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Sustainability Analysis of Hydropower In Nepal

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Abstract

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The purpose of this thesis project was to analyze the sustainability of the hydropower in Nepal. As, Nepal is the second richest country in terms of the water resources, this thesis aims to provide a clear picture of the overall sustainability of the hydropower by measuring social, economical, political and environmental factors with worldwide accepted parameters. The analysis of the parameters was made and then expressed in a quantitative form to make it easy for anyone to understand the theme at a single glance.

The sustainability analysis was made on the basis of the literature review drafted by the Nepal government, private and public companies and organizations, non-government organizations (NGOs), international non-government organizations (INGOs), individual power producers association of Nepal (IPPAN), hydropower journals and the water resources journalists who have been directly or indirectly involved in hydropower development in Nepal. The case studies of some hydropower plants operating or under construction were also considered for analyzing the parameters. The core parameters for analyzing the sustainability of hydropower as determined by the International Hydropower Association were analyzed in the context of Nepal. All the possible supporting facts and evidence were collected and analyzed. After that, grading was done according to the weight age of the positive or negative supporting evidence.

This thesis project was challenged by two issues: 1) reliability of the available data and the supporting argumentations from the lists of numerous available sources and 2) the difficulty of getting updated information. Despite the challenges, this thesis is based upon an unbiased as neutral updated argumentation and evaluation as possible. Therefore, it is a useful tool for someone who is willing to know about, invest in, or do sustainability analysis of other hydropower plants in Nepal or in some other countries. All the data and circumstances described in the thesis are relative and can change over a period of time and as a result of changes in the socio political conditions, provided that the principles behind the analysis always remain the same.

When using this thesis, it is recommended to check and review the present situation of the analyzed parameters.

Keywords	hydropower, sustainability, EIA, assessment, environmental impacts

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This thesis is the end of my long journey in obtaining my degree in Environmental Engineering and the first gift to Nepal from my side. I have not traveled in a vacuum in this journey. There are some people who made this journey easier by fueling me with encouragement and intellectual motivation by offering me with different ideas and suggestions to expand my ideas.

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Abbreviations

ACRP	Acquisition Compensation and Rehabilitation Plan
ADB	Asian Development Bank
BA	Biological Assessment
BO	Biological Opinion
CPR	Common Property Resources
DDC	District Development Committee
DoED	Department of Electricity development
EIA	Environment Impact Assessment
EMP	Environmental Management Plan
EPR	Environment Protection Regulation
ETFC	Electricity Tariff Fixing Commission
FDI	Foreign Direct Investment
FNCCI	Federation of Nepalese Chamber Of Commerce and Industry
GLOF	Glacial Lake Outburst Floods
ICIMOD	International Centre for Integrated Mountain Development
IEEE	Institute of Electrical and Electronics Engineers, USA
INGO	International Non-Government Organizations
INPS	Integrated Nepal Power System
IPPAN	Independent Power Producers Association of Nepal
IPCC	Intergovernmental Panel on Climate Change
KVA	Kilo Volt Ampere
KW	Kilo Watt
MMP	Mitigation Management Plan
MoEST	Ministry of Environment Science and Technology
MoPPI	Ministry of Physical Planning and Infrastructure
MoWR	Ministry of Water Resources
mVA	Mega Volt Amperes
MW	Mega Watt
NEA	Nepal Electricity Authority
NERC	Nepal Energy Resources Centre

NG	Nepal Government
NGO	Non-Government Organizations
NSSD	National Strategy for Sustainable Development
OECD	Organization for Economic Co-operation and Development
PAN	Permanent account Number
PDA	Power Development Agency
PDF	Power Development Fund
PDP	Power Development Projects
PPA	Power Purchase Agreement
SDAN	Sustainable Development Agenda for Nepal
SWOT	Strength Weakness Opportunity Threat
UNCBD	United Nations Convention on Biological Diversity
UNCCD	United Nations Convention to Combat Desertification
UNFCC	United Nations Framework for Climate Change
UNDP	United Nations Development Program
VAT	Value Added Tax
VDC	Village Development Committee
WECS	Water and Energy Commission Secretariat
WSSD	World Summit on Sustainable Development

Contents

1 Introduction

Hydropower is a sustainable form of energy produced solely by transforming the energy stored in water. Hydropower has gained the prestige due to low greenhouse gas emissions, long life, low operation and maintenance cost and many other benefits. However, the condition of sustainability can differ according to the country, its people and other various factors prevailing in that specific area and time. Broadly speaking, rules regulations, project holders' intention, socio corporate responsibilities and the economic aspect define and adjust the sustainability value. Nepal is a small Himalayan republic with the second largest hydropower development potential and a supporting geography; still, less than 1% of its hydropower potential has been developed today. Therefore, a sustainability analysis of Hydropower in Nepal is made and its results are presented numerically.

