using 3.24 liter per month and small amount of diesel in end-uses like agroprocessing mills. The continuous financial resources drainage has been avoided due to reduction of consumption of kerosene by the communities and revenue from MHP is remaining with the communities. It has reduced the burden on the country’s import and trade balance.

- Underutilization of local resources sustainability is the reflection of underdevelopment (e.g. Dahal et al 1993), so in the case of MHP, local resources have been utilized thus reducing external dependencies. MHP utilizes falling water, most of the components are locally made, and only a few components are imported.
- Local industrial development because of manufacturing companies that are increasing in numbers every year, service centers to provide repair and maintenances and end-use enterprises based on electricity generated.
- MHP in present state contributes nearly one percent of the GDP of manufacturing sector.
- On the average, three end-use enterprises are being developed in each MHP project site. If we take the average capacity of MHP as 20-25 kW then there will be a significant number of end-use enterprises in the rural areas every year.
- A significant amount is being mobilized locally for the investment and revenue generated from the plants is being utilized for the local purposes thus creating local economic activities.
- A level of poverty reduction has been found due to the employment opportunities thus rising income and saving in fuel consumption. People in the communities, on the average, are saving almost 40-50 of their expenses on lighting as compared to before the project. Those employed by the system in the villages are earning, on the average, almost 68% more than national per capita income. Sustainable energy project would not directly provide assistances to each and every poor family in terms of cash, however, if a person's earning potential is increased, the assistance may ultimately be translated into cash equivalent, which is being happening in few villages where MHP projects are being implemented.

From the ***ecological*** aspects, the following are the findings from the study:

- About 1.376 tons of CO2e GHG per kW would be avoided in the current situation of rural people's living style. If one electric bulb were considered equal to one kerosene wick lamp[288], then about 4.266 tons of GHG would be avoided.

- About 312 pairs of dry cells per kW that were used for radio, cassette players and torchlight would be replaced by MHP electricity.
- No significant negative ecological as well as environmental impacts are noticed. However, civil component of the system has minor impacts.
- Indoor pollution, water and soil pollution that is caused by kerosene, diesel and dry cell batteries would be reduced.

From the ***social*** perspective, the following are the impacts of MHP:

- About two hours per day of manual labour per household has been saved especially of women and children after avoiding manual agroprocessing like grinding, husking and expelling. In the aspect of women and children's drudgery reduction, micro hydropower has done a lot especially in agro processing and removal of negative health impacts from primitive and traditional dirty kerosene lamps.
- Improved sanitation and clean household environment improved health condition.
- Local institution building thus empowered community has been observed.
- Overall betterment of living style because of information transformation, better learning environment for the children and enhanced possibilities and opportunities to increase the income of the people.
- Equity issues of providing access to electricity to all members of the community has been accomplished, especially in the community owned MHP.

From the above-mentioned findings, it is clear that the set hypotheses are proved in a larger extent. The MHP technology and MHP energy system as an enterprise would promote the sustainability of rural Nepal because, from the study and findings, the following ***principles of sustainability*** are being fulfilled by the MHP technology in Nepal.

- intra-generational equity or distribution of development benefits,
- enhancing accessibility in decision making, participation, empowerment and capability expansion,

[288] If one electric bulb will be replaced with one kerosene wick lamp used for 2.7 hours.

- precautionary principle based on reducing waste generation and uncertainty,
- enhancement of scale of economic activities and living style,
- technological development and resource substitution, and
- compromise and compensation.

As discussed previously, the Nepalese state owned electricity-supplying system would not be able to supply electricity to the Nepalese, who are living in very remote villages of hills and mountains within the next few decades because of multiple problems. For the people living there, where potential exists, MHP could be the only alternative. From on-going activities, it also indicates that technologically, ecologically and economically, MHP are viable to the remote communities in providing electricity and dependent facilities faster than the centralized plan. The study showed that almost all families within the community, who owns MHP, have access to electricity[289]. No families were deprived off in the community. From the perspective of intra-generational equity or distribution of development benefits of electricity, MHP projects are consistent with the principle of sustainability.

As most of centralized systems are being managed by the utilities themselves, village people are being provided the grid in some areas without any additional benefits to both parties[290]. Whereas in the decentralized community owned MHPs, which were/are planned, implemented and owned by the people, all related activities are shared by the communities themselves and the net revenue collected by them (i.e. benefits) will remain in the areas for other developmental activities. Once people will have to deal with these management activities, people's capabilities will be enhanced in decision-making for the development process, to manage accessibility to such processes and to control their own resources. Such phenomena, in the longer term, will help to sustain the socio-ecological environment promoting sustainability through participation.

The precautionary principle meant in the context of MHP covers two aspects: conservation of the local as well as global ecological damages and ascertaining the supply of energy. Conservation of ecological environment means reducing emission

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[289] This could not be the case in privately owned MHP plants.

[290] No benefits to both parties because suppliers are facing the problem of low load factor and high administrative costs and receivers are paying tariff which is normally unidirectional in flow, i.e. no activities from that revenue in that area and the people have no say (no control on decision making) to the system's management, i.e. tariff fixing, regulatory of supply, etc.

of GHG (about 85,667[291] tons of GHG will be avoided per year if MHP is provided for lighting to 20% households of Nepal currently living in the hills and mountains) due to the use of fossil fuels like kerosene and diesel, indoor air pollution, soil and water pollution due to the use of dry cell batteries. Moreover, if MHPs are not being implemented and the grid is extended with big hydro systems then there will also be several ecological damages (see ORNL 1994, WCD 2000).

From the perspective of uncertainty in the supply of energy, especially that of lighting energy, MHP would be favorable and sustainable. Supply of fossil fuels is uncertain due to the geographical as well as political reasons as discussed in Chapter Five. Being a land locked country, Nepal should import its fossil fuel via India and the country has already experienced two trade-embargos imposed by India. The impact of embargo was, among others, unavailability of lighting energy (kerosene) to about 90% of the population in 1989. There were also other economic as well as ecological consequences like the speedy deforestation[292]. Moreover, the changing climate, thus induced meteorological events, are making the grid systems based on big hydropower plants vulnerable (see Mirza et al 1997, Gyawali et al 1994). The phenomena of glacier burst and snow melting are well reported by IPCC (2001). On the other side, adaptation and mitigation activities of such meteorological events are difficult in the case of big hydro whereas in the case of MHP, it is locally manageable to some extent. Therefore, from this perspective and other seismic, geological events and geographical difficulties, the grid system is not reliable to remote communities. Therefore, MHP could be better in this aspect.

Enhancement of economic activities and living standards due to the implementation of MHP projects in the remote areas have already been listed and discussed in previous chapters. More MHP projects will bring the scale of economic activities to the level that would be significant from the national perspective as well because the absence of energy supplies in rural areas can, under certain settings, hamper the economic activities (e.g. Meier 2001:72). The decentralized economic activities will provide opportunities in different regions thus enhancing the sustainable development

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[291] This is the case when one wick lamp used by community is considered to be replaced by electricity, however if it is assumed that one bulb (25 watt) is equivalent to one kerosene wick lamp then the GHG avoided would be 268,627 tons.

[292] As most of the small and cottage industries in the rural and suburban areas were dependent on fossil fuels, the sudden stoppage of fossil fuel forced to look for easier alternatives and fuelwood was the easiest, cheapest and the quickest solution, thus inducing faster deforestation.

activities through enhanced livelihoods. About 500 end-use enterprises per year would be established in remote villages if 3 MW of MHP is implemented.

**Table 8.1 Sustainability matrix of MHP project**

| | | Components | Reference parameters | Factors | |
|---|---|---|---|---|---|
| Community owned MHP for 20-30 years | Used for domestic lighting, end-use technologies and other socio-economic uses | Economic | Limit | Enhanced economic activities through end-uses | Level of sustainability (weak to complete, i.e. fulfilling one factor to all) |
| | | | | Fossil fuel and battery are replaced by renewable resources/systems | |
| | | | | More efficient lighting and agroprocessing | |
| | | Ecological | Carrying capacity | Emission and pollution from fossil fuel and dry cell reduced | |
| | | | | Renewable resource is consumed | |
| | | | | Increased nos. of kerosene wick-lamp and diesel mills are reduced | |
| | | Social | Just distribution (Equity/Justice) | Electricity is distributed to all community households | |
| | | | | People have access and rights in tariff fixing and management | |
| | | | | Voluntary labor, subsidy and responsibility to manage | |

Source: Author

From the perspective of resource substitution, through MHP projects, a significant amount of kerosene used for lighting has been avoided thus making ecological as well as economic benefits to the society and the nation. If 20% of the families in Nepal use MHP in lighting only, then about 32,677 kilo-liters of kerosene and about 27.65 million pairs[293] of dry cell battery will be replaced, in the current scenario of fossil fuel and dry cell use in Nepal. By introducing environment friendly technology in the

[293] Assuming that the current 20% rural households in Nepal will abandon the use of kerosene and dry cell battery after MHP being implemented, and these 20% households also use the same amount of kerosene (3.24 liter/year) and dry cell battery (2.76 pairs/month).

villages, other useful technologies will also enter the society like in the health sector, educational sector, etc.

People, who are using the community owned MHP are also investing their labor and cash for the implementation of the system. They are partly compromising their private profits. The government, on the other side, is providing compensation through subsidy so that people do not feel the economic burden due to the MHP system. The subsidy provided to kerosene could be converted to subsidy to the MHP although it could bring financial burden to the government in the short term only.

From the above discussions, it is clear that the MHP technology promotes economic prosperity, ecological integrity and socially just equity, which are the ingredient of sustainability in the development process in Nepal. However, from traditional perspective of financial analysis, the MHP projects are observed to be unsustainable. The reasons for financially unsustainability have been already discussed in Chapter Five and Six. These hurdles would be overcome with the new financing mechanisms incorporating externalities as discussed in the previous chapters. Therefore, with all figures, data and discussions, it shows that the MHP projects are the best tools for promoting sustainability in Nepal thus proving the hypothesis set by the study.

## 8.2 Complexes and Paradoxes

Despite proving the set hypotheses, several complexes and paradoxes are prevailing in the Nepalese villages, which have to be considered while planning, implementing, and analyzing the rural energy projects. These complexes and paradoxes are listed below:

- Payment of a significant amount of money for the means of lighting by using kerosene and dry cells is found from the field level data, however, on the average, people are paying, in the several cases, lower than before and getting better facility after MHP being implemented. This could have helped to reduce economic poverty but most of the MHP systems are, when analyzed from perspective of the pure financial profit, unsustainable.
- However, the willingness to pay was higher for the better lighting than what people were paying for the traditional sources of lighting, before project has been implemented and in a few cases even after implementation.

- The price that people were paying to traditional form of energy could not be the measure of willingness to pay, because due to technical and other reasons people did not light their gardens, verandahs, balcony, etc. previously as done after MHP. If they have done so previously, they could have spent more money.
- Moreover, willingness to pay price is very complex in case of lighting; it depends upon technology or resources available, easiness in handling or using, people's perception and accessibility and modes of tariff payment.
- Why MHP for mechanical milling system is generally said to be 'financially' viable but not electricity generation system although the "add-one" cost or "electrification plus" cost or "cost of electrical equipment" are found to be only 20-25% from the study (e.g. ADB/N 1987). For stand-alone systems, which are not bigger than 10-15 kW, this must not be a problem.
- In most of the cases, people are willing to invest voluntary labor for MHP but not the real investment in cash. If people invest their labor and get subsidy and small amount of loan for the system, practically system seems to be easy to implement. However, if pure conservative financial analysis is done by including voluntary cost then projects are not viable to provide subsidies and loan.

Therefore, the above-mentioned findings have their own limitations and preciseness. From the existing data and collected primary data, the findings certainly represent the true nature even though quantitatively, the found figures can be slightly lower or higher than actual results that would be.

# Chapter Nine

## Conclusions and Recommendations for Further Research Studies and Activities

The widely discussed issues of sustainable development and sustainability are broad but it is tried to put in operationalization to all development processes, activities or projects as well as programmes in different perspectives. Every nation in the world has its own development paradigm. Since WCED (1987) and Rio Declaration (1992), several nations have tried to make their development objectives consistent to sustainability with different strategies, although the meaning and perception of sustainability is diverse and conflicting in theory as well as in operational strategies. In the context of Nepal, the goal of sustainable development is to expedite a process that provides to its citizens and successive generations at least the basic means of livelihood with the broadest opportunities in the field of social, economic, political, cultural and ecological aspects of their lives (MOPE 2002). For the achievement of sustainability goal of at least basic means of livelihood, the country must implement several development activities that promote sustainability in the respective sectors. The development activities must bring net benefits in all dimensions of sustainability: social, ecological and economic, making no net negative impacts. The net benefits of developmental activities to the society are or will be accomplished only after careful planning, implementations and evaluations. Therefore, sustainability has to be operationally defined with several issues encompassing into it.

Sustainability could be promoted with any project or enterprise. For that, projects or enterprises are to be sustainable themselves. Rural energy projects, if they are enhancing social, ecological as well as economic components of the society, are sustainable and promote sustainability of the communities. Rural energy projects, in poor developing countries, are also the part of these sustainable development endeavors because they are being implemented to alleviate the energy poverty of rural people. Energy is nucleus of overall poverty in rural areas of developing countries.

Rawls (1971) first principle of equality in the assignment of basic rights and duties can guide the strategy of sustainability promoting activities. Equality in basic rights is very vague but basic rights includes all rights that guarantee at least the basic means of livelihood with the broadest opportunities in the field of social, economic, political, cultural and ecological aspects of human lives. Energy for cooking, lighting and for other basic activities and including access to the resources to utilize for the well-being comes under these rights. In this regard, the energy supplying enterprises that are to be controlled by the communities and policy of assigning such rights and duties to the communities are consistent with the social justice thus with sustainability.

**A way forward for sustainable rural energy system**

Among the several development efforts, electrification is among the most wanted and demanded development in developing countries. Nepal can provide it to its rural people in three ways: firstly, bring the rural people to semi-urban or urban centers where electricity is available or easily available; secondly, expand the expensive grid to the rural hamlets and; thirdly, choose decentralized ways of providing the electricity by utilizing local resources wherever possible. The first two approaches are not manageable, sustainable, or suitable because the majority of people are subsistence farmers and there are no industries to absorb the migrated people to urban centers; and extending grids every corners of the country is not possible due to scattered communities and geographical difficulties. The third alternative would be to utilize the local resources and technologies. In the beginning, since people need electricity only for lighting and a few electrical appliances that consume low amount of energy, the small-decentralized systems with local managements are suitable. The decentralized decisionmaking encompasses the local sustainability constraints because participatory decision-making in the resources sharing and distribution of benefits are functioning very well, for example, the distribution of electricity or forestry products or irrigation water from the community owned systems in Nepal. The decentralized rural energy enterprise are owned and managed by the communities with lower level of conflicts.

MHP projects are to be developed from the several perspectives: price equalization of energy for all, national solidarity to develop the remote and rural areas, to boost rural economic activities and save ecology.

There are also very few alternatives to divert people from subsistence farming in hilly and mountain regions. Among the very few alternatives, activities like promotion of tourism, processing and value addition to herbs and other agricultural and horticultural products needs technology and energy. A significant numbers of job opportunities could be envisaged from these activities. These activities need a sustainable form of energy system like MHP. In this regard, as study showed that the MHP could contribute directly and indirectly in the accomplishment of such development goals. MHP is serving communities with not only energy but also enhanced economic activities and induced better life. Most of the rural people in the hills and mountains are subsistence farmers and due to increasing population, the farmers are becoming poor with limited land and production of means of survival. Creating employment opportunities would be the immediate route of alleviating poverty. MHP, in this regards, provides a few job opportunities locally and alleviating poverty appreciably, because it has very short gestation period and with the local participation, financially and voluntarily many power plants can be built in a short period and create jobs.

The most lacking aspect of development process is also regional development. The gap between urban cities and remote rural area is vast and among the several efforts to fill the gap, electrification and supply of clean energy are the most desired development activities by the rural people. Micro hydro could also reduce these imbalances to some extent.

Regarding the capability of the country, on the technical side, various kinds of turbines such as propeller, cross flow, pelton wheels, multipurpose power units, *peltric sets* and traditional *improved Ghattas* needed for the MHPs are already developed and manufactured in Nepal. Several local and rural people are also being trained by different agencies to operate and manage micro hydro systems.