There are various ways of analyzing the sustainability of the hydropower projects available in the market. One of the best techniques is the use of the guidelines provided by the International Hydropower Association (IHA) that tries to address all the social, economic and environmental aspects related to the hydropower development. The analysis is made of every determining factor based on the Nepal's geo-political situation, its policies and the socio economic achievements. A further analysis was made if the sustainability factors were being affected or were affecting the situation. The results of the analysis were presented numerically according to their favorability on sustainability. The overall values of the aspects and elements of the sustainability analysis are averaged to get one value which tells the degree of the sustainability of Nepalese Hydropower.

An average value above the score of three (3) indicates the social, economical, and environmental sustainability of hydropower in the Nepalese rivers.

2. Hydropower Details

Hydropower is the energy generated from water. This section will briefly describe the history of hydropower and the scientific principle behind hydropower production.

2.1 History

Hydropower is a very old achievement of the human being. With a very long history, hydropower has been recognized and used as waterwheel and mills, hydraulic power pipes and compressed air hydro till today. [1] The technology behind the energy production from water has progressed significantly, but the principle remains the same. The following section will present the principle of hydropower.

2.2 Principle of Hydropower

The guiding principle behind hydropower is the basic law of energy according to which energy is neither created, nor destroyed but transformed from one form to another form. The mechanism involves the conversion from potential energy of water to kinetic energy. Potential energy is the energy stored in the body by virtue of position or height, whereas the kinetic energy is the energy possessed by the object due to virtue of motion.

The water from the catchment area, is either collected in big reservoirs (storage type) or directly used in Run of River (ROR) types, made to run from higher elevation to lower elevation through a penstock pipe. The water turns a water wheel or turbine and via a connected shaft (Figure 1) to an electrical generator creates electricity. The turbine and the generator works combined to convert mechanical energy into electric energy.

Hence, power production from a hydropower plant is proportional to the flow of the river and the available head. The flow of the river is the amount of water (in m^3/s) that flows in a certain amount of time of a cross section of the river. Head is the vertical difference in the level (in meters) the water falls down.

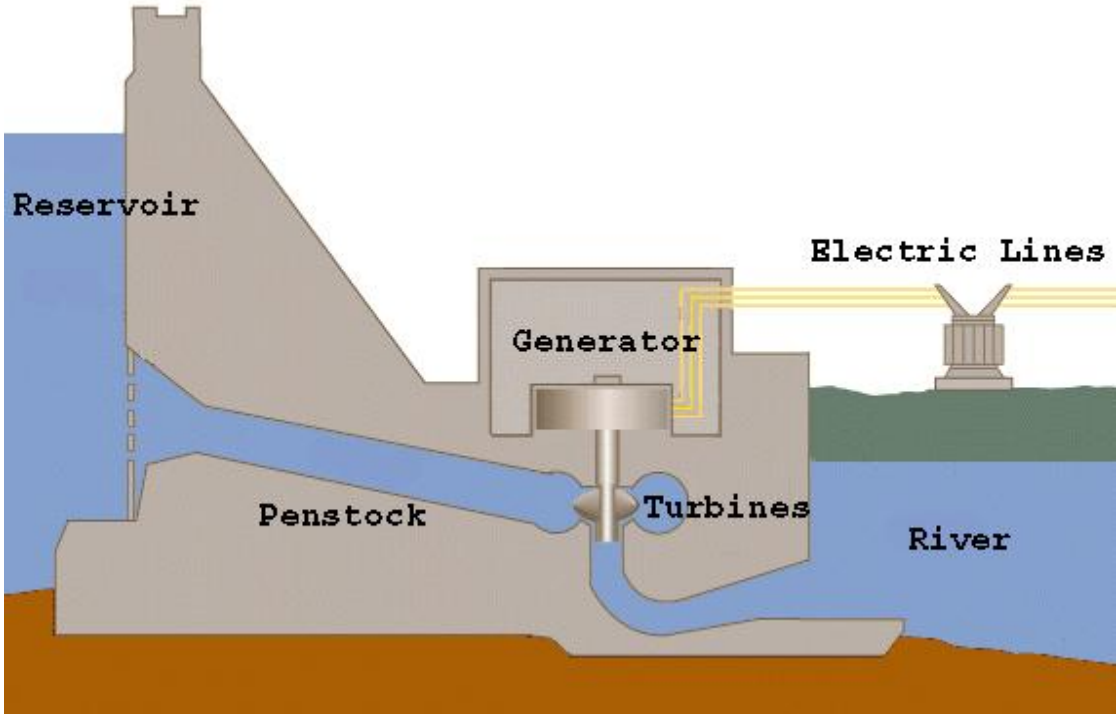

Figure 1: Hydroelectric plant [2]

Theoretically, power *(P)* that can be obtained from the given head of water is proportional to the Head (*H*) and the flow *(Q):*

$$P = Q*H*c \qquad (1)$$

where *c is* constant and equal to the product of the density water and the acceleration due to gravity *(g*).

If P is measured in *Watts*, *Q* in m^3/s and *H* in *meters,* the gross power generated due to the flow of water can be calculated as follows:

$$P = g*Q*H \qquad (2)$$

The available power will be converted by the hydro turbine in mechanical power. As the turbine cannot convert all energy into hydroelectricity because of loss and other mechanical factors, the generated power will be some fractions of the available gross power.

The net power that is practically produced by the hydropower plant can be calculated as follows:

$$P = \eta * g * Q * H \qquad (3)$$

where η is the efficiency of power plant and g is the acceleration due to gravity in m/s^2

The efficiency of a power plant is always less than 100%; hence, the actual power produced is always less than gross production capacity.

2.3 Components of a Hydropower

A good hydropower project contains various components. The components, as shown in figure 1, start from water storage and ends in the transmission. Thus, the major components of a hydropower projects can be listed as follows:

- Reservoir (Dam): An impounding structure to store water for creating head and to assure the controlled and continuous flow.
- Penstock: A pipe from the fore-bay of the dam till the mouth of the turbine serving as a water conductor system.
- Turbine: The main electrical installation that helps to transform the mechanical energy of the water into the kinetic energy.
- Generator: An electrical installation to transform mechanical energy of the turbines to electric energy.
- Power house: A civil structure used for electro mechanical installations.
- Tailrace channel: A pool to release the water back into the flowing water body.
- Transmission mains: Transmission units to supply produced electricity to the customer.

2.4 Types of Hydropower

Hydropower is classified in two parts based upon the method of generation and the size and the production capacity.

2.4.1 Methods of Generation

Hydroelectricity is the energy produced from water by virtue of the height and the amount of flow. The classification of hydropower is based on the different methods of generation and the use of the dams. On the basis of these criteria, there are three (3) types of hydroelectricity generation:

- ROR based hydroelectricity: Projects based on perennial rivers and without the use of dams. [3]
- Pumped-storage hydroelectricity: Projects featuring heavily availability of water but lacking the head [3]
- Conventional hydroelectric (storage type): Projects that accumulate mechanical energy by storing water in dam and then transfer the energy by flowing water through a pipe through a certain height. [3]

2.4.2 Method of Size and Production Capacity

In the global context, hydropower can be classified into five (5) different types according to their size and capacity of production:

- Large Scale Hydropower: The capacity of these types of the power plants ranges from 30 MW to 10 Giga watt [3].
- Small Scale Hydropower: Plants with maximum capacity of power generation of up to 10 MW [3] are regarded as small scale hydropower
- Mini Scale Hydropower: The capacity of mini hydropower plant is assumed to be between 100-500 kW [3]. These can be developed under the small scale hydropower projects.
- Micro Scale Hydropower: Hydropower projects with installation capacity up to 100kW [3] can be regarded as micro scale hydropower project. These are golden for providing electricity to small types of communities as they are more economic and most environmentally friendly.

- Pico Scale Hydropower: Hydropower plants with a capacity less than 5kW [3] are Pico hydropower projects. They do not require dams.

2.5 Characteristics of Hydropower

Hydropower is a beneficial source of energy. Some of the characteristics of hydropower are as follows:

- Security in water supply
- Irrigation
- Flood control
- Social benefits
- Recreational opportunities
- Improved navigation
- Development of fisheries
- Wide distribution
- Advanced technology
- Peak load balancer
- Low Operation & Maintenance (O&M) with long life
- Renewability

3. Development, Installation and Feasibility of Hydropower

Although Nepal is a country with immense hydropower potentialities, a very little of it has been installed till today. Many researches and surveys have been made on various rivers regarding the economic and technical feasibility of power production by various non-government organizations (NGOs), international non-government organizations (INGOs) and even from the government sectors and independent power producers of Nepal. The following section will discuss the development trends, the planned and the installed hydropower, transmission lines and the studied feasible hydropower of some of the projects and transmission lines.

3.1 Hydropower in Nepal

Of the whole world's power production, 20% of the energy is only produced from hydropower although the world has a vast amount of hydropower undeveloped. Table 1 below illustrates the overall technical and the economical hydropower feasibility of each continents of the world.