On the economic side, there is already a significant nos. of MHP financially supported by the local communities and local banks as well as the local entrepreneurs after the government's subsidy policy. The communities can mobilize the partial investment capital locally and may need only subsidies from outside. These types of effort are coming up in Nepal.

Current national policies are coming up with more decentralization and focusing on more decentralized decision-making, especially in the utilization of natural resources. Such continuous endeavors in the future, especially in implementation policies, will provide the opportunity for further development of the MHP sector.

From the perspective of financing MHP projects in Nepal, there are also realizable options. Among them, grasping the opportunities to mobilize the additional financial resources from emission trading like CDM could encourage the local communities to implement

MHP projects because CDM is supposed to support the RET projects that are in the absence of “additional” financial capital flow not financially viable. For MHP, which reduces the GHG avoiding the use of fossil fuels and dry cells, obtaining CERs would be very likely after international market price increases. Not only would that, internalizing externalities also motivate the communities to invest their resources to MHP than in imported fossil fuel. Certainly, internalization of externalities is a gradual process but ultimately, it benefits MHP and other RETs.

The potential of MHP is more than sufficient for one third of the hilly and mountainous people of Nepal. As suggested in financial mechanism in previous chapter, about 80 MW of MHP could be implemented within the next 20 years to energize the rural masses. One thing is very important to mention that without uplifting the current living standards, most of the energy systems are not financially sustainable because of economic poverty. If a village will have 20 years of electricity from MHP, there would be more energy need in later years and once the country develops from its current subsistence economy, the grid can be extended wherever possible. More interestingly, even if the rural areas of Nepal get the grid supply in the next 20-30 years, the village community will have a regular source of income as they can feed electricity to the grid and earn revenue for the development of their own communities. This opportunity would be realized if policies are formulated in favor of such endeavors. So MHP for the time being would be unopposed way of electrifying the villages, wherever potential exists.

While considering energy system that is needed for the lighting and other socio-ecological and economic activities in the context of climate change, carrying capacity of ecological environment, inter- and intra generational equity aspects of developmental benefits, MHP systems would be the first priority for the future sustainable energy use in the Nepalese mountainous and hilly areas. MHP, because of its resource, technical and socio-economical potential in the future development scenario, can bring several benefits to the communities promoting sustainability endeavors.

**Sustainability questions from different perspectives**

Critics could be that power produced from micro hydro is not enough to meet Nepal's demands because they are isolated and cannot be fed into the grid and synchronizing techniques are costly. However, when environmental and social cost of other energy systems and resources are considered and internalized in the production cost, the synchronizing technology will not be expensive in comparison in one side, on the other side, technological innovation can make the local/regional/national grid feeding financially feasible.

The major problem of low load factor faced by micro hydro can be solved if Nepal adopts the policy of utilizing environmental friendly energy. Interestingly, the problem of low load factor can be seen as an opportunity to develop the agro based rural small-scale industries and enterprises in the targeted sector that could lead to self-sustained rural community.

Another criticism for micro hydro is that it cannot support the industrial demand. As already discussed, the remote and rural areas dominate the country. There are almost no industries in the hilly and mountainous regions. By bringing national grid there, initially electricity will be utilized for lighting only and it will certainly create in addition to poor financial returns, technical problems as well e.g. different load density, load fluctuation etc. If Nepal implements micro hydro in these remote and rural areas, people will utilize the electricity in the daytime for small-scale industries. These industries will perpetuate the demand of electricity in the future. After some years, there may be the possibility of development of regional or district power pool to feed into the grid when grid-feeding technology becomes cheaper.

Tourism is one of the major hard currency earning sectors. The mountains of Nepal provides some of the most spectacular scenery in the world, which attracts large numbers of tourists for trekking and mountaineering each year but there is hardly electricity or clean form of energy available in these areas. The economic condition of the country demands that tourism should be developed and increased as much as possible. This has direct impacts on natural resources and one of them is fuel wood. The derived demand of energy due to tourists is high. The market centers and trekking routes are rugged and construction of national grid is uneconomical and difficult. The alternative is to provide energy through micro hydro wherever possible to prevent increasing pressure on local natural resources and attract more eco-tourists with ecological friendly facilities to enhance the local economic situation.

The hilly and mountain areas of Nepal has lots of market centers and small towns which are acting as buffers between villages and cities and are providing off-farm employment, serving objective of equity, territorial justice and decentralization from a national perspective. These small market centers lack facilities like electricity. Bringing electricity into these areas will certainly enhance the pace of small enterprise development based on agriculture and local products and resources. Once improved facility is available, these centers will reduce the rate of migration to bigger urban cities and plain areas and will increase local livelihood through enhanced economic activities. Micro hydro can contribute enormously to develop these areas because it would take still few decades to bring national grid in all hilly market centers in Nepal.

Subsidy given to MHP has also been questioned from the sustainability perspective, although if the amount of resources drained for import of fossil fuel needed to the rural areas and subsidy given to the same could be diverted, then the subsidy issue from the sustainability perspective could be understood differently.

As per the experiences gained by hundreds of rural communities in Nepal, Micro Hydro has already shown the way for promoting sustainable development: Creation of local job opportunity, equity in natural resources sharing, enhancement of local micro economic activities and betterment of local livelihoods that is an ecological and socio-economic benefit, which promotes the sustainable development in Nepal.

**The challenges**

The development of MHP is often contested against the possibility of optimum use of power generated as it is difficult to increase end use activities in the rural sector, where extra efforts and resources are required, which depends primarily on several factors i.e. social, economic and on technology in general. Electricity, at present in rural Nepal, is generally viewed as a facility, primarily to replace the use of kerosene for lighting (traditional forms) and not as a tool to increase on the economic activities. This is also a major challenge that requires emphasis to have sustainable impacts of micro hydropower.

Diverse uses of electricity for local empowerment have to be propagated, especially for agriculture, horticulture and tourism based industries and enterprises. Appropriate policies, adequate human resource development to operate and manage the systems and technical components standardization have to be focused.

Because of low load factor MHP are not financially attractive for private sectors. Entrepreneurs or communities that are implementing MHP projects are being given subsidies. Subsidies are most of time supported by foreign aid so sustainability of subsidy aspects can also be questioned. So a new type of economic analysis is needed which includes all positive and non-cash benefits of MHP to change the traditional views of only narrow financial profits.

Existing tariff system based on wattage connected seems suitable for better financial recovery because it does not count the losses. However, several existing systems are still underutilized causing low revenue collection. Either intensive end-use development activities or power selling activities to neighboring communities should be implemented.

Micro Hydro may not contribute substantially to GDP or GNP and may not change drastically macroeconomic conditions of the country but it is certainly making impacts on micro-economy of local areas where micro hydro is being implemented. Sustainability cannot be promoted only when a project increases the GDP of the country but it has to enhance the well-being of the poor people bringing them into a level where minimum basic needs concerned to the projects are accessible. Obviously, many improvements of microeconomic in hundreds of local areas will have more positive results than macroeconomic indicators that do not care the equity and environmental aspects. Why should one bothers about those indicators if the locals are happier and ecology is better than before making no one worse off?

Without internalization of externalities, MHP could not prove to be the best alternative from the financial perspectives. Rural community still may use cheaper kerosene and other unsustainable resources. On the other side, reducing the subsidy and incentives given to fossil fuels is not simple because poor people who cannot switch to RET immediately will suffer. However, for the hilly and mountainous region, especially in remote areas, fossil fuel is comparatively expensive due to transportation and internalization of externalities may have lesser impacts than in the plain and urban areas.

**Issues and further activities, studies and research needed**

For the development and further extension of MHP to promote sustainability, there are few issues to be dealt through policies, adaptations, research and development and studies for the smooth development of MHP sector in Nepal. By adopting plausible policies and implementation approaches, some issues can be solved. The followings are the major issues to be considered (also see e.g. ITDG/CRT 1995, Rijal 1998, Baskota et al 2000, Rijal 1997a, 1997b, ICIMOD 1998, ICIMOD 1993, CES 2000):

**Technical**

- reliable, fast and easily available, decentralized technical back up and repair maintenance services have to be offered,
- standardization of parts and accessories that could lead to the reduction of the cost of electromechanical components,
- utilization of indigenous material for the construction of canal thus reducing the cost as well as environmental effects of construction material like cements,
- development of cost effective synchronizing equipment through adaptive research and design to connect the MHP output into the high voltage grid, because in the future, communities can sell their excess power to the regional grid,
- research on the reduction of cost in manufacturing and installation components and process and
- technical possibilities of energy mix have to study and such system to be developed for decentralized communities, i.e. heating, cooking, lighting energy from solar, biogas and MHP.

**Economic**

- lack of investment capital was mentioned one of the main hurdles in the extension of MHP and other RETs, a participatory investment mechanism in community systems would have to be formulated,
- in-depth study and research on the externalities of rural energy use are necessary to find out the actual economic viability of RETs like MHP in Nepal,
- insurance or warranty of systems after installation has to be provided, and
- end-use diversification to increase the load factor, an innovative and adaptive research is needed to make technology or enterprises suitable to niche character.

**Social**

- water rights and arising conflicts are the major critical issues although in community owned MHPs these hurdles are reduced at least at the community level and, social mobilization tools are to be used before implementation

- in private owned MHP, accessibility of all community members to the generated electricity must be ascertained with appropriate mechanism that is acceptable locally to reduce the conflicts and to address the equity issues.

**Environmental**

- Even though MHP projects are known to be environmentally friendly, certain level of water flow has to be maintained in the stream and such provisions have to be made during the feasibility study and design and
- impact of climate change on MHP project (i.e. the quantity of stream flow that is needed (*diverted*) to run runner) has to be found out at the macro and micro level and simultaneously, local level mitigation approaches have to be suggested.

**Policy related**

- holistic approach of project analysis for decision-making is needed so that the contribution of MHP projects in promoting sustainability will be fairly evaluated,
- mechanism to internalize externalities especially of fossil fuels are to be developed to regulate custom duty and tax structure as well as minimize market distortion giving all environmental friendly technology equal level playing.
- a financial policy is needed to make MHP sustainable and to mobilize financial resources needed for the investment, subsidy and incentives, especially from the perspective of carbon trading,
- local specificities (backwardness, poorer regions, remoteness, lack of end-uses and other factors that make RET expensive) have to be recognized in policy making and project analyzing because it affects the approach of implementation, ownership, choice of project alternatives, social acceptability and environmentally absorbability,
- proper planning of rural electrification so that there will be no duplication of the grid extension and MHP implementation thus making the whole MHP effort meaningless bringing the grid after few years; and a detailed study to identify "MHP area" has to be conducted so that intensive MHP development will bring fruitful results,
- a policy of feed-in tariff system is needed to connect MHP into the grid if the grid is brought to the areas where MHP is being already implemented (it could happen in future due to unwanted reasons).
- in the grid-covered areas, a private party can be encouraged without subsidy to implement MHP projects and feed in the grid,

- add-on schemes could be promoted for private entrepreneurs because of its cost effectiveness,
- more than 20 kW MHP could be operated by the communities or co-operatives only because for a private entrepreneur, excluding site specific examples of success, financial recovery is difficult as in remote areas the load factor is low,
- excess power selling to other neighboring communities would have to be designed recover the financial losses until the grid feeding in could not be realized.
- expedite the use of CFLs and smaller transfers for power transmission to cover more families or to meet energy demands
- finally, a pro-poor financially viable MHP financing approach has to be formulated.

Not only the realization of sustainability paradigm, but also availability of technically, socially, economically as well as politically feasible energy system potential in Nepal is not a hypothesis but is veracity. Maintaining the complete sustainability criteria, available of energy resources - especially water resources, could be utilized for the alleviation of energy poverty and enhancement of optimum scale of socio-economic activities in Nepal. If policies are adopted integrally with other socio-economic and ecological development activities, MHP promotes synergic effects and sustainability could be envisaged more vividly.

**It is worth to mention here the views of Lovins**

***"People are more important than goods; hence energy, technology, and economic activity are means, not ends, and their quantity is not a measure of welfare; hence economic rationality is a narrow and often defective test of the wisdom of broad social choices, and economic costs and prices, which depend largely on philosophical conventions, are neither revealed truth nor a meaningful test of rational or desirable behaviors" (Lovins 1977:12)***

**Annex 1.1 List of some Community Owned MHP System in 10 Districts of Nepal**

| S.N. | District | MHP Schemes | Capacity KW | Beneficiary Households | Investment cost in NRs. |
|---|---|---|---|---|---|
| 1 | Achham | Ardoli Gad | 15 | 140 | 1,822,707 |
| 2 | Achham | Barala Khola | 16 | 156 | 1,662,998 |
| 3 | Baglung | Tangram Khola | 17 | 191 | 1,859,315 |
| 4 | Baglung | Taman Khola | 20 | 200 | 2,326,327 |
| 5 | Baglung | Kulunkhola | 22 | 230 | 2,383,759 |
| 6 | Baglung | Urjakhola | 26 | 250 | 2,170,974 |
| 7 | Baglung | Theule Khola | 24 | 290 | 2,559,261 |
| 8 | Baitadi | Baga Gad | 20 | 158 | 2,397,815 |
| 9 | Baitadi | Jamari Gad | 21 | 197 | 2,156,050 |
| 10 | Baitadi | Ballekhola | 8 | 85 | 1,012,749 |
| 11 | Dadeldhura | Makailkhola | 10 | 80 | 1,007,616 |
| 12 | Dadeldhura | Gairigaukhola | 6 | 78 | 830,000 |
| 13 | Dadeldhura | Chama Gad | 7 | 78 | 847,851 |
| 14 | Dolakha | Orangkhola | 10 | 116 | 1,069,607 |
| 15 | Dolakha | Kaptikhola | 25 | 234 | 2,160,707 |
| 16 | Dolakha | Bhadrawatikhola | 15 | 135 | 1,450,557 |
| 17 | Dolakha | Jamkitarkhola | 20 | 172 | 1,995,037 |
| 18 | Dolakha | Mahadevkhola | 17 | 232 | 1,706,067 |
| 19 | Dolakha | Syankhukhola | 22 | 165 | 2,279,576 |
| 20 | Kavre | Chaurigangakhola | 18 | 206 | 2,258,482 |
| 21 | Kavre | Daunekhola | 12 | 107 | 1,336,671 |
| 22 | Kavre | Chakhola | 16 | 148 | 1,799,357 |
| 23 | Kavre | Chaurikhola II | 22 | 200 | 2,166,536 |
| 24 | Kavre | Chaurikhola | 22 | 205 | 2,497,525 |
| 25 | Kavre | Khanikhola | 23 | 154 | 2,109,974 |
| 26 | Myagdi | Mahakhola | 11 | 82 | 1,206,043 |
| 27 | Myagdi | Darakhola II | 25 | 254 | 3,217,684 |
| 28 | Myagdi | Dajungkhola | 30 | 252 | 3,081,730 |
| 29 | Myagdi | Bagarkhola | 35 | 288 | 3,650,310 |
| 30 | Myagdi | Darakhola I | 50 | 437 | 4,748,815 |
| 31 | Parbat | Bachha Khola | 19 | 184 | 1,763,174 |
| 32 | Parbat | Charcharekhola | 9 | 90 | 1,371,909 |
| 33 | Parbat | Ghattekhola | 16 | 158 | 1,814,113 |
| 34 | Parbat | Thadokhola | 27 | 258 | 2,847,390 |
| 35 | Sindhupalchowk | Handikhola | 20 | 214 | 2,109,212 |
| 36 | Sindhupalchowk | Ghattekhola | 9 | 121 | 1,057,976 |
| 37 | Sindhupalchowk | Handikhola II | 26 | 275 | 2,167,164 |
| 38 | Tanahun | Likhandikhola | 20 | 190 | 2,632,015 |
| 39 | Tanahun | Kyandikhola I | 15 | 138 | 1,487,412 |
| 40 | Tanahun | Kyandikhola II | 12 | 140 | 1,295,261 |

Source: REDP (2000a, 2000b, 2001, 2002)