Table 1: World's feasibility on hydropower production [4, 11]

Continent	Technical feasiblity (TWh/yr)	Economic feasiblity (TWh/yr)
Africa	1750	1000
Asia	6800	3600
North+ Central America	1660	1000
South Americas	2665	1600
Total	**12875**	**7200**

Thus, of the world's capacity, Nepal only has the capacity or the potential of producing 299TWh/year (83000 MW) of electricity, which is almost 3% of the whole world's capacity. Nepal is blessed with enormous amount of water and the geography for the production of the electricity. Almost 96% of the

electricity produced today comes from hydropower plants. Kali Gandaki-A is the largest operating hydroelectric plant in Nepal today with capacity of 144MW. The electricity generated from the power plants is transmitted through the 132KV single and double circuit national transmission grid line of 1563 km and the 66KV single circuit, double circuit of 354.7km [5]. Nepal has a subtotal station capacity of 1415mVA [5] today. The per capita energy consumption of Nepal is 15 GJ per year. [3] The consumption trend is shown in Table 2 below.

Table 2: Percentage contribution of energy sources in Nepal [3]

S. N.	Main divisions	Description	Percentage
1.	Sectored use	Residential	90
		Industrial	4
		Commercial	1
		Transportation	4
		Agriculture	1
2.	Fuel type	Biomass	86
		Petroleum	9
		Electricity	2
		Renewable	1
		Coal	2
3	Sources of electricity	Hydropower	71
		Thermal	8
		Imports/IPPs	21

Diesel plants contribute less than 4% of the total power produced which implies that Nepal is fully dependent on hydropower for electricity.

The existing major hydropower plants of Nepal produces about 459.159 MW of hydroelectricity which is nominal compared to the actual hydropower potentiality. This is because of many factors such as financial requirements, planning, time and manpower, transportation of the construction material and

installation of the machines. The small hydropower plants collaborate with the large ones and contribute about 472.994MW. Other existing isolated small hydropower plants and the diesel plants produce about 58MW. In addition, more than 23000MW of hydropower are either identified or being developed. These figures exclude the private public participated hydropower plants.

3.2 Transmission Lines

To use the generated electricity, the national wise grid system is helpful because it carries the power from one corner of the country to the other corner of the country that needs it. The capacity of transmission lines vary according to the purpose of the lines. The 132 kV national and the regional transmission lines are the major transmission lines, along with the 220 V normal household distribution lines. Some of them are single circuited whereas some are double circuited. One of the most important and the most ambitious trans-country transmission grid between Nepal and India is the *double circuited inter country transmission grid* which is currently being developed and, according to the news on BBC Nepali Service of 2011 December 5, is planned to be completed in 2013 with a transmission capacity of 3000 MW. [6] The grid is connected to both the energy thirst countries, and, hence, the agreed supply cannot be assured to meet their demand and deficiency.

In addition to the national and inter-country transmission grid, there is the transmission grid of 66kV for the electricity distribution in a certain region. Under the government's millennium goal and poverty reduction plan, government is continually elaborating the projects of rural electrifications as 132kV transmission lines. Appendix 3 presents a table showing the development, installed capacities and the future expansion potentialities of hydropower plant and transmission lines in Nepal.

4. Sustainability Analysis of Nepalese Hydropower Projects

Sustainability simply means the ability of a project to maintain its projected operations, targeted services and benefits during its projected life time. Sustainability Analysis is defined as "the identification and analysis of degree of presence or absence of the factors that are likely to impact, either positively or negatively on the prospects of sustained delivery of project benefits". [7] Social, environmental and economic aspects of new and existing hydropower projects are the three pillars of sustainability analysis (Figure 2). The union of any two aspects will create either bearable, equitable or viable situation, but the intersection of all the aspects will create a sustainable situation and ensure social, environmental harmony at its best and, if not, they will at least mitigate or compensate and on same run maximize the positive outcome. [7]

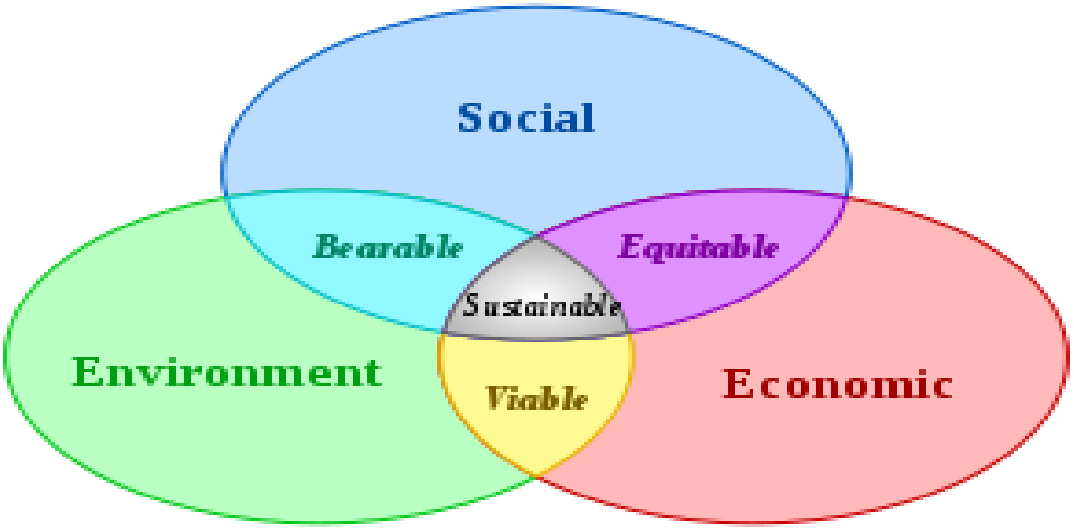

Figure 2: Three aspects of sustainability

The sustainability analysis reported on in this thesis is based on the International Hydropower Association (IHA) guidelines and the supporting evidence scores. The analysis includes twenty three (23) fundamental aspects of economic, social, and environmental sustainability in correlation to the situation and application in Nepal. Evidence on approaches, process adequacy

and the reliable sources from the government, both public and private, were the basis for the evaluation. The aspects were first analyzed and then rated according to their sustainable deviated attitude.

Table 3 below, provided by the IHA, and explains the general ratings from 5 to 0. The sustainability analysis is based upon the rating criteria described in this table.

Table 3: Rating score for comparing sustainability of hydropower [8]

Performance	Score	Description
Outstanding / Strong / Comprehensive	5	• At or very near international best practice. • Suitable, adequate, and effective planning and management systems. • Meet or exceed objectives and measurable targets.
Good to Very Good	4	• High standard performance. • Generally suitable, adequate, and effective (minor gaps only) planning and management systems. • Meets most objectives and measurable targets including all critical ones.
Satisfactory	3	• Essentially meets the requirements of the Sustainability Guidelines (no major gaps). • Generally compliant with regulations and commitments (minor exceptions only). • Some non-critical gaps in planning and management systems. • Some non-critical gaps in meeting objectives and measurable targets

Less that Satisfactory	2	• Gaps in meeting the requirements of the Sustainability Guidelines • Some gaps in compliance with regulations and commitments. • Gaps in planning and management systems. • Gaps in meeting objectives and measurable targets
Poor / Very Limited	1	• Poor performance. • Major gaps in compliance with regulations and commitments. • Major gaps in planning and management systems. • Major gaps in meeting objectives and measurable targets.
Very Poor	0	• No evidence of meeting the requirements of the Sustainability Guidelines. • Very poor performance or failure to address fundamental issues. • Little or no compliance with regulations and commitments. • Ineffective or absent planning or management systems. • Fails to meet objectives and measurable targets.

Almost every dimension of the sustainability analysis revolves around the local conditions; O&M cost, economic benefit and environmental impact assessment (EIA). Each of the twenty three (23) elements under the five (5) factors, as prescribed by the IHA is analyzed to give them a score of sustainability deviation. The following section will present the analysis of the factors and of the elements in more details.

4.1 Government Policy

Government policy is the basic and the most important factor in determining the sustainability of all projects operating in the country. This factor includes the sustainability of the government, the volatility of the government, energy policies of the government, the ability and the fore-seeing during the decision making process. The elements of the factors will be discussed in more details in the context of Nepal in the following subsections.

4.1.1 Government Stability

Good governance within the country and good impression at the international level is an essential sustainable hydropower development prerequisite. The Nepalese government is an example of the negative brand of Nepalese people. The government is not stable and has been changing very often. At domestic level, the government has not been able to make a directive impression to the people. More than 10 governments have been changed in the time of 10 years. Because of the bad political culture among the parties, all parties just think about getting into the government and have no time to think about the welfare of the people. Thus, at the domestic level, sound environmental, social and economic policies have not been able to be drafted as the political parties and the governments do not find time to draft the new constitution of the country. Also, the democratic institutions and the bureaucratic aspects of Nepal do not seem responsive and responsible to the needs of the people. Laws are sometimes not respected, and a considerable intensity of corruption is prevailing in the republic of Nepal.

However, the advantage of Nepal is that, in spite of the unstable politics and the government, democracy is highly respected there. Whatever rights you can enjoy in the west, can be enjoyed in Nepal. The desire for development inside the people is so dense that even without the interest of the government; the

people themselves try to maintain the rule of law and to discourage corruption. Gender equity and human rights are in a considerably good state.