**Annex 1.2 Characteristics of some MHP projects in Nepal**

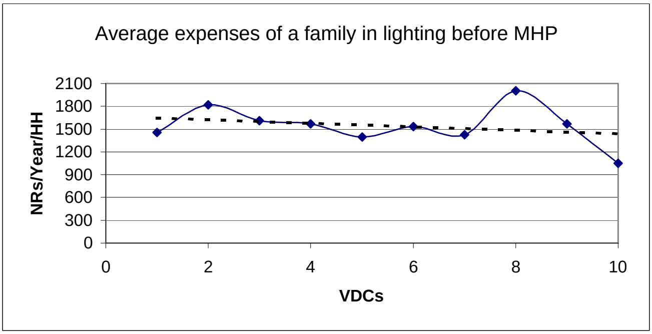
| S.N. | District | MHP Schemes | HH/ kW | Cost NRs./kw | Cost NRs./ Household |
|---|---|---|---|---|---|
| 1 | Achham | Ardoli Gad | 9 | 121,514 | 13,019 |
| 2 | Achham | Barala Khola | 10 | 103,937 | 10,660 |
| 3 | Baglung | Tangram Khola | 11 | 109,371 | 9,735 |
| 4 | Baglung | Taman Khola | 10 | 116,316 | 11,632 |
| 5 | Baglung | Kulunkhola | 10 | 108,353 | 10,364 |
| 6 | Baglung | Urjakhola | 10 | 83,499 | 8,684 |
| 7 | Baglung | Theule Khola | 12 | 106,636 | 8,825 |
| 8 | Baitadi | Baga Gad | 8 | 119,891 | 15,176 |
| 9 | Baitadi | Jamari Gad | 9 | 102,669 | 10,944 |
| 10 | Baitadi | Ballekhola | 11 | 126,594 | 11,915 |
| 11 | Dadeldhura | Makailkhola | 8 | 100,762 | 12,595 |
| 12 | Dadeldhura | Gairigaukhola | 13 | 138,333 | 10,641 |
| 13 | Dadeldhura | Chama Gad | 11 | 121,122 | 10,870 |
| 14 | Dolakha | Orangkhola | 12 | 106,961 | 9,221 |
| 15 | Dolakha | Kaptikhola | 9 | 86,428 | 9,234 |
| 16 | Dolakha | Bhadrawatikhola | 9 | 96,704 | 10,745 |
| 17 | Dolakha | Jamkitarkhola | 9 | 99,752 | 11,599 |
| 18 | Dolakha | Mahadevkhola | 14 | 100,357 | 7,354 |
| 19 | Dolakha | Syankhukhola | 8 | 103,617 | 13,816 |
| 20 | Kavre | Chaurigangakhola | 11 | 125,471 | 10,964 |
| 21 | Kavre | Daunekhola | 9 | 111,389 | 12,492 |
| 22 | Kavre | Chakhola | 9 | 112,460 | 12,158 |
| 23 | Kavre | Chaurikhola II | 9 | 98,479 | 10,833 |
| 24 | Kavre | Chaurikhola | 9 | 113,524 | 12,183 |
| 25 | Kavre | Khanikhola | 7 | 91,738 | 13,701 |
| 26 | Myagdi | Mahakhola | 7 | 109,640 | 14,708 |
| 27 | Myagdi | Darakhola II | 10 | 128,707 | 12,668 |
| 28 | Myagdi | Dajungkhola | 8 | 102,724 | 12,229 |
| 29 | Myagdi | Bagarkhola | 8 | 104,295 | 12,675 |
| 30 | Myagdi | Darakhola I | 9 | 94,976 | 10,867 |
| 31 | Parbat | Bachha Khola | 10 | 92,799 | 9,582 |
| 32 | Parbat | Charcharekhola | 10 | 152,434 | 15,243 |
| 33 | Parbat | Ghattekhola | 10 | 113,382 | 11,482 |
| 34 | Parbat | Thadokhola | 10 | 105,459 | 11,036 |
| 35 | Sindhupalchowk | Handikhola | 11 | 105,461 | 9,856 |
| 36 | Sindhupalchowk | Ghattekhola | 13 | 117,553 | 8,744 |
| 37 | Sindhupalchowk | Handikhola II | 11 | 83,352 | 7,881 |
| 38 | Tanahun | Likhandikhola | 10 | 131,601 | 13,853 |
| 39 | Tanahun | Kyandikhola I | 9 | 99,161 | 10,778 |
| 40 | Tanahun | Kyandikhola II | 12 | 107,938 | 9,252 |
| | ***Average*** | | ***10*** | ***108,884*** | ***11,255*** |

Source: Based on REDP (1998, 2000a, 2000b, 2001, 2002)

**Annex 1.3 Average consumption of kerosene, dry cells and expenses of a family**

| S.N. | VDCs/ Districts | Kerosene consumed in liter/month | Battery consumed in pairs/month | Kerosene exp/HH/ month in Rs. | Battery exp/HH/month in Rs | Expense Rs/HH/year |
|---|---|---|---|---|---|---|
| 1 | Bima/Myagdi | 3.1 | 2.50 | 71.30 | 50.00 | 1455.60 |
| 2 | Arman/Myagdi | 4.09 | 2.64 | 85.91 | 65.91 | 1821.84 |
| 3 | Marang/Myagdi | 3 | 2.00 | 78.00 | 56.00 | 1608.00 |
| 4 | Lulang/Myagdi | 2.76 | 2.33 | 69.78 | 60.86 | 1567.68 |
| 5 | Okharbot/Myagdi | 2.98 | 2.60 | 52.25 | 64.33 | 1398.96 |
| 6 | Bhuktangle/Parbat | 3.56 | 2.89 | 56.89 | 70.94 | 1533.96 |
| 7 | Sarkuwa/Baglung | 3.14 | 2.86 | 50.29 | 68.57 | 1426.32 |
| 8 | Taman/Baglung | 3.2 | 4.11 | 64.07 | 102.83 | 2002.80 |
| 9 | Sirsha/Dadeldhura | 3.81 | 2.93 | 56.12 | 74.59 | 1568.52 |
| 10 | Thampalkot/ Sindhupalchowk | 2.4 | 2.20 | 38.67 | 48.67 | 1048.08 |
| | **Average** | **3.24** | **2.76** | **62.33** | **66.27** | **1543.18** |

Source: Author



**Annex 1.4 Analysis of correlations between 40 MHP projects in 10 districts of Nepal**

The Pearson correlation coefficient, which is a measure of linear association between two variables, between capacity of MHP plant and non local cost is strong and positive and is 0.965 and similarly correlation coefficient between capacity of plant and beneficiaries household is also 0.955. More details is shown in the correlation Table below. The positive value of the correlation coefficient indicates the strength, with larger positive values indicating stronger relationships between variables. Therefore, the relationships between different three parameters of 40 MHP sites are having stronger relationship. The descriptive statistics of the same data are also given in the following table.

**Figure A Pearson correlations**

**Correlations**

| | | Capacity of MHP plant in kW | Non Local cost in Nepalese Rs. | Beneficiries Households |
|---|---|---|---|---|
| Capacity of MHP plant in kW | Pearson Correlation | 1,000 | ,965** | ,955** |
| | Sig. (2-tailed) | , | ,000 | ,000 |
| | N | 40 | 40 | 40 |
| Non Local cost in Nepalese Rs. | Pearson Correlation | ,965** | 1,000 | ,921** |
| | Sig. (2-tailed) | ,000 | , | ,000 |
| | N | 40 | 40 | 40 |
| Beneficiries Households | Pearson Correlation | ,955** | ,921** | 1,000 |
| | Sig. (2-tailed) | ,000 | ,000 | , |
| | N | 40 | 40 | 40 |

**. Correlation is significant at the 0.01 level (2-tailed).

**Source: Author**

**Figure B**

**Descriptive Statistics**

| | Mean | Std. Deviation | N |
|---|---|---|---|
| Capacity of MHP plant in kW | 18,200 | 8,692 | 40 |
| Non Local cost in Nepalese Rs. | 1938714 | 809618,8071 | 40 |
| Beneficiries Households | 172,33 | 76,90 | 40 |

**Source: Author**

Regarding the relationship between beneficiary households and non-local cost in Nepalese Rs. is strong because its significance is 0.000. If the significance value of is smaller than 0.05 then the independent variables (beneficiary households) explains strong relationship with the dependent variable (non-local cost of MHP). In addition to that, a model with a large regression sum of squares in comparison to the residual sum of squares indicates that the model accounts for most of variation in the dependent variable. In the following case residual is about 15% therefore the relation is good. The figure D also shows that the model cost is almost similar as real investment cost of the project

**Figure C**

**ANOVA[b]**

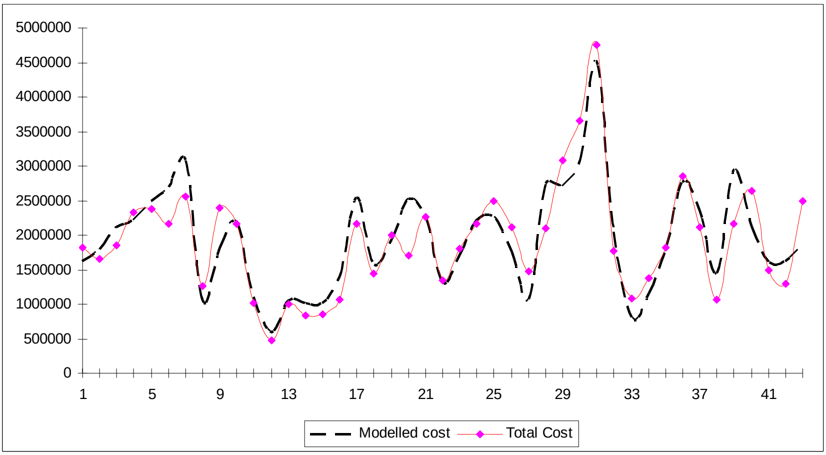
| Model | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| 1 | Regression | 2,17E+13 | 1 | 2,166E+13 | 211,014 | ,000[a] |
| | Residual | 3,90E+12 | 38 | 1,027E+11 | | |
| | Total | 2,56E+13 | 39 | | | |

a. Predictors: (Constant), Beneficiries Households

b. Dependent Variable: Non Local cost in Nepalese Rs.

**Source: Author**

**Figure D Model cost and investment cost in NRs.**




**Source: Author**

**Model: Non-Local invetsment cost (NRs) = 268650 + HH * 9691 (in NRs)**

**Figure E**

**Coefficients[a]**

| Model | | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. |
|---|---|---|---|---|---|---|
| | | B | Std. Error | Beta | | |
| 1 | (Constant) | 268650,1 | 125635,0 | | 2,138 | ,039 |
| | Beneficiries Households | 9691,364 | 667,158 | ,921 | 14,526 | ,000 |

a. Dependent Variable: Non Local cost in Nepalese Rs.

**Source: Author**

Similarly, the relationship between capacity of the plant in kW and Beneficiary households in numbers is also strong. The significance level is less than 0.000 that means precision of the results fall within stronger range. Similarly, the residual is only 8.83%

**Figure F**

**ANOVA[b]**

| Model | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| 1 | Regression | 210284,3 | 1 | 210284,345 | 392,467 | ,000[a] |
| | Residual | 20360,430 | 38 | 535,801 | | |
| | Total | 230644,8 | 39 | | | |

a. Predictors: (Constant), Capacity of MHP plant in kW

b. Dependent Variable: Beneficiries Households

**Source: Author**

**Figure G**

**Coefficients[a]**

| Model | | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. |
|---|---|---|---|---|---|---|
| | | B | Std. Error | Beta | | |
| 1 | (Constant) | 18,570 | 8,581 | | 2,164 | ,037 |
| | Capacity of MHP plant in kW | 8,448 | ,426 | ,955 | 19,811 | ,000 |

a. Dependent Variable: Beneficiries Households

**Source: Author**

**Model: Beneficiary households = 18.570 + capacity in kW x 8.448**

The relation between non-local investment cost in NRs. and the capacity of the plant is also strong. The significance level is less than 0.000 and the residual value is 6.96% as illustrated in following figures.

**Figure H**

**ANOVA[b]**

| Model | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| 1 | Regression | 2741,259 | 1 | 2741,259 | 507,787 | ,000[a] |
| | Residual | 205,141 | 38 | 5,398 | | |
| | Total | 2946,400 | 39 | | | |

a. Predictors: (Constant), Non Local cost in Nepalese Rs.

b. Dependent Variable: Capacity of MHP plant in kW

**Source: Author**

**Figure I**

**Coefficients[a]**

| Model | | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. |
|---|---|---|---|---|---|---|
| | | B | Std. Error | Beta | | |
| 1 | (Constant) | -1,876 | ,964 | | -1,947 | ,059 |
| | Non Local cost in Nepalese Rs. | 1,036E-05 | ,000 | ,965 | 22,534 | ,000 |

a. Dependent Variable: Capacity of MHP plant in kW

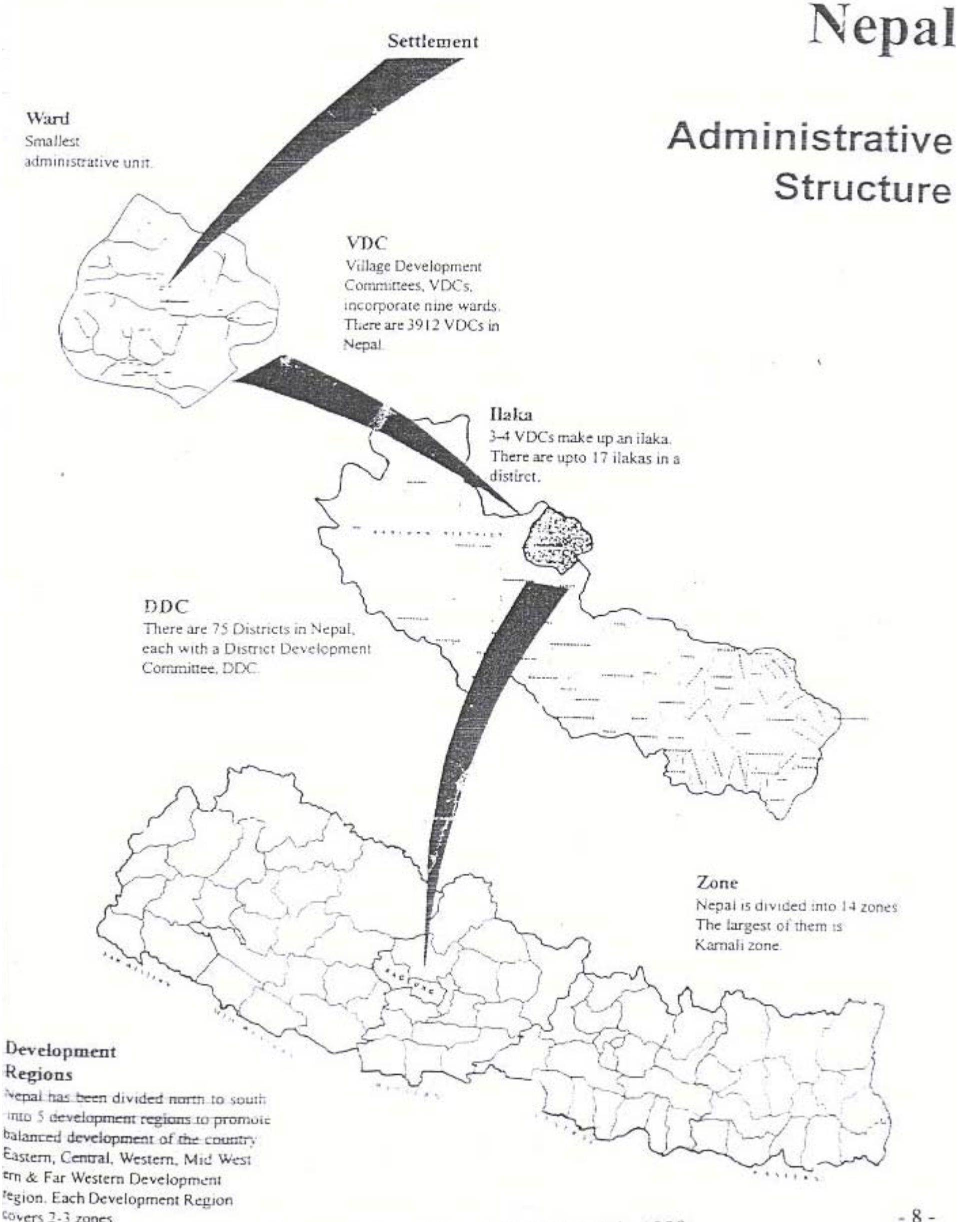
**Source: Author**

**Model: Capacity of the Plant in kW = -1.876+ Non-local cost x 1.036 x$10^{-5}$**

From the brief analysis by using SPSS 10, it can be concluded that the relationship between three parameters of 40 community owned MHP projects in different parts of Nepal is strong. Although the qualitative and socio-economic parameters could not be analyzed like type of community, paying capacity of the communities, economic activities around the communities etc. However, it can be said that most of the MHP are in the hilly and mountain regions of Nepal and above-mentioned parameters can certainly show some relationship among them. So few MHP will be taken in analysis assuming the outcome represents general scenario of MHP in Nepal.