The international image of Nepal is very good in terms of people but not in terms of political situation and political culture. It is not wrong to say that more than 80% of the hydropower investors (national and international investors) are afraid to invest in Nepal because of the political instability of the government and the political culture that has developed. Thus, Nepal is like the darkness under light or poverty under riches.

4.1.2 National and Regional Energy Policies

The element national and regional energy policies define the comprehensiveness of these policies and the compatibility of these policies with hydropower schemes. Without effective policies, no foreign companies and investors are willing to risk their money in hydropower. The Nepalese government has some policies that are of mixed behavior i.e. that looks beneficial if looked from one angle and awful if looked from another angle. Some of the main laws that govern the investment and hydropower laws are as follows: [5]

- Foreign Investment and Technology Transfer Act – 1993
- Foreign Investment and One Window Policy Act – 1993
- The Hydropower Development Policy – 1992
- Water Resources Act – 1992
- Water Regulation Act – 1993
- Electricity Regulation Act -1993

The 10-year hydropower development plan of 2009 has formulated a program for developing 10000 MW in the following 10 years to overcome the ongoing energy crisis.[18] Other policies involve *license freedom for hydropower up to 3 MW, public private partnership in the hydropower for capital mobilization* and

Foreign Direct Investments. BOOT principle of capital investment in Nepal is an attraction for investors who want to invest in some area for a certain period of time. Also, as a part of the South Asian Regional Initiative (SARI/E) under USAIDS, Nepal has been promoting energy security program through: [9]

- Cross Boarder Energy Trade
- Energy Market formation
- Regional clean energy development

The energy policy of Nepal had focused on the efficient regional energy utilization, transparent and profitable energy production and practice. Also, attempts have been made to address environmental protection concerns, increased regional access and security in energy by means of the government policies.

4.1.3 Policy Inconsistencies

The incentive Hydropower Policy of 1992 made provisions for License validity for 50 years, tax holiday for 15 years, income tax (applicable after 15 years) at the rate of 10% below prevailing corporate income tax, an allowance of 25% return on invested share capital, 1% customs duty on imported goods for the project, exemption on import license, exemption on sales tax and the easy availability of NG land to be leased for the duration of license. [10] Khimti Hydropower Project-60 MW, Bhote Koshi Hydropower project-36 MW and a few locally financed projects such as Indrawati Project came into existence because of this progressive policy of Nepalese Government. [10]

The new Hydropower Policy that came into effect in 2001 was a catastrophic policy in the history of the Nepalese hydropower policy sector. The catastrophic aspects of the policy were the reduction of license validity from 50 years to 35 years, incremental royalty payment, 'scrapping of income tax holiday, bringing

the hydropower projects under the usual corporate tax net of 21.5% and the introduction of Value Added Tax (VAT) for the projects above the capacity of 3 MW.

Thus, inconsistencies of policies occur in the national and regional sectors are demonstrated by the Table 4 given below:

Table 4: Analysis of government water and hydropower policies [10, 11]

Issues	**1992 Policy**	**2001 Policy**
License Validity	50 years	35 years
Royalty	a) Rs.100/kW per annum and 2% from average sale for 15 years b) Rs. 1000/kW per annum and 10% from average sale for 15 years	a) Rs.(100-200)/kW per annum and 2% from average sale for 15 years b) Rs. (1000-1500)/kW per annum and 10% from average sales for 15 years 1% royalty transfer to DDC
Concession	a) Concession loan to project that is < 100k W	-----
Income tax	a) No tax for projects <1000kW b) Tax Holiday for plants >1000kW c) When relevant,10% less income tax	a) Taxation as per the prevailing Tax Act of the government
Custom/sales Tax	a) 1% custom on good not produced in Nepal b) No import license/sales tax	a) 1% custom duty b).No VAT on the electricity

Energy rate	a) Allowance of 25% dividend on share capital	-----
Land	a) Private land Acquisition according to Land Acquisition act-2034 b) NG land can be leased throughout the license period	a) Private land Acquisition according to Land Acquisition act-2034 b) NG land can be leased throughout the license period
One-window Policy	a) Provided	a) Provided by DoED
Geo-Hydrologic Risk	---	a) License extent up to 5 years as compensation
Resettlement Cost	---	a) Cost bared by developer
Security Cost	---	a) Cost bared by developer
Institutional Provisions	---	a) Formation of: -Regulation body (NERC) -Study body(WECS) -Promotional body(DoED) b) Unbundling of NEA Electric Energy Management Institutions

Increased consistencies in the government policy refer to the increased uncertainty, which has hindered and will hinder the spontaneity and interest in the investment and the development of the hydropower.

4.1.4 Planning Deficiencies

Long term planning and implementing of the project plan in the infrastructure development is the major issue for the sustainability of the hydropower

projects. Access road and transmission line for power transmission are the main deterministic infrastructural factors of hydropower projects. Such a policy is absent in Nepal. Thus, the haphazard construction mode with no proper plan in Nepal direct the projects infrastructure to be heavily expensive than they should be.

If looked from the organizational point of view, there are an enormous number of agencies who are directly or indirectly involved in the planning of the hydropower projects. They are: [11]

- Ministry of water resources
- National Development Council
- National Planning Commission
- Water and Energy Commission
- Water resource Development council
- Environment Protection Council
- Alternative Energy Promotion Centre (AEPC)
- Nepal Micro-hydropower Development Association(NMHDA)
- Generation Business group
- Clean Energy Nepal

These are only some major councils and development commissions. There are many such agencies but almost none of them succeeded in keeping a sustainable infrastructure development as well as a well-planned transmission network within the country and with the neighbors. The Ministry of Physical Planning and Physical Infrastructure (MoPPI) has some sort of infrastructure development projects and plans that are heavily concentrated to the urban areas like Kathmandu and the other major cities of the country. Areas like Karnali and the other places where the availability and potentiality of the hydropower is immense, the government has not even thought to provide the basic infrastructure. Also, if the infrastructures are developed, the proper

regulation and monitoring bodies are so vulnerable that the quality of the planning and the construction of the infrastructure cannot be ascertained to the international quality.

The role of the private sector in infrastructure planning and development is an example at its best, but because of many bureaucracy hindrance in socio-economic and geopolitics, their entire plan cannot be implemented. Thus, in general, due to the absence of such an agency, even a small hydropower project has to construct the access road and transmission line for its power evacuation and bear the heavy burden of investment in infrastructure development rather than the hydropower construction.

From the government policy point of view, energy planning in Nepal is done as a part of a 5 year development plan without any official energy regulator. According to the Electricity Act 2009, an Electricity Tariff Fixation Commission is established as a regulating body and this is just an energy regulatory body in the country till today although it has not got legal approval. Formulation of National Electricity Regulatory Commission is a talk of town but has not come into existence yet. Hence, the lack of well planned infrastructures due to the government pace and the depression in the private sector due to the government bureaucracy and the red tape is hindering the development of the hydropower sector and many million cubic meters of water just flow in the river for nothing.

4.1.5 Licensing Anomalies

The presence of the irresponsible government with weak and powerless policies have resulted to such a condition in Nepal that most of the hydropower licenses are held by individuals and companies ('water resources mafias') with neither technical understanding nor the financial capability of implementing hydropower projects. Table 5 presented below was prepared based on the

information available in the Department of Electricity Development (DoED) website about license issuance in Nepal according to type and purpose.

Table 5: Licensing status of hydropower till 1 July 2008 [12]

S. N.	Category	Numbers	Capacity (MW)
1	Application for hydropower survey	738	49982
2	Survey license issued	197	4846
3	License issued for electricity generation	25	463
Sum		**960**	**55291**

A large number of hydropower licenses, of all scales and magnitudes, have been issued in Nepal. But the tendency of just occupying the license and putting the river in the bag, pocket and paper has increased. Many of the big and small licenses are issued just to ministers, high class officials and politically approachable people and *water resource mafia*. Thus, concrete development in hydropower production in Nepal has not been seen as should have happened on the basis of the license issue data.

In contradiction to such a trend, the first government of the republic of Nepal tried to make a strong decision regarding *the only license holders* by either cancelling or not renewing 11 licenses of total 177.6 MW capacities as an incentive measure to depress the license hoarding intentions. These include Lower Balephi (5 MW), Kolpha Khola (2.23 MW), Madhkyu Khola (5 MW), Upallo Khimti (4.5 MW), Tamor Mewa Khola (101 MW), Thapa Khola (2.34 MW), Lower Phame Khola (2.2 MW), Small Likhu Khola (1.5 MW), Rasuwa - Bhotekoshi (22.6 MW), Khimti-2 (27 MW), Daraudi Khola (5 MW). [12] But, in the parallel run, the introduction of Power Development Agency (PDA) is a new problem in the Nepalese hydropower sector because it serves as a reservator and legal supporter to the regaining of confiscated licenses, whatever be the

reason for their confiscation. With the aid of this PDA, the water resources mafias try recapture the river by negotiating with the PDA when their license is about to expire. It means about 1200MW of hydropower is in the hands of the *mafias* and cannot be expected to be accomplished till the PDA works rationally.