Annex 3.1

*Administrative structure of Nepal*




Source: Collected from DDC Myagdi in 1999.

### Annex 3.2 Different organisations supporting MHP developmental activities in Nepal

| Organisation | Funded/Supported By | Approaches | Subsidy/Support mechanism | Started/ Time Period | Remarks |
|---|---|---|---|---|---|
| Agriculture Development Bank/Nepal | HMG/N | Providing loan and subsidy through sites offices/ Supported also pre-feasibility survey. Individual as well as communities have been supported | 50% of electrical components + Rs 5000/kW for electric pole | from 1985 to 2000 | more investment interest, no customer's choice in selecting product, cartel in product due to selected pre-qualified companies |
| Remote Area Development Committee | HMG/N | Providing every support to the very remote community of remote districts of Nepal. Community has to take all responsibilities of management and operations | all non local cost plus transportation has been supported by RADC and community contributed voluntary labour | since 1993 | no end-use induced approach, no back up service after installations |
| Annapurna Conservation Area Project | King Mahendra Trust for Nature Conservations | Providing every support to community of project area. Community has to take all responsibilities of management and operations | most of the cost plus transportation has been supported by ACAP and community contributed voluntary labour | 1995 | no strong particiaptory approach to include, women, backward community equialy |

| | | | | | |
|---|---|---|---|---|---|
| Rural Energy Development Programme | UNDP | With holistic approach through community mobilization. Facilitating communities to take decisions from the beginning of planning, implementation and operations | 50% of the non-local cost of the scheme and technical support | 1996/after 2003 WB will support for the schemes | social and institutional issues has been focused strongly than technical component. Intensive end-use oriented, and strong participation from all sectors of society |
| ITDG/Nepal | ITDG | Supporting communities or individual entrepreneur technically | Free technical as well as some finacial support especially for R & D works | | No implementing agency |
| ESAP/AEPC | HMG/N and DANIDA | Provides subsidy to the community as well as private individual as per subsidy policy set by AEPC/HMG under interim rural energy development fund | Rs 70000 for MHP installation plus partial transportation cost according to remoteness | 2000 | just subsidy providing, no participation of community. Subsidy amount is given to directly the manufacturers |
| UMN/DCS | Different international agencies, INGOs | Especially training, research and development work | | 1960s | |
| NGOs (CRT, CECI & others) | Different international agencies, INGOs | Coordination with different government and community organisations | Provides subsidy to MHP of different types as per donors conditions and based on programmes | | CRT is only NGO supporting Ghattas, CECI is also supporting community owned systems |

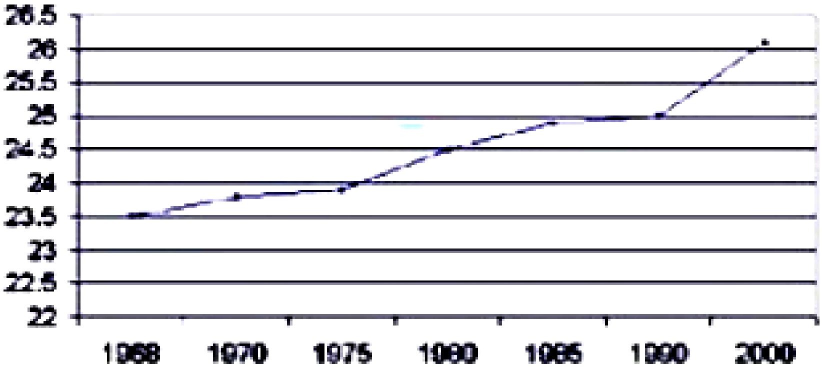
Source: Compiled from ICIMOD (1993), deLucia (1997), Baskota et al (2000), AEPC (2002)

**Annex 3.3 MHP Technology Development Chronology in Nepal**

| Year | Development Endeavor |
|---|---|
| 1960 and before | Different waterwheel of wood and metal, improved grinding devices |
| 1962/64 | Fabrication and installation of first propeller turbine |
| 1973-74 | Development and installation of first cross-flow turbine |
| 1975 | Initiated work on hydraulic governor, development of locally manufactured pelton turbine |
| 1978 | Cross-flow turbine for rural electrification |
| 1979 | Improvement on traditional water wheel |
| 1980 | Manufacturing of Multi-Purpose Power Unit (MPPU), development of open-cross flow turbine |
| 1982 | Development of turgo impulse water turbine, segner's wheel, first electrification through MPPU |
| 1983 | Development of first split-flow turbine, first stand alone electrification unit, add-on generator, development of propeller turbine in scroll case, mini poncelet water wheel |
| 1985/86 | Electric motor converted into induction generator, subsidy for electrical component has been initiated |
| 1990 | Peltric set developed, |
| 1992 | 100 kW stand-alone unit installed, 250 kW Francis turbine manufactured locally, transmission tower tested |
| 1996 | UNDP brought REDP programme for community MHP, His Majesty's govt. started through RADC all with Electronic Load Controller. |
| 1998 | PAT has been tested by KMI and REDP |
| 2000 | Development of Pico Hydro by NHE, DANIDA is providing subsidy to MHP through AEPC. |

*Source: ICIMOD 1993, REDP 1998b, REDP 2000a, and revised by author based on several other information)*

**Annex 4.1 Average maximum temperature measured in Kathmandu Valley in °C**



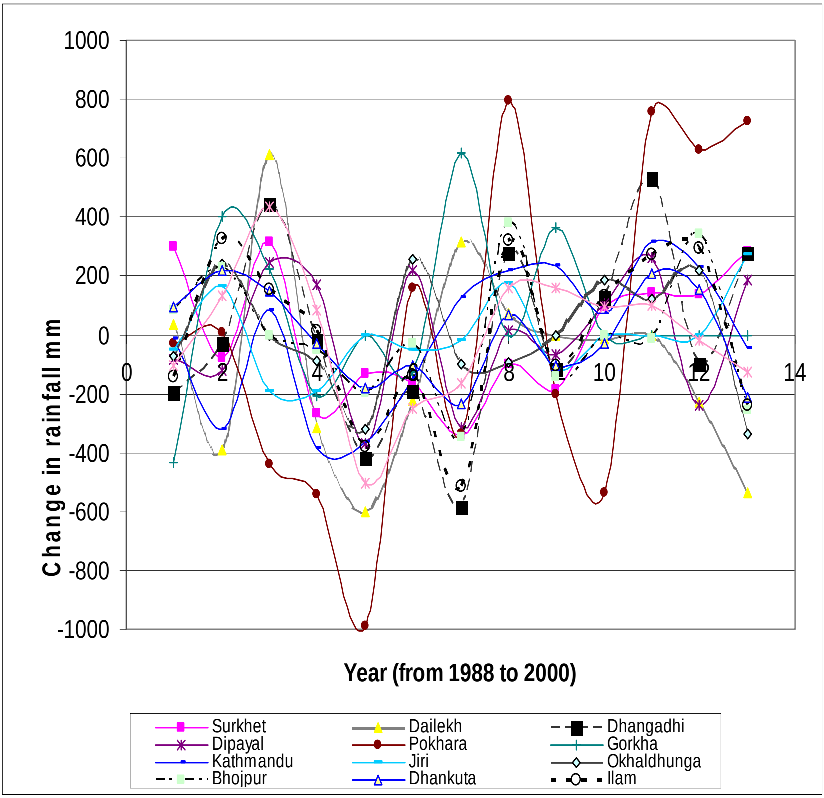

Source: Kantipur (2001)

**<u>Temperature rise in Nepal</u>**

**Citing the recent study conducted by the Department of Hydrology and Metrology (DHM) of Nepal, Director General Dr. Adarsha Pokharel mentioned that the temperature in Himalayas is rising at the rate of 0.12 degree Celsius, in mid hills at the rate of 0.03 degree Celsius and in Terai (plain areas) at the rate of 0.06 degree Celsius in Nepal. Dr. Pokharel said, " If the temperature continues to rise at this rate the situation will be horrible…unimaginable." The finding, according to him, is based on the analysis of last two decades' metrological data recorded by DHM's 45 metrological stations across the country.**

**Source: Abstracted from *Surendra Phuyal, The Kathmandu Post April 20, 2001***

**Annex 4.2 Change in rainfall in the hilly and mountainous rain measuring stations of Nepal**




Source: Compiled and put into graph based on CBS (1999 and 2002a)

**Annex 5.1 : Consumption of Petroleum Products and Export Value of the Commodities**

| Year / Description | 1987/88 | 1988/89 | 1989/90 | 1990/91 | 1991/92 | 1992/93 | 1993/94 | 1994/95 | 1995/96 | 1996/97 | 1997/98 | 1998/99 | 1999/2000 | 2000/01 | 2001/02 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Petrol | 15609 | 17340 | 14708 | 17241 | 26780 | 29910 | 31056 | 34942 | 41191 | 44889 | 46939 | 49994 | 55589 | 59245 | 63271 |
| High speed Diesel | 73321 | 75356 | 103273 | 106438 | 2E+05 | 179900 | 2E+05 | 227226 | 250504 | 3E+05 | 300604 | 315780 | 310561 | 326060 | 286233 |
| Kerosene Oil | 51835 | 63246 | 95672 | 75939 | 1E+05 | 149237 | 2E+05 | 180536 | 208720 | 2E+05 | 282026 | 294982 | 331120 | 316381 | 386593 |
| Llight diesel Oil | 5719 | 6074 | - | 2476 | 2542 | 1530 | - | 4191 | 4375 | 2017 | 967 | 547 | 4005 | 3418 | 2413 |
| Furnace Oil | 7435 | 6836 | - | 6209 | 11062 | 20222 | 27319 | 31567 | 18449 | 16858 | 27776 | 33860 | 26876 | 20999 | 18255 |
| Aircraft Turbine Oil | 19698 | 16244 | 9327 | 16541 | 24836 | 29210 | 30250 | 37536 | 40621 | 47688 | 51412 | 55549 | 56849 | 63130 | 47453 |
| L.P. Gas | 422 | 443 | - | 253 | 312 | 386 | - | - | - | - | - | - | - | 40102 | 48757 |
| **Total** | **174,039** | **190,873** | **222,980** | **225,097** | **363,935** | **410,395** | **446,749** | **516,331** | **563,860** | **611,692** | **709,724** | **750,712** | **785,000** | **829,335** | **852,975** |
| **Value (Rs. in Million)** | **972** | **841** | **2,178** | **3,026** | **4,411** | **4,109** | **4,971** | **535** | **632** | **745** | **1,032** | **1,114** | **1,462** | **1,869** | **1,812** |
| **Import of petrolum products/commodity export (%)** | **23.6** | **26.6** | **42.2** | **40.9** | **32.2** | **23.8** | **25.8** | **30.30** | **31.80** | **32.90** | **37.60** | **31.21** | **29.30** | **33.60** | **-** |

Source: Compiled from HMG/N (2003)

**Annex 5.2 Resource drain to import kerosene**

| Fiscal Year | 1997/98 | 1998/99 | 1999/00 | 2000/01 | 2001/02 | Total | Average US$ |
|---|---|---|---|---|---|---|---|
| Import Value in US$ million | 48.21 | 49.08 | 108.29 | 196.85 | 105.08 | 507.51 | 0.31 |
| Kerosene in million Liter | 287.595 | 298.351 | 350.196 | 325.198 | 386.59 | 1647.93 | per Liter |

Source: NOC (2002)

**Annex 5.3 Kerosene and dry cells consumption in few villages in Nepal**

| VDCs/ Districts | Kerosene consumed in liter | Battery consumed in pairs | Kerosene exp/HH in Rs. | Battery Exp/HH in Rs | Expense Rs/HH/ year | Nos. of HH using MHP | Nos. of HH interviewed |
|---|---|---|---|---|---|---|---|
| Bima/Myagdi | 3.10 | 2.50 | 71.30 | 50.00 | 1455.60 | 48 | 15 |
| Arman/Myagdi | 4.09 | 2.64 | 85.91 | 65.91 | 1821.84 | 82 | 15 |
| Marang/Myagdi | 3.00 | 2.00 | 78.00 | 56.00 | 1608.00 | 272 | 15 |
| Lulang/Myagdi | 2. 76 | 2.33 | 69.78 | 60.86 | 1567.68 | 252 | 15 |
| Okharbot/Myagdi | 2.98 | 2.60 | 52.25 | 64.33 | 1398.96 | 264 | 110 |
| Bhuktangle/Parbat | 3.56 | 2.89 | 56.89 | 70.94 | 1533.96 | 258 | 15 |
| Sarkuwa/Baglung | 3.14 | 2.86 | 50.29 | 68.57 | 1426.32 | 290 | 15 |
| Taman/Baglung | 3.20 | 4.11 | 64.07 | 102.83 | 2002.80 | 200 | 209 |
| Sirsha/Dadeldhura | 3.81 | 2.93 | 56.12 | 74.59 | 1568.52 | 129 | 99 |
| Thampalkot/ Sindhupalchowk | 2.40 | 2.20 | 38.67 | 48.67 | 1048.08 | 271 | 270 |
| Average | 3.24 | 2.76 | 62.33 | 66.27 | 1543.18 | | |

Source: Author

**Annex 5.4 No. of employment in petrolum transportation, management and marketing in Nepal**

| Details | Permanent transporter vehicle | Adhoc transporter vehicle | General dealer | Packed dealer | Kerosene dealer | Employee | **Total employment** |
|---|---|---|---|---|---|---|---|
| No. | 811 | 168 | 903 | 334 | 747 | 507 | |
| No. of person engaged in a unit | 2 | 2 | 4 | 2 | 1 | | Persons/Year |
| No. of possible person engaged* | 1,622 | 336 | 3,612 | 668 | 747 | 507 | 7,492 |

* Based on interaction with dealers on the no. of average employment in each unit
Source: Author's compilation and analysis based on NOC (2002) and field interaction

| | | |
|---|---|---|
| **Total employment related to kerosene fuel management** | **1980** | **per Year** |
| ***Employment related to the use of kerosene in rural areas*** | ***769*** | ***per Year*** |
| *Kerosene consumed in the country in KL* | **360,000** | ***per Year*** |
| ***Kerosene consumed in rural areas of the country in KL*** | **136,563** | ***per Year*** |
| *Job/employment provided per liter in the country* | **0.000014** | ***per Year*** |
| ***Job/employment provided per liter in rural areas*** | **0.000006** | ***per Year*** |
| Job/employment opportunity from kerosene consumed by 10 HH | ***0.0022*** | ***per Year*** |

**Analysis**: looking at the figure the employment opportunity offered by kerosene is very small. Even if it is considered that 50% transportation is covered by kerosene, then 1980 no. of employment opportunity is offered by kerosene. If it is assumed , as per discussion in chapter five, 38.81% kerosene is consumed by rural population then the employment opportunities offered by this rural sector is only 769 per year. 10 HH is taken to compare with one kW of MHP, which is, on the average, consumed by 10 hh.

| | | |
|---|---|---|
| Comparing with MHP implementation, the job opportunity difference | 0.9978 | ***See chapter six for details*** |
| Comparing with MHP O & M after installation, the difference | 0.2478 | |

***Monetarily the difference will be***

| | | |
|---|---|---|
| **Comparing with MHP implementation, the job opportunity difference** | **25,061** | **Rs. per Year** |
| **Comparing with MHP O & M after installation, the difference** | **6,224** | **Rs. per Year** |

**Bringing it per HH figure (10 HH per kW)**

| | | |
|---|---|---|
| **Comparing with MHP implementation, the job opportunity difference** | 2,506 | **Rs. per Year** |
| **Comparing with MHP O & M after installation, the difference** | 622 | **Rs. per Year** |

**Annex 5.5 Salary paid to the staffs in community owned systems**

| Scheme/District | Capacity kW | Operators 1 | Operator II | Manager I | Manager II |
|---|---|---|---|---|---|
| | | in Rs. | in Rs. | in Rs. | |
| Roshikhola/Kavre | 8 | 1,500 | - | - | |
| Daunekhola/Kavre | 12 | 1,000 | - | 1,000 | |
| Chakhola/Kavre | 16 | 3,000 | 1,500 | 1,000 | |
| Chaurikhola/Kavre | 22 | 2,000 | 2,000 | 2,000 | |
| Chauriganga/Kavre | 22 | 2,000 | - | 2,000 | |
| Budhakhani | 21 | 1,500 | - | 1,500 | |
| Khanikhola/Kavre | 23 | 2,000 | 1,500 | 1,000 | |
| Chaurikhola III/Kavre | 22 | 2,500 | 2,500 | 2,500 | |
| Ghattekhola/Parbat | 16 | 2,700 | 2,700 | 2,300 | |
| Bachchhakhola I/Parbat | 19 | 3,100 | - | 3,000 | |
| Bachchhakhola II/Parbat | 11 | 1,600 | 1,200 | - | |
| Chharchharekhola/Parbat | 9 | 2,500 | - | 2,000 | |
| Chhaharekhola/Parbat | 6 | 2,200 | - | 2,200 | |
| Thadokhola/Parbat | 27 | 2,700 | 1,000 | 1,800 | 1,000 |
| Sanimkhola/Myagdi | 8 | 3,000 | 900 | 1,000 | |
| Mahakhola/Myagdi | 11 | 1,500 | - | 1,500 | |
| Darakhola I/Myagdi | 50 | 4,800 | 4,800 | 2,500 | |
| Dajungkhola/Myagdi | 30 | 2,800 | 2,800 | 2,800 | |
| Darakhola II/Myagdi | 25 | 2,200 | 2,200 | 2,225 | |
| Taman/Baglung | 24 | 2,500 | 2,500 | - | Voluntary |
| Barshakhola/Tanahun | 23 | 1,500 | 1,500 | 1,500 | |
| **Average Rs./month** | **2,093** | **Average Rs./Year** | | | **25,116** |

Source: Author

**Annex 5.6 Fuelwood collection time and quantity per month**

| VDC/district | Distance from Road head | Avg. Size of HH | Avg time consumed for fuelwood collection hr/month/HH | | | Fuelwood consumed per month |
|---|---|---|---|---|---|---|
| | Hr. | No. | Male | Female | Total | Kg |
| Bima/Myagdi | 12 | 5.45 | 57.27 | 76.36 | 133.64 | 290.00 |
| Arman/Myagdi | 8 | 7.91 | 47.73 | 43.64 | 91.36 | 424.55 |
| Marang/Myagdi | 16 | 4.63 | 22.50 | 86.50 | 109.00 | 350.00 |
| Lulang/Myagdi | 18 | 5.75 | 145.00 | 150.00 | 295.00 | 415.42 |
| Okharbot/Myagdi | 12 | 8.42 | 76.42 | 123.00 | 199.42 | 477.00 |
| Bhuktangle/Parbat | 4 | 5.22 | 136.67 | 102.00 | 238.67 | 350.56 |
| Sarkuwa/Baglung | 5 | 5.86 | 67.14 | 273.57 | 340.71 | 273.57 |
| Taman/Baglung | | 5.92 | 94 | 118 | 212.00 | 477 |
| Thampalkot/ Sindhupalchowk | | 6.01 | 72 | 104 | 176.00 | 186 |
| **Average** | | **6.13** | **80** | **120** | **200** | **360** |

Source: Author

**Annex 6.1 Ecological impacts of few MHP schemes in Nepal**

| S.N. | MHP Schemes | Capacity | Districts | Impacts due to civil components |
|---|---|---|---|---|
| 1 | Ghattekhola | 16 kW | Parabt | No impacts on existing paddy field |
| 2 | Bachchakhola I | 19 kW | Parbat | No impacts on paddy field, water right conflict were resolved by community |
| 3 | Bachchakhola II | 11 kW | Parbat | Existing irrigation canal used |
| 4 | Chharcharekhola | 9 kW | Parbat | No impacts on existing paddy field, forest and other structure |
| 5 | Chhaharekhola | 6 kW | Parbat | No impacts on existing paddy field, forest and other resources |
| 6 | Thadokhola | 27 kW | Parbat | No impacts on existing paddy field, forest and other structure |
| 7 | Aguwakhola | 12 kW | Parbat | Existing canal used, improved irrigation after construction |
| 8 | Darakhola I | 50 kW | Myagdi | New canal, improved irrigation for small paddy field |
| 9 | Darakhola II | 25 kW | Myagdi | No impacts, improved protection from flood, paddy field used for powerhouse |
| 10 | Bagarkhola | 35 kW | Myagdi | No impacts on forest, improved protection for landslide, flood. Minor impacts on maize fields due to canal |
| 11 | Dajungkhola | 30 kW | Myagdi | No impacts on forest, extension of existing canal, stabilization of areas around power house and afforestation |

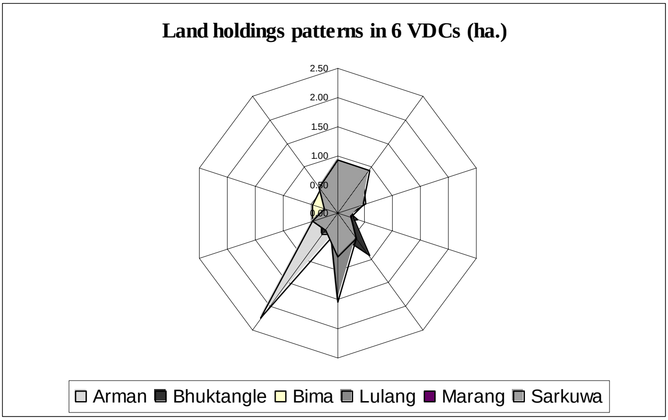
Source: Author (Based on interaction and interview with REDS-Prabat and Myagdi staffs, Community members and community mobilizers and own observations)

**Annex 6.2 Ecological benefits (GHG) from end-uses in Thampalkot in Sindhupalchowk**

| Activities | Consumption before/would have been consumed | Amount consumed after | Saving of fossil fuel liter/ year liter | CO2 ton/year | Remarks |
|---|---|---|---|---|---|
| Industry | Even if MHP were not installed, it is assumed that these activities would have been done | 140 GJ | 3,691 | 9.904 | Assuming diesel could have been used in the absence of electricity |
| Commercial | | 8 GJ | 211 | 11.059 | |
| Total | | | 3,902 | 20.961 | |
| Emission per HH (for two scheme 486 HH) | | | | 0.043 | |

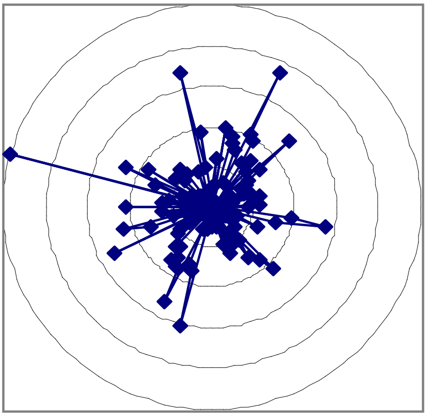
Source: Author

**Annex 6.3 Justifications of classification of rural households**

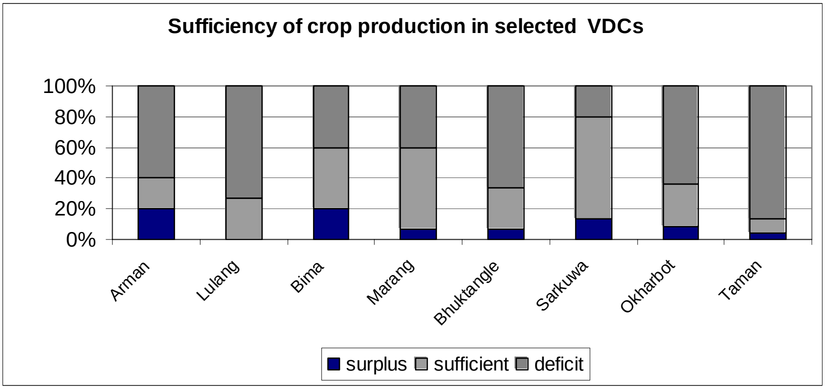



(The land holding pattern shows that majority of the people are having less than 0.5 hector land and others are having less than 1 hector. Only very few people have more than one hectare)
Source: Author

**Land Holding Patterns in Okharbot**

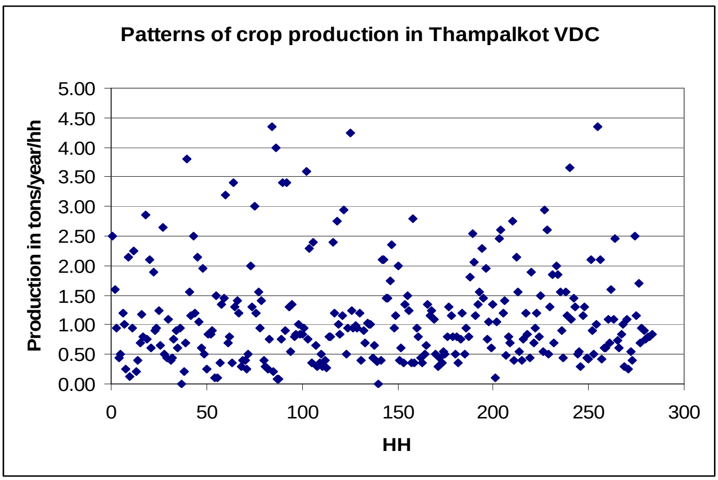


Source: Author

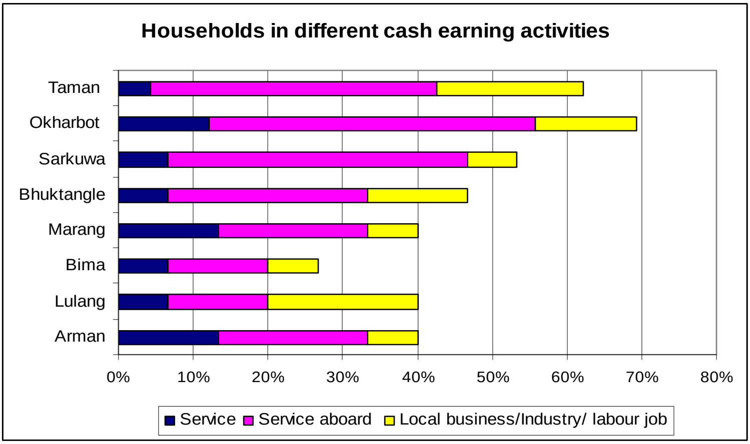



Source: Author (from sampled households from MHP beneficiaries)

(Comments: There are three groups, a very few group has surplus food among the sampled families. A large percentage is in food deficit. 20% to almost 85% people in the villages have shortage of food. However, among these three groups a few are also earning the cash from different activities. So division of households can be done several ways in several parts but in our perspective diving into three groups is sufficient to analyze.)




Source: Author (the size of family is on the average 6.01 members)




Source: Author
(A Few cash earning business are done simultaneously with agriculture. Traditional agriculture is not included in cash earning activities. There are sometimes two or more members from a family doing cash earning activities other than agriculture but only nos. of households were counted. Service means government, semi government or NGO and INGOs jobs. Service abroad includes also the seasonal laborers going to India)

**Annex 6.4 Expenses before and after MHP installation in few VDCS in Myagdi**

| VDC | kW | Cost | Beneficiaries HH | Lighting expenses before/HH | Lighting expenses now/HH |
|---|---|---|---|---|---|
| Okharbot | 30 | 3,088,732 | 264 | 1398.96 | 756.73 |
| Lulang | 25 | 3,257,686 | 254 | 1567.68 | 628.68 |
| Muna | 50 | 5,137,024 | 437 | 1298.16 | 611.78 |
| Chimkhola | 35 | 3,760,657 | 284 | 1610.28 | 830.32 |
| Arman | 11 | 1,229,168 | 82 | 1821.84 | 1053.66 |

Source: Author

**Annex 6.5 Employment in community owned MHPs**

| Schemes/District | Plant Capacity kW | Operators | Manager |
|---|---|---|---|
| Daunekhola/Kavre | 12 | 1 | 1 |
| Chakhola/Kavre | 16 | 2 | 1 |
| Chaurikhola/Kavre | 22 | 2 | 1 |
| Chauriganga/Kavre | 22 | 1 | 1 |
| Budhakhani/Kavre | 21 | 1 | 1 |
| Khanikhola/Kavre | 23 | 2 | 1 |
| Chaurikhola III/Kavre | 22 | 2 | 1 |
| Ghattekhola/Parbat | 16 | 2 | 1 |
| Chhaharekhola/Parbat | 6 | 2 | 1 |
| Thadokhola/Parbat | 27 | 2 | 2 |
| Sanimkhola/Myagdi | 8 | 2 | 1 |
| Mahakhola/Myagdi | 11 | 1 | 1 |
| Darakhola I/Myagdi | 50 | 2 | 1 |
| Dajungkhola/Myagdi | 30 | 2 | 1 |
| Darakhola II/Myagdi | 25 | 2 | 1 |
| Taman/Baglung | 24 | 2 | 1 |
| Barshakhola/Tanahun | 23 | 2 | 1 |
| Average | | **2** | **1** |

Source: Author

**Annex 6.6 Macroeconomic indicators: GDP, inflation, etc. in Nepal**

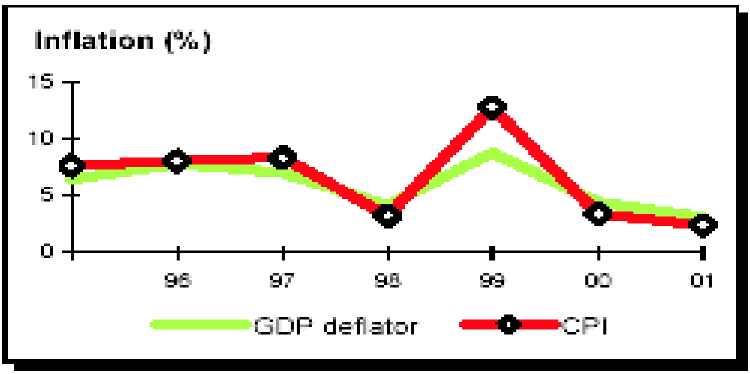
| Year | 1998/99 | 1999/00 | 2000/01 | 2001/02 | 2002/03 | 2003/04 |
|---|---|---|---|---|---|---|
| GDP (% change) | 4.5 | 6.2 | 5.1* | 2.5* | 6.2* | 6.2* |
| Agricultural GDP (% change) | 2.7 | 5.0 | 4.0 | 1.5 | 4.1 | 4.1 |
| Non-agricultural GDP (% change) | 5.7 | 6.9 | 5.9 | 3.2 | 7.3 | 7.4 |
| Fiscal Deficit* (after grants) | 5.2 | 4.7 | 5.6 | 6.3 | 5.2 | 5.0 |
| Revenue* | 11.3 | 11.8 | 12.1 | 12.1 | 12.1 | 12.4 |
| National Savings*@ | 17.8 | 19.3 | 20.1 | 20.3 | 20.5 | 20.7 |
| Investment* @ | 20.5 | 23.7 | 25.6 | 27.0 | 27.4 | 27.6 |
| Inflation | 11.4 | 3.4 | 2.4 | 5.0 | 5.0 | 5.0 |

***Inflation 5.37 average***

* *Percent of GDP*

@ *These numbers may not tally with other publications, because of different methodology used (Source: CBS).*

Source: NPC (2002): concept paper on perspective 10th Plan (http:// www.npc.gov.np)




Source: The World Bank (2002) (www.worldbank.org)

**Annex 6.7: Details of few community owned MHP systems in Nepal**

| MHP scheme /District | Capa-city kW | Benefited HH | Investment in NRs.[1] | Cost/kW in NRs. | Distance from road head in Hr. | Year of commission |
|---|---|---|---|---|---|---|
| Ardoli Gad /Achham | 15 | 140 | 1,822,707 | 121,514 | 10 | 2000 |
| Tamankhola/ Baglung | 20 | 200 | 2,326,327 | 116,316 | 50 | 1999 |
| Baga Gad / Baitadi | 20 | 158 | 2,397,981 | 119,899 | 15 | 1998 |
| Sirse Gad / Dadeldhura | 22 | 129 | 2,628,000 | 119,455 | 3 | 1999 |
| Kaptikhola / Dolakha | 25 | 234 | 2,160,707 | 86,428 | 20 | 2000 |
| Parvatikhola/ Kavre | 20 | 150 | 1,967,642 | 98,382 | 40 | 2001 |
| Dharakhola II/ Myagdi | 25 | 254 | 3,217,684 | 130,307 | 25 | 2001 |
| Thadokhola/ Parbat | 27 | 258 | 2,847,390 | 105,459 | 5 | 2000 |
| Handikhola II/ Sindhu. | 26 | 275 | 2,167,164 | 83,352 | 7 | 2001 |
| Cherangakhola/ Tanahun | 35 | 223 | 3,749,473 | 107,128 | 12 | 1999 |
| **Average** | | | | 108,824 | | |

*Source: REDP (2000a), Author's collection from field and through email from the REDP head office in Kathmandu.*

[1] Non local cost only, excluding voluntary labor.

**Annex 6.8 Different end-uses technology and services after electrification of the villages**

| Scheme | Capacity kW | Types of End-use | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Agro-Mills | Saw-mill | Poultry | Video | Battery charging | Others | Total |
| Tangram/Baglung | 17 | | | 1 | 1 | | 1 | 3 |
| Charchhare/Parbat | 9 | | | 3 | 1 | 1 | | 5 |
| Mahakhola/Myagdi | 11 | 1 | | 1 | | | | 2 |
| Dajungkhola/Myagdi | 30 | 2 | 1 | 1 | 2 | | | 6 |
| Darakhola I/Myagdi | 50 | 3 | | 1 | 1 | | 1 | 6 |
| Darakhola II/Myagdi | 25 | 2 | | 1 | 1 | | | 4 |
| Bagarkhola/Myagdi | 35 | 1 | | 1 | 1 | | 1 | 4 |
| Thampalkot/Sindhupal chowk (Two schemes) | 20+26 | 2 | 1 | 1 | | 1 | 3 | 8 |
| Bhuktangle/Parbat | 27 | 2 | | 1 | | | 1 | 4 |
| Taman/Baglung | 20 | 1 | | 1 | | | 2 | 4 |
| Barshakhola/Tanahun | 23 | 1 | | 3 | 1 | | | 5 |

Source: Author

**Annex 6.8 Small-scale industries and commercial activities after MHP**

| Project Site/District | Industrial activities no. | Commercial activities no. | Plant capacity, in kW |
|---|---|---|---|
| Mahakhola/Myagdi | 1 | 2 | 11 |
| Dajungkhola/Myagdi | 3 | 3 | 30 |
| Darakhola I/Myagdi | 3 | 3 | 50 |
| Darakhola II/Myagdi | 2 | 2 | 25 |
| Thampalkot/Sindhupal chowk (Two schemes) | 4 | 4 | 46 |
| Bhuktangle/Parbat | 2 | 2 | 20 |
| Taman/Baglung | 2 | 2 | 20 |
| Kota/Tanahun | 4 | 2 | 23 |

Source: Author

**Annex 6.9 Socio-economic condition of the Okharbot VDC, Myagdi**

| | |
|---|---|
| Households: 369, and only 264 households have access to electricity from Dajungkhola MHP, whereas others have either solar, peltric set or still in process. | |
| Population | 2483 |
| Malnutrition | 51.3% |
| Food insufficiency (Those who can manage only less than 6 Months) | 29.3% |
| Cooking fuel: fuel wood | 99.2% |
| Agriculture land | 0.7 ha/HH |
| Lighting (before) by kerosene | 96% HH |
| Average kerosene in Litre/Year/HH | 35.36 |
| Battery needed per year | 31.2 pairs |
| Crop production/HH | 1.06 Metric Ton |
| Bronchitis diseases | 10.9% people suffering |
| Life expectancy national average in 1998 | 58 Years |
| Adult education of VDC | 9.1 % |
| Combined primary, secondary and tertiary literacy | 53.5% |
| Income in NRs. | 10,992 as per data of DDC office |
| PPP $ income of the people | 779.12 |
| HDI | 0.300 |

Source: (Data Compiled from DDC Myagdi Monthly Progress Reports of REDS (2002) and questionnaire survey, CBS (2002a) and DDC/Myagdi n.d.)

## Annex 6.9 Details of Dajungkhola MHP (Okharbot VDC) in Myagdi

| Kw | 30 | HH | 264 |
|---|---|---|---|
| **Investment** | **Local (voluntary) Rs.** | **Non-Local Rs.** | **Total Rs.** |
| Civil Cost | 340,190 | 465,519 | 805,709 |
| Mech Cost | | 433,770 | 433,770 |
| Elect Cost | | 1,362,000 | 1,362,000 |
| Extra Elect/Mech Cost | | - | - |
| Distribution Lines | | 200,250 | 200,250 |
| Poles | 22,500 | 334,550 | 357,050 |
| Installation Cost | | 170,000 | 170,000 |
| Transport Cost | 269,000 | 76,580 | 345,580 |
| Design and Tech Cost | | 7,000 | 7,000 |
| Contingencies | | 39,063 | 39,063 |
| **Total** | **631,690** | **3,088,732** | **3,720,422** |

| Investment Mechanism | in Rs. | Contribution | Rs. | Percentage |
|---|---|---|---|---|
| Subsidy from REDP | 1,419,394 | Govt/Donor | 2,267,824 | 61% |
| VDC investment | 530,756 | Local Authorities | 680,756 | 18% |
| DDC Investment | 150,000 | Community | 708,272 | 19% |
| HMG Subsidy | 848,430 | Loan | 63,570 | 2% |
| Loan | 63,570 | **Total Rs.** | 3,720,422 | 100% |
| Cash by community | 76,580 | | | |
| Local Contribution of labour | 442,692 | | | |
| Local Donation | 189,000 | | | |
| **Total Rs.** | 3,720,422 | | | |

| ***Income*** | **Rate Rs.** | **Monthly** | **Yearly (Rs.)** |
|---|---|---|---|
| From Lighting | Rp0.80 | - | **199,776** |
| Enduses | | | |
| Mill - Nos. 3 | 500 | 1,500 | 18,000 |
| Poultry - Nos. 1 | 500 | 500 | 6,000 |
| Video - Nos. 2 | 500 | 1,000 | 12,000 |
| **Total Income** | | | **235,776** |
| ***Expenses*** | | | |
| Operator | 2,800 | 5,600 | 67,200 |
| Manager | 2,800 | 2,800 | 33,600 |
| R & M ) | | | 59,535 |
| **Total expenses** | | | **160,335** |
| ***Profit (Net Income) Rs./Year*** | | | **75,441** |

***Actual situation in the project site***

| Particulars | Lighting | End-uses | Total |
|---|---|---|---|
| Revenue collected Rs./year | 199,776 | 36,000 | 235,776 |
| Operation (Salary) Rs./year | 100,800 | - | 100,800 |
| Maintenace Rs./year | 59,535 | - | 59,535 |
| Net Income Rs./year (actual) | | | 75,441 |

## Annex 6.9 Details of Bagarkhola MHP(Chimakhola VDC) in Myagdi, Nepal

| Kw | 35 | Beneficiary HH | 284 | **Contribution of stakeholders** | | |
|---|---|---|---|---|---|---|
| **Investment (all in Rs.)** | **Local** | **Non-Local** | **Total** | *Contributions* | Rs. | Percentage** |
| Civil Cost | 342,506 | 941,896 | 1,284,402 | *Govt/Donor* | 2,155,781 | 52.01% |
| Mech Cost | | 419,010 | 419,010 | *Local Authorities* | 991,400 | 23.92% |
| Elect Cost | | 1,113,700 | 1,113,700 | *Community* | 1,206,991 | 29.12% |
| Extra Elect/Mech Cost | | - | - | *Loan** | - | 0.00% |
| Distribution Lines | | 353,550 | 353,550 | *Total* | 4,354,172 | |
| Poles | 62,111 | 227,953 | 290,064 | | | |
| Installation Cost | | 127,500 | 127,500 | *(Due to higher contribution from stakeholders | | |
| Transport Cost | 40,000 | 420,489 | 460,489 | and surplus of money collected community di | | |
| Design and Tech Cost | | 50,347 | 50,347 | not take loan | | |
| Contingencies | | 46,212 | 46,212 | ** of investment cost | | |
| **Total** | 444,617 | 3,700,657 | 4,145,274 | | | |

| **Investment Mechanism** | **Rs.** | **Income and expenditure (In Rs.)** | | | | |
|---|---|---|---|---|---|---|
| Subsidy from REDP/UNDP | 1,481,878 | ***Income*** | | **Rate** | **Monthly** | **Yearly** |
| VDC investment | 845,000 | From Lighting | | Rp1.00 | | 209,490 |
| DDC Investment | 146,400 | End-uses- Mill | 2 | 500 | 1,000 | 12,000 |
| HMG Subsidy | 673,903 | Poultry | 2 | 400 | 800 | 9,600 |
| Loan | - | Video | 2 | 500 | 1,000 | 12,000 |
| Cash by community | 762,374 | **Total** | | | 2,800 | 304,865 |
| Local Contribution of labor | 444,617 | ***Expenses*** | | | | |
| | 4,354,172 | Operator | 2 | 3,000 | 6,000 | 72,000 |
| | | Manager | 1 | 1,700 | 1,700 | 20,400 |
| | | R & M | | | | 51,989 |
| | | **Total** | | | | **144,389** |
| | | **Profit (Net Income)** | | | | **160,476** |

## Annex 6.9 Details of Darakhola-II MHP(Lulang VDC) in Myagdi, Nepal

| Capacity Kw | 25 | Benef. HH | 254 | **Contribution of stakeholders** | | |
|---|---|---|---|---|---|---|
| **Investment (all in Rs.)** | **Local** | **Non-Local** | **Total** | *Contributions* | Rs. | Percentage |
| Civil Cost | 450,942 | 1,133,301 | 1,584,243 | *Govt/Donor* | 2,013,750 | 53.59% |
| Mech Cost | | 382,350 | 382,350 | *Local Authorities* | 931,984 | 24.80% |
| Elect Cost | | 426,587 | 426,587 | *Community* | 524,150 | 13.95% |
| Extra Elect/Mech Cost | | 143,848 | 143,848 | *Loan* | 287,668 | 7.66% |
| Distribution Lines | | 326,325 | 326,325 | *Total* | 3,757,552 | |
| Poles | 49,671 | 187,800 | 237,471 | | | |
| Installation Cost | | 88,000 | 88,000 | | | |
| Transport Cost | - | 407,000 | 407,000 | | | |
| Spareparts & Tools | | 20,000 | 20,000 | | | |
| Design and Tech Cost | | 40,000 | 40,000 | | | |
| Contingencies | | 101,728 | 101,728 | | | |
| **Total** | 500,613 | 3,256,939 | 3,757,552 | | | |

| **Investment Mechanism** | **Rs.** | **Income and expenditure (In Rs.)** | | | | |
|---|---|---|---|---|---|---|
| Subsidy from REDP | 1,029,375 | Income | | **Rate** | **Monthly** | **Yearly** |
| VDC investment | 809,500 | From Lighting | | Rp1.25 | | 277,560 |
| DDC Investment | 122,484 | End-uses | 2 | 1,200 | 2,400 | 28,800 |
| HMG Subsidy | 984,375 | Poultry | 1 | 500 | 500 | 6,000 |
| Loan | 287,668 | Video | 1 | 350 | 350 | 4,200 |
| Cash by community | 24,282 | **Total** | | | 3,250 | 345,685 |
| Local Contribution of labor | 499,868 | Expenditure | | | | |
| | 3,757,552 | Operator | 2 | 2,200 | 4,400 | 52,800 |
| | | Manager | 1 | 2,250 | 2,250 | 27,000 |
| | | R & M | | | | 40,620 |
| | | **Total** | | | | **120,420** |
| | | **Profit (Net Income)** | | | | **225,265** |

Source: Author

## Annex 6.9 Detail of Darakhola-I MHP(Muna VDC) in Myagdi, Nepal

| | | | |
|---|---|---|---|
| Capacity Kw | 50 | Benef. HH | 437 |
| **Investment (all in Rs.)** | **Local** | **Non-Local** | **Total** |
| Civil Cost | 782,371 | 1,847,087 | 2,629,458 |
| Mech Cost | | 884,350 | 884,350 |
| Elect Cost | | 859,030 | 859,030 |
| Extra Elect/Mech Cost | | 220,361 | 220,361 |
| Distribution Lines | | 506,800 | 506,800 |
| Poles | | 240,242 | 240,242 |
| Installation Cost | | 281,904 | 281,904 |
| Transport Cost | 171,000 | 121,655 | 292,655 |
| Spareparts & Tools | | 25,000 | 25,000 |
| Design and Tech Cost | | 80,000 | 80,000 |
| Contingencies | | 70,595 | 70,595 |
| **Total** | 953,371 | 5,137,024 | 6,090,395 |

| **Investment Mechanism** | **Rs.** |
|---|---|
| Subsidy from REDP | 2,083,750 |
| VDC investment | 606,795 |
| DDC Investment | 278,990 |
| HMG Subsidy | 1,968,750 |
| Loan | 104,140 |
| Cash by community | 94,601 |
| Local Contribution of labor | 953,370 |
| **Total** | 6,090,396 |

| **Contributions of stakeholders** | | |
|---|---|---|
| ***Contributions*** | **Rs.** | **Percentage** |
| *Govt/Donor* | 4,052,500 | 66.54% |
| *Local Authorities* | 885,785 | 14.54% |
| *Community* | 1,047,971 | 17.21% |
| *Loan* | 104,140 | 1.71% |
| ***Total*** | 6,090,396 | |

| **Income and expenditure (In Rs.)** | | | | |
|---|---|---|---|---|
| ***Income*** | | **Rate** | **Monthly** | **Yearly** |
| From Lighting | | Rp1.00 | | 277,560 |
| End-uses- Mill | 3 | 1,000 | 3,000 | 36,000 |
| Poultry | 1 | 500 | 500 | 6,000 |
| Video | 2 | 500 | 1,000 | 12,000 |
| **Total** | | | 4,500 | 331,560 |
| ***Expenses*** | | | | |
| Operator | 2 | 2,200 | 4,400 | 52,800 |
| Manager | 1 | 2,250 | 2,250 | 27,000 |
| R & M | | | | 110,400 |
| **Total** | | | | **190,200** |
| **Profit (Net Income)** | | | | **141,360** |

## Annex 6.10 Economic analysis of few MHP projects in Nepal considering "subsidy externalities"

| Scheme/District | Capacity of plant kW | Beneficiaries HH | Investment cost in Rs. | Investment/HH | Revenue Rs./Year | Expenses Rs./Year | Income/ HH/Yr | Discounted investment Rs./HH per year | | | | Benefits in Rs. to households as an invester | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Total | Total | | without | with 5.5% | with 12% | with 1% | without | with 5.5% | with 12% | with 1% |
| Bagarkhola/ Myagdi | 35 | 284 | 3,700,657 | 13,030 | 243,090 | 144,389 | 348 | 652 | 1,090 | 1,745 | 722 | 63 | - 376 | - 1,030 | - 8 |
| Mahakhola/ Myagdi | 10 | 82 | 1,206,043 | 14,708 | 85,440 | 49,608 | 437 | 735 | 1,231 | 1,969 | 815 | 68 | - 427 | - 1,165 | - 11 |
| Darakhola I /Myagdi | 50 | 437 | 5,137,024 | 11,755 | 331,560 | 190,200 | 323 | 588 | 984 | 1,574 | 651 | 103 | - 293 | - 883 | 39 |
| Darakhola II /Myagdi | 25 | 254 | 3,256,939 | 12,823 | 186,684 | 120,420 | 261 | 641 | 1,073 | 1,717 | 711 | - 13 | - 445 | - 1,089 | - 83 |
| Charcharekhola /Parbat | 9 | 90 | 1,325,526 | 14,728 | 83,400 | 58,284 | 279 | 736 | 1,232 | 1,972 | 816 | - 90 | - 587 | - 1,326 | - 170 |
| Chakhola/ Kavre | 16 | 148 | 1,799,357 | 12,158 | 127,200 | 111,900 | 103 | 608 | 1,017 | 1,628 | 674 | -138 | - 547 | - 1,157 | - 203 |

Source: Author

## Annex 6.10 Economic analysis of few MHP projects in Nepal considering "pecuniary externalities"

| Name of the scheme/District | Capacity of plant kW | Beneficiaries HH | Investment cost in Rs. | Investment/HH in Rs. | Revenue Rs./Year | Expenses Rs./Year | Income Rs./HH/Yr | Discounted investment Rs./HH per year | | | | Benefits in Rs. to households as an invester | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Total | Total | | without | with 5.5% | with 12% | with 16% | without | with 5.5% | with 12% | with 16% |
| Bagarkhola/ Myagdi | 35 | 284 | 3,700,657 | 13,030 | 243,090 | 144,389 | 348 | 652 | 1,090 | 1,745 | 2,198 | 1,741 | 1,302 | 648 | 195 |
| Mahakhola/ Myagdi | 10 | 82 | 1,206,043 | 14,708 | 85,440 | 49,608 | 437 | 735 | 1,231 | 1,969 | 2,481 | 1,747 | 1,251 | 513 | 1 |
| Darakhola I /Myagdi | 50 | 437 | 5,137,024 | 11,755 | 331,560 | 190,200 | 323 | 588 | 984 | 1,574 | 1,983 | 1,781 | 1,385 | 795 | 386 |
| Darakhola II /Myagdi | 25 | 254 | 3,256,939 | 12,823 | 186,684 | 120,420 | 261 | 641 | 1,073 | 1,717 | 2,163 | 1,665 | 1,233 | 589 | 143 |
| Charcharekhola/ Parbat | 9 | 90 | 1,325,526 | 14,728 | 83,400 | 58,284 | 279 | 736 | 1,232 | 1,972 | 2,484 | 1,588 | 1,092 | 352 | - 160 |
| Chakhola/ Kavre | 16 | 148 | 1,799,357 | 12,158 | 127,200 | 111,900 | 103 | 608 | 1,017 | 1,628 | 2,051 | 1,540 | 1,131 | 521 | 98 |

Source: Author

## Annex 6.11: Financial Analysis of a hypothetical site based on different load factors

**The hypothetical site is based on average data of several MHP sites**

| | | | | |
|---|---|---|---|---|
| Capacity Kw | 20 | HH | 200 | ***at 100watt/HH*** |
| **Investment (all in Rs.)** | **2,176,480** | **at 108,824/kW rate** | | |
| **Income and expenditure (In Rs.)** | | | | |
| **Income** | | **Rs.** | | |
| From Lighting | ***80% consumption*** | 288,000 | ***at Rs. 1/watt/month*** | |
| End-uses | ***% of total power consumption*** | | **Considering different load factor, i.e. utilization of % of power generated for end-uses at the rate of Rs. 5.45/kWh** | |
| **Condition 1** | 10% | 54,500 | | |
| **Condition 2** | 15% | 81,750 | | |
| **Condition 3** | 20% | 109,000 | | |
| **Expenses** Operator | 2 @ 2,500/month | 60,000 | | |
| Manager | 1@ 2250/month | 27,000 | | |
| R & M | 3% of investment | 65,294 | | |

**Financial analysis in Rs.**

| Year | 0 | 1 | 2 | 3 | 19 | 20 |
|---|---|---|---|---|---|---|
| **Total Revenue in condn I** | 0 | 342,500 | 342,500 | 342,500 | 342,500 | 342,500 |
| ***Discounted revenue*** | 0 | 326,190 | 310,658 | 295,864 | 135,539 | 129,085 |
| **Total Revenue in condn II** | 0 | 369,750 | 369,750 | 369,750 | 369,750 | 369,750 |
| ***Discounted revenue*** | | 352,143 | 335,374 | 319,404 | 146,323 | 139,355 |
| **Total Revenue in condn III** | 0 | 397,000 | 397,000 | 397,000 | 397,000 | 397,000 |
| ***Discounted revenue*** | | 378,095 | 360,091 | 342,944 | 157,106 | 149,625 |
| **Total cost (Rs.)** | 2,176,480 | 152,294 | 152,294 | 152,294 | 152,294 | 152,294 |
| ***Discounted cost*** | 2,176,480 | 145,042 | 138,136 | 131,558 | 60,268 | 57,398 |
| | | | | | | |
| **Netcash flow in condn I** | - 2,176,480 | 190,206 | 190,206 | 190,206 | 190,206 | 190,206 |
| **Netcash flow in condn II** | - 2,176,480 | 217,456 | 217,456 | 217,456 | 217,456 | 217,456 |
| **Netcash flow in condn III** | - 2,176,480 | 244,706 | 244,706 | 244,706 | 244,706 | 244,706 |
| | | | | | | |
| **Discount Factor** | **5%** | **6.5%** | **8.0%** | **12.0%** | | |
| | | | | | | |
| ***NPV in condn I*** | 193,902 | - 511,159 | - 727,824 | - 1,151,765 | | |
| ***NPV in condn II*** | 533,497 | - 210,905 | - 460,280 | - 948,223 | | |
| ***NPV in condn III*** | 873,093 | 89,349 | - 192,735 | - 744,681 | | |
| | | | | | | |
| **B/C Ratio in cond I** | 1.05 | 0.88 | 0.82 | 0.69 | | |
| **B/C Ratio in cond II** | 1.13 | 0.95 | 0.89 | 0.74 | | |
| **B/C Ratio in cond III** | 1.21 | 1.02 | 0.95 | 0.80 | | |
| | | | | | | |
| ***IRR in condn I*** | 6.03% | 3.79% | 3.79% | 3.79% | | |
| ***IRR in condn II*** | 7.74% | 5.42% | 5.42% | 5.42% | | |
| ***IRR in condn III*** | 9.37% | 6.95% | 6.95% | 6.95% | | |

**Assuming 10% of generated energy would be used for end-uses paying the tariff similar to NEA i.e. Rs 5.45/kWh. Similarly 80% of the generated power would be connected to consumers charging Rs. 1.00 /watt / month. As households are connected on watt basis for lighting only losses in transmission to certain extent will not be a problem in charging tariff.**

Source: Author

**Annex 6.12 Time consumed in collection or fetching up of kerosene and battery**

| ***Village*** | ***Average time to fetch kerosene and battery*** | ***Remarks*** |
|---|---|---|
| Bima/Myagdi | 1 hr | Few local shops sell nearby but expensive and not adequate, the village is one and half day way from nearest road head |
| Arman/Myagdi | 0.33 hr | Local shops are transporting using porters or mules one day |
| Marang/Myagdi | 0.33 hr | using porters or mules two days |
| Lulang/Myagdi | 0.25 hr | porters or mules need two days |
| Okharbot/Myagdi | 0.5 hr | Transportation duration for porters or mules almost two days |
| Bhuktangle/Parbat | 0.25 hr | porters or mules are used to transport a half day |
| Sarkuwa/Baglung | 0.25 hr | porters or mules are used to transport a half day |
| Taman/Baglung | 0.25 hr | Local shops are transporting using porters or mules almost 3 days |
| Sirsha/Dadeldhura | 3 hr | |
| Thampalkot/Sindhupalchowk | 3.5 hr | |

Source: Author (based on household survey carried out by the REDP/UNDP's district offices)

**Annex 6.13 Financial analysis of Dajungkhola MHP avoiding kerosene subsidy**

| **Capacity Kw** | **30** | **HH** | **264** |
|---|---|---|---|
| **Investment** | **Local Rs.** | **Non-Local Rs.** | **Total Rs.** |
| Civil Cost | 340,190 | 465,519 | 805,709 |
| Mech Cost | | 433,770 | 433,770 |
| Elect Cost | | 1,362,000 | 1,362,000 |
| Extra Elect/Mech Cost | | - | - |
| Distribution Lines | | 200,250 | 200,250 |
| Poles | 22,500 | 334,550 | 357,050 |
| Installation Cost | | 170,000 | 170,000 |
| Transport Cost | 269,000 | 76,580 | 345,580 |
| Design and Tech Cost | | 7,000 | 7,000 |
| Contingencies | | 39,063 | 39,063 |
| **Total investment** | **631,690** | **3,088,732** | **3,720,422** |
| ***Income*** | **Rate Rs.** | **Monthly** | **Yearly (Rs.)** |
| From Lighting | | - | **451,126** |
| Enduses | | | |
| Mill - Nos. 3 | 500 | 1,500 | 18,000 |
| Poultry - Nos. 1 | 500 | 500 | 6,000 |
| Video - Nos. 2 | 500 | 1,000 | 12,000 |
| **Total Income** | | | **487,126** |
| ***Expenses*** | | | |
| Operator | 2,800 | 5,600 | 67,200 |
| Manager | 2,800 | 2,800 | 33,600 |
| R & M | | | 59,535 |
| **Total expenses** | | | **160,335** |
| ***Profit (Net Income) Rs./Year*** | | | **326,791** |

***considering the case mentioned in chapter six, 6.7 condition I***

**When people buy same amount of kerosene even after subsidy avoided and pay the amount that they were paying before plus subsidy amount to MHP**

| **Year** | - | 1 | 2 | 3 | 19 | 20 |
|---|---|---|---|---|---|---|
| **Total Revenue** | - | 487,126 | 487,126 | 487,126 | 487,126 | 487,126 |
| ***Discounted benefit*** | - | 448,964 | 413,792 | 381,375 | 103,389 | 95,290 |
| **Total Expenditure** | 3,088,732 | 160,335 | 160,335 | 160,335 | 160,335 | 160,335 |
| ***Discounted cost*** | 3,088,732 | 147,774 | 136,197 | 125,528 | 34,030 | 31,364 |
| **Netcash Flow** | - 3,088,732 | 326,791 | 326,791 | 326,791 | 326,791 | 326,791 |
| **Discount Factor (8.5%)** | 1.00 | 0.92 | 0.85 | 0.78 | 0.21 | 0.20 |
| NPV | 3,800 | | | | | |
| B/C Ratio | 1.0008 | | | | | |
| IRR | 8.52% | | | | | |

Source: Author

## Annex 6.13 Analysis of Darakhola-II MHP in Myagdi avoiding kerosene subsidy

**Exluding voluntary labour cost from investment cost**

| Capacity Kw | 25 | HH | 254 |
|---|---|---|---|
| **Investment (all in Rs.)** | **Local** | **Non-Local** | **Total** |
| Civil Cost | 450,942 | 1,133,301 | 1,584,243 |
| Mech Cost | | 382,350 | 382,350 |
| Elect Cost | | 426,587 | 426,587 |
| Extra Elect/Mech Cost | | 143,848 | 143,848 |
| Distribution Lines | | 326,325 | 326,325 |
| Poles | 49,671 | 187,800 | 237,471 |
| Installation Cost | | 88,000 | 88,000 |
| Transport Cost | - | 407,000 | 407,000 |
| Spareparts & Tools | | 20,000 | 20,000 |
| Design and Tech Cost | | 40,000 | 40,000 |
| Contingencies | | 101,728 | 101,728 |
| **Total** | 500,613 | 3,256,939 | 3,757,552 |

**When people buy same amount of kerosene even after subsidy avoided and pay the amount that they were paying before plus subsidy amount to MHP**

**Income and expenditure (In Rs.)**

| ***Income*** | | **Rate** | **Monthly** | **Yearly** |
|---|---|---|---|---|
| From Lighting | | Rp0.75 | | 477,195 |
| End-uses Mill | 2 | 1,200 | 2,400 | 28,800 |
| Poultry | 1 | 500 | 500 | 6,000 |
| Video | 1 | 350 | 350 | 4,200 |
| **Total** | | | 3,250 | 516,195 |
| ***Expenses*** | | | | |
| Operator | 2 | 2,200 | 4,400 | 52,800 |
| Manager | 1 | 2,250 | 2,250 | 27,000 |
| R & M | | | | 40,620 |
| **Total** | | | | **120,420** |
| **Profit (Net Income)** | | | | **395,775** |

**Financial analysis**

| **Year** | 0 | 1 | 2 | 3 | 19 | 20 |
|---|---|---|---|---|---|---|
| **Total Revenue (Rs.)** | 0 | 516,195 | 516,195 | 516,195 | 516,195 | 516,195 |
| Discounted benefits | 0 | 469268 | 426607 | 387825 | 84402 | 76729 |
| **Total Expenditure (Rs.)** | 3,256,939 | 120,420 | 120,420 | 120,420 | 120,420 | 120,420 |
| Discounted cost | 3,256,939 | 109,473 | 99,521 | 90,473 | 19,690 | 17,900 |
| **Netcash (Rs.)** | - 3,256,939 | 395,775 | 395,775 | 395,775 | 395,775 | 395,775 |
| **Discount Factor (10%)** | 1.00 | 0.91 | 0.83 | 0.75 | 0.16 | 0.15 |
| **NPV (Rs.)** | 112,516 | | | | | |
| **B/C Ratio** | 1.03 | | | | | |
| **IRR** | 10.50% | | | | | |

Source: Author

## Annex 6.14 Economic analysis of few MHP projects considering increment of kerosene boader price*

| Name of the scheme | Capacity of plant kW | Beneficiaries HH | Investment cost in Rs. | Investment Rs. per HH | Revenue generated in Rs./Year | | | Expenses in Rs./Year | | | NPV Rs. | BCR | IRR % | with no discount project is |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Lighting | End-uses | Total | Salary | O & M and other | Total | increasing kerosene boarder price by 32% and at 5.37% discount rate | | | |
| Bagarkhola/Myagdi | 35 | 284 | 3,700,657 | 13,030 | 209,094 | 24,840 | 243,090 | 92,400 | 51,989 | 144,389 | - 904,965 | 0.83 | 2.23 | feasible |
| Mahakhola/Myagdi | 10 | 82 | 1,206,043 | 14,708 | 81,240 | 4,200 | 85,440 | 32,136 | 17,472 | 49,608 | - 388,980 | 0.78 | 2.06 | feasible |
| Darakhola I /Myagdi | 50 | 437 | 5,137,024 | 11,755 | 277,560 | 54,000 | 331,560 | 79,800 | 110,400 | 190,200 | - 962,221 | 0.87 | 3.81 | feasible |
| Darakhola II /Myagdi | 25 | 254 | 3,256,939 | 12,823 | 147,684 | 39,000 | 186,684 | 79,800 | 40,620 | 120,420 | - 1,022,465 | 0.78 | 1.24 | feasible |
| Charcharekhola/Parbat | 9 | 90 | 1,325,526 | 14,728 | 77,400 | 6,000 | 83,400 | 47,100 | 11,184 | 58,284 | - 585,343 | 0.7 | 0.13 | feasible |
| Chakhola /Kavre | 16 | 148 | 1,799,357 | 12,158 | 127,200 | - | 127,200 | 61,983 | 49,917 | 111,900 | - 868,668 | 0.71 | -0.59 | feasible |

Source: Author

* **Note**: The boarder price kerosene in Nepal is Rs. 21.99 per liter. There is only Rs. 0.30 customs duty per liter. Where as for MHP components its about 32%. The case here is considered that the boarder price of kerosene is increased by 32% charging custom duty as in MHP; and rural people would have been using the same amount of kerosene despite increased price (because consumption level is subsistence, i.e. minimum requirement), now these people pay that increased amount to MHP plus their usual tariff (i.e.new total revenue of MHP must be, previous revenue plus kerosene consumed previously multiply by 32% of boarder price).

## Annex 6.15 Financial Analysis of Dajungkhola MHP in Myagdi, Nepal

**An Example (Reducing the local voluntary labor cost from investment)**

| **Capacity Kw** | 30 | **HH** | 264 |
|---|---|---|---|
| **Investment (all in Rs.)** | **Local** | **Non-Local** | **Total** |
| Civil Cost | 340,190 | 465,519 | 805,709 |
| Mech Cost | | 433,770 | 433,770 |
| Elect Cost | | 1,362,000 | 1,362,000 |
| Distribution Lines | | 200,250 | 200,250 |
| Poles | 22,500 | 334,550 | 357,050 |
| Installation Cost | | 170,000 | 170,000 |
| Transport Cost | 269,000 | 76,580 | 345,580 |
| Design and Tech Cost | | 7,000 | 7,000 |
| Contingencies | | 39,063 | 39,063 |
| **Total Investment** | 631,690 | 3,088,732 | 3,720,422 |

| **Contributions of stakeholders** | | |
|---|---|---|
| ***Contributions*** | **Rs.** | **Percentage** |
| *Govt/Donor* | 2,267,824 | 60.96% |
| *Local Authorities* | 680,756 | 18.30% |
| *Community* | 519,272 | 13.96% |
| *Loan** | 63,570 | 1.71% |

| **Income and expenditure (In Rs.)** | | | | |
|---|---|---|---|---|
| ***Income*** | | **Rate** | **Monthly** | **Yearly** |
| From Lighting | | Rp0.80 | | 199,776 |
| End-uses- Mill | 3 | 500 | 1,500 | 18,000 |
| Poultry | 1 | 500 | 500 | 6,000 |
| Video | 2 | 500 | 1,000 | 12,000 |
| **Total** | | | 3,000 | 235,776 |
| ***Expenses*** | | | | |
| Operator | 2 | 2,800 | 5,600 | 67,200 |
| Manager | 1 | 2,800 | 2,800 | 33,600 |
| R & M | | | | 59,535 |
| **Total** | | | | **160,335** |
| **Profit (Net Income) Rs.** | | | | **75,441** |

**Financial analysis (with Govt/Donor subsidy)**

| **Year** | 0 | 1 | 2 | 3 | 19 | 20 |
|---|---|---|---|---|---|---|
| **Total Revenue (Rs.)** | 0 | 235,776 | 235,776 | 235,776 | 235,776 | 235,776 |
| Discounted revenue (Rs.) | 0 | 210514 | 187959 | 167821 | 27375 | 24442 |
| **Total Expenditure (Rs.)** | 820,908 | 160,335 | 160,335 | 160,335 | 160,335 | 160,335 |
| Discounted cost (Rs.) | 820,908 | 143,156 | 127,818 | 114,123 | 18,616 | 16,621 |
| **Netcash flow (Rs.)** | - 820,908 | 75,441 | 75,441 | 75,441 | 75,441 | 75,441 |
| **Discount Factor (12%)** | 1.00 | 0.89 | 0.80 | 0.71 | 0.12 | 0.10 |
| **NPV (Rs.)** | - 257,406 | | | | | |
| **B/C Ratio** | 0.87 | | | | | |
| **IRR** | 6.66% | | | | | |

**Financial analysis (without subsidy)**

| **Year** | 0 | 1 | 2 | 3 | 19 | 20 |
|---|---|---|---|---|---|---|
| **Total Revenue (Rs.)** | 0 | 235,776 | 235,776 | 235,776 | 235,776 | 235,776 |
| Discounted benefits (Rs.) | 0 | 210514 | 187959 | 167821 | 27375 | 24442 |
| **Total Expenditure (Rs.)** | 3,088,732 | 160,335 | 160,335 | 160,335 | 160,335 | 160,335 |
| Discounted cost (Rs.) | 3,088,732 | 143,156 | 127,818 | 114,123 | 18,616 | 16,621 |
| **Netcash (Rs.)** | - 3,088,732 | 75,441 | 75,441 | 75,441 | 75,441 | 75,441 |
| **Discount Factor (12%)** | 1.00 | 0.89 | 0.80 | 0.71 | 0.12 | 0.10 |
| **Annual NPV (Rs.)** | - 3,088,732 | 67358 | 60141 | 53697 | 8759 | 7821 |
| **NPV (Rs.)** | - 2,525,230 | | | | | |
| **B/C Ratio** | 0.41 | | | | | |
| **IRR** | -6.03% | | | | | |

## Annex 6.16 Tentative employments in survey and design of MHP

| Name of MHP scheme surveyed | Village/ District | Distance from nearest road head/airport | Capacity kW | Estimated cost of the scheme, NRs | Tentative Cost of Survey NRs | Tentative person days needed (all types of manpower) |
|---|---|---|---|---|---|---|
| Hundikhola MHP | Takumajh,-Lakuribot, Gorkha | 1 day | 27 | 3,970,000 | 60,000 | 45 |
| Istulkhola MHP | Swanra,Gorkha | 1.5 days | 48 | 6,939,256 | 60,000 | 45 |
| GothiMHP | Gothi,Humal | 4 days from Airport | 50 | 8,647,285 | 200,000 | 55 |
| Lapa MHP | Lapa Dhading | 5 days | 27.5 | 4,351,637 | 55,000 | 50 |
| LumdikholaMHP | Dullubaskot Baglung | 2 days | 15.4 | 2,311,043 | 40,000 | 45 |
| Jamarigad MHP | Matheraj Baitadi | 4 days | 21.5 | 3,005,740 | 60,000 | 45 |
| Ghattekhola MHP | Pyuthan /Arkha | 1.5 day | 16 | 2,366,445 | 40,000 | 40 |
| Palung Khola MHP | Rangkhani Baglung | 2 days | 18.4 | 2,749,217 | 50,000 | 40 |
| GhattekholaIII | Barpak Gorkha | 2 days | 95 | 10,032,695 | 120,000 | 70 |
| Istulkhola II | Panchkuwa , Gorkha | 1 days | 38.36 | 5,346,180 | 60,000 | 45 |
| Mahadevkhola | Bhuji,Ramechap | 2.5 days | 55 | 7,327,252 | 75,000 | 50 |
| Pyuthankhola | Therathum/ Gumnam | 4hrs | 5.3 | 798,300 | 30,000 | 30 |
| Pangboche | khumjung/ Solu | 8 days/ 4 days | 82.7 | 9,960,232 | 140,000 | 55 |
| Jhyallakhola | Muchhok,Gorkha | 1.5 days | 55 | 7,619,090 | 60,000 | 40 |
| Thamserkukhola | Manjo,Solu | 7 days/1 day | 30 | 4,439,619 | 65,000 | 45 |
| Handikhola-I | Thampaldhap/Sindhupal chowk/ | 1days | 27 | 3,737,175 | 50,000 | 35 |
| Hilme | Simjung/Gorkha | 1day | 10.8 | 1,443,998 | 30,000 | 30 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Lohakhola | PangrangParbat | 2days | 11 | 2,140,162 | 40,000 | 40 |
| Urjakhola | Rankhani,Banglung | 2days | 20 | 3,183,577 | 40,000 | 45 |

Source: Obtained from FEED Pvt. Ltd. , Kathamndu, Nepal (2002)

**Annex 6.16 Tentative employment in survey and design of MHP**

| **Name of scheme** | **District/Village** | **Distance** | **Capacity kW** | **Tentative investment NRs.** | **Man days needed for survey and Report Preparation** |
|---|---|---|---|---|---|
| 1.Saptangkhola MHP | Salve-7 Nuwakot | 8 hrs from roadhead | 30 | 4,263,709 | 3.5 weeks (detailed) |
| 2. Tapkhola MHP | Sapteswor, Khotang | 8 hrs from airport | 18 | 2,418,581 | 3 weeks (detailed) |
| 3. Chyota khola MHP | Sertung-1 Dhading | 3 days from roadhead | 24.6 | 3,186,565 | 2.5 weeks (prefeasibility) |
| 4. Yunglang khola MHP | Sertung 9, Dhading | 3 days from roadhead | 9.5 | 1,386,000 | 2 weeks (prefeasibility) |
| 5. Chuda-Chu khola | Lamtang 6 ,Rasuwa | 1 day from roadhead | 15 | 2,177,580 | 2 weeks (prefeasibility) |
| 6.Chu-Barma khola | Lamtang, Rasuwa | 1 day from roadhead | 5.6 | 1,015,400 | 2 weeks (prefeasibility) |
| 7.Tengchet khola MHP | Lapa - 2 , Dhading | 5 days from roadhead | 9.00 | 1,549,050 | 2 weeks (prefeasibility) |
| 8.Durguni khola MHP | Tipling-9, Dhading | 5 days from roadhead | 10.8 | 1,826,700 | 2 weeks (prefeasibility) |
| 9. Gorangdikhola MHP | Khairang, Makawanpur | 1.5 day from roadhead | 11 | 1,616,900 | 2 weeks (prefeasibility) |
| 10. Krakta khola MHP | Khairang, Makawanpur | 1.5 day from roadhead | 11 | 1,635,400 | 2 weeks (prefeasibility) |

Source: Obtained from Mr Krishna Devkpta, UCS Pvt Ltd. Kathmandu, Nepal

**Annex 6.17 Actual material used in MHPs in Myagdi District**

| Description | Unit | Darakhola | Bagarkhola | Mahakhola |
|---|---|---|---|---|
| Skilled labor | Nos | 1,644 | 662 | 56 |
| Unskilled labor | Nos | 5,564 | 1,580 | 435 |
| Stone | m3 | 1,057 | 411.7 | 103 |
| Aggregate | m3 | 118 | 24.52 | 8.12 |
| Sand | m3 | 288 | 129.65 | 26 |
| Cement | bag | 1,800 | 432.24 | 222 |
| Reinforcement | kg | 465 | 100 | 10 |
| Wood | m3 | 2.83 | 2.76 | 2.073 |
| G. I. Wire | kg | 1,188 | 270 | 38 |
| Slate | m2 | 105 | 0 | 20 |
| CGI Sheet | m2 | 0 | 33 | 0 |
| Mud | m3 | 15.12 | 11.12 | 7.61 |
| HDPE Pipe | RM | 0 | 350 (315 mm Dia) | 100 (125 mm Dia) |
| MS Pipe for headrace | RM | 16 | 0 | 0 |
| Flow | LPs | 170 | 130 | 15 |
| Head | M | 60 | 49 | 150 |
| Power output | kW | 50 | 35 | 11 |
| Canal length | M | 1,130 | 680 | 600 |
| New | M | 1,130 | 330 | 0 |
| Pipe | M | 0 | 350 | 100 |
| Existing canal length | M | 0 | 0 | 500 |

Source: Author

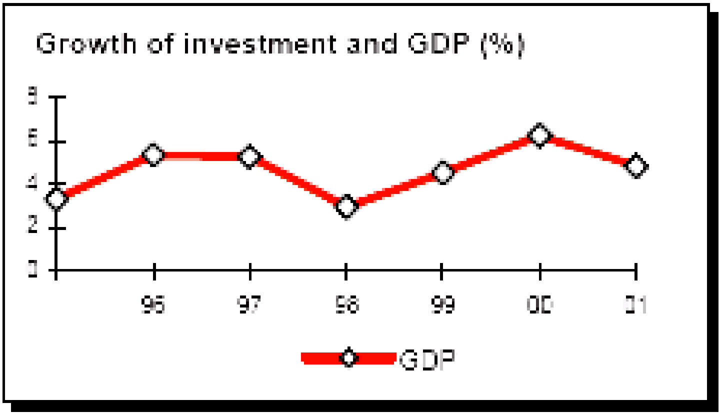
Note: m3 = cubic meter, m2 = square meter, M = meter, RM = running meter

**Annex 6.18 No. of bulbs with different capacities used by HHs in few MHPs**

| SN | Name of Scheme/ VDC | No. of Bulbs (Bulbs with capacity in watt) | | | | | Revenue per year from HH lighting in Rs. | Rate per Watt in Rs. | Benefited Household |
|---|---|---|---|---|---|---|---|---|---|
| | | 5 | 25 | 40 | 60 | 100 | | | |
| 1 | Dajung Khola MHP/ Okharbot | 4 | 589 | 109 | 29 | 12 | 198,405 | 0.8 | 264 |
| 2 | Bagarkhola MHP/ Chimkhola | 15 | 517 | 140 | 54 | 13 | 208,260 | 0.75 | 284 |
| 3 | Darakhola I MHP/Muna | 28 | 698 | 137 | 65 | 18 | 276,192 | 0.8 | 437 |
| 4 | Darakhola II MHP/ Lulang | 2 | 541 | 24 | 17 | 8 | 146,835 | 0.75 | 254 |

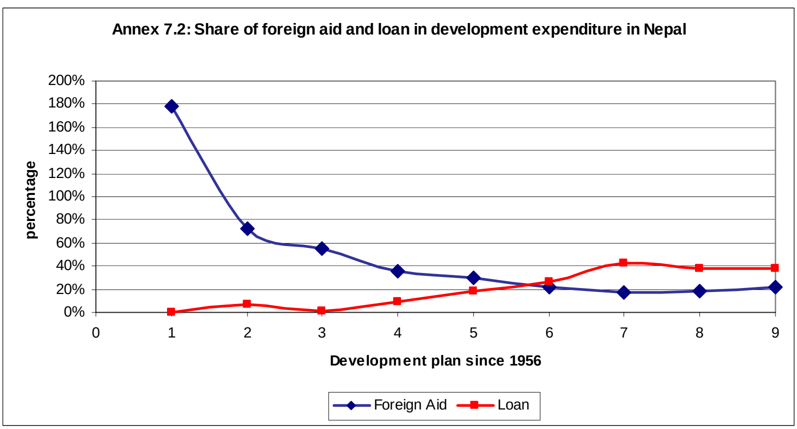
**Source: Author (collected from REDS/Myagdi office)**

**Annex 7.1 Average GDP growth rate of Nepal**




Source: [www.worldbank.org](http://www.worldbank.org) (down loaded on Jan 23, 2002)

**Annex 7.2 Share of foreign aid and loan in development expenditure in Nepal**




Source: Compiled from NPC (1956, 1962, 1966, 1971, 1975, 1982, 1985, 1992, 1997)

## Annex 7.3 Reasons Why Big Hydropower are unsustainable in Nepal (at least Now)

**Environmental reasons**

- Dam or diversion has effects on down stream and has effects on aquatic life.
- Dam construction in geologically not suitable in the region.
- Big rivers depend on Snow-covers in Himalayas but due to climate change that will be reduced or make unsecured.
- Climate change can cause flooding/avalanches thus project sites can be swept out. Taking the case of Khumbu in 80s, Bagmati river incidents and other cases.
- Himalayan rivers are carrying huge sedimentation load every year and reducing the life of reservoirs, turbines and other components.

**Technological reasons**

- For design, planning and dam construction needs foreign manpower.
- Almost all components have to be imported.
- Transmission and distribution is expensive due to scattered settlement and difficult geographical train.
- Replacement and prevention works of plants from extreme events are very difficult to manage locally.
- High sedimentation in Nepal causes faster damages of plant's components.
- High probability of Earthquakes and weak geological structure can cause big problem for dam and structures.

**Economic Reasons**

- Opportunity cost is high and uunavailability of own resources to invest.
- Foreign investment hardly go to remote areas without infrastructure.
- People's paying capacity without income is low.
- No other economic activities.
- Mitigation due to extreme events would be very expensive and locally impossible.

**Social**

- Diverting or building dam makes social impacts i.e. recreation, resettlement, changing culture and other habits.
- Rural and remote areas will have to wait some decades for electricity because opportunity cost of not developing is negligible.

(Source: compiled from Dahal 1998, Pandey 1994, Pandey 1998, Bandhopadhyay et al 1994, Gyawali et al 1994, Christiansen et 1997, Gyawali 2001, Ahmed et 1999, Thapa 1997 and others)

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<u>**Curriculum Vitae**</u>

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| Family Name | : | **Pokharel** |
| Name | : | Govind Raj |
| Date of Birth | : | 20 January, 1967 |
| Address | : | Raspurkot-4, Pyuthan, Nepal |
| Marital Status | : | Married with Lokmaya have sons Gokul & Girish |

**Academic Qualification**

- **Master of Science (M.Sc**.) in Appropriate Technology and Extension Skills, from University of Flensburg, Germany in 1997.
- **Bachelor of Engineering (B.E.)** in Mechanical Engineering from University of Rajasthan, India in 1992.

**Job Experiences**

**Project and Consulting Sector**

- ***Executive Director:*** People, Energy and Environment Development Association (PEEDA), Kathmandu, Nepal since Sept 2004
- ***District Energy Advisor*** (1998-1999) in Rural Energy Development Program (REDP) of UNDP, Nepal. During my tenure four Micro Hydro Projects were installed in four villages providing about 1100 households electricity. Other tasks were facilitating grass-root energy planning, mobilization of local resources and co-ordinate with local agencies and NGOs.
- ***Consultant, Team Leader and Team Member*** in several energy management, energy policy and planning and mechanical engineering related studies, projects, research and consultancies; and worked as an advisor in a private company to design, extend and installation of Solar PV systems in Nepal.

**Academic Sector**

- ***Working as an assistant Professor*** since 1992 and toughed several subjects in Mechanical Engineering in Thapathali & Pulchowk Campus, Institute of Engineering in Kathmandu, Nepal. Held post of assistant and acting *Campus Chief* to manage the Campus and organizing a course on Bachelor of Engineering in Industrial Engineering in Nepal.

**Research, Publications and Conferences papers**

Published several articles, research papers and participated in number of conferences and seminars.

**Extra Activities**

Member of several NGOs, Professional organizations like Nepal Engineering Association, Nepal Hydropower Association and several others in different capacity.

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Flensburg, den 1. März 2005

Govind Raj Pokharel