The DoED increased the survey license fee for small hydro power projects from Rs. 150 to Rs. 50,000 as a step to reduce the license hoarding trend. This step is just a start and further measures to screen the applicants on the basis of technical capability, financial capability and other criteria are essential. The new government of Babu Ram Bhattarai is hoped to bring some sort of positive rules and positive changes concerning policy and action and as a result the whole attention of the world will be drawn towards Nepal. The situation is not good but hopeful.

Thus, license issuance has heated the national and international hydropower market and if the license can be kept out of the reach of *mafias* will certainly yield the higher sustainability in project development.

4.1.6 Strategic Assessment

The element Strategic Assessment involves overall impacts of hydropower projects, land use issues, environmental priorities, socio and economic goals. In addition, the assessment considers issues concerning global warming, socio-economy and the environmental aspect of energy planning. Collaborative action of the government and the public private sectors has played a vital role in the lives of the Nepalese people, in the corporate sector and in the control of green house emissions. The Nepalese energy sector carries the motto of Promoting the energy sector in a transparent way, but because of the dominance of state owned corporations and politically selected people; this motto has failed in real life. Presently, strategic assessment can be made using the following perspective plans in Nepal: [11]

- Renewable Energy Perspective Plan(2000-2020)
- Perspective Energy Plan(1991-2017)
- National Electricity Crisis Resolution Action Plan 2008
- Rural Energy Policy 2006
- 10 year Hydropower Development Plan 2009
- Rural Energy Development Program (REDP)

The strategic assessment of plans show green light to further hydropower development. A motivating factor in the strategy is that the government has provided an 80% subsidy for micro hydro below 1 MW. [13] The concept of ten (10), i.e. Producing 10000MW energy in 10 year is encouraging. Rural areas energy need is addressed by the government by the creation of a rural energy subsidy with the development of an efficient credit system.

The regulation also defines the social cost to be borne by project developers provided that the areas of development are defined by the developers whereas the social costs are defined by the representative of the project area. [13] Water and Energy Commission Secretariat of Nepal (WECS) Nepal is the commission that has proven itself a very beneficial and powerful commission to deal with the strategic assessment of hydropower and energy as they help in collaborative decision-making, under a framework of shared water management policy. [13]

Hence, strategic assessment seems very little in theory but its results are very genuine and show to achieve the sustainability.

4.1.7 Attention to Climate Concerns in Energy Focused Projects

Framework Convention on Climate Change (UNFCCC), Convention to Combat Desertification (UNCCD) and Convention on Biodiversity (UNCBD) are the three international conventions ratified by the NG in terms of climate change.

Integrated Watershed Management, Community-Based Soil and Water Management, climate related risk and flooding and siltation are some of the defined measures the government has promised the international community that it will take to reduce climate risks. [14]. Nepal's Country Profile for the WSSD (2002) addresses the climate change only in the context of mitigation of greenhouse gas emissions; but the adaptation to climate change and various other related issues are not mentioned. [14] The *Sustainable Mountain Development Program* addresses the issues of humans, animals, flora and fauna and the higher tundra to the challenging climate change in the mountains.

Infrastructure, agriculture, drinking water, irrigation, hydropower, and biodiversity and the risk of Glacial Lake Outburst Floods (GLOFs) are the areas where the global issue of the green house gases and climate change has severe effects. Taking all the above factors into consideration, taking concrete disaster mitigation measures, adopting emergency management policy, developing flood warning systems, enforcing and updating the design standard of the infrastructure are proposed. [14]

Thus, Nepal's climate concerns policy is highly appreciable but lacks some aspects that need to be addressed. In spite of Nepal's significantly lower greenhouse gas emissions in the atmosphere, Nepal's climate policy is a respected policy to be implemented.

4.2 Decision Making Process

The factor decision making process involves the decision making process not only of the government but also of the local people, project proponent and all directly or indirectly involved people and stakeholders. Decision making process involves choosing the right alternatives of the power plant selection, the EIA,

the strategic assessment of the project and various other factors relating the sustainability of the project.

Nepal is a country with high democracy and freedom in the decision making process and all the projects need to aggregate the decision from the central level to the local level for carrying out any types of development projects. The decision making process covers all the aspects and the elements of the hydropower project. The decision making process is based upon the social, economic and the environment issues and a conclusion is ensured either as a unanimous agreement or majority decision. The main principle behind the decision making is 'All different discussions lead to the same decision'. The elements of this factor of sustainability will be analyzed in the following paragraphs:

4.2.1 Evaluation of Alternative Energy Options

As the responsibility of NG towards the people and the development, the government emphasizes the project developer to maximize, upgrade and update the environmental, social and economic benefit arising from the particular project to minimize risk. Among available options, the best choice is made based on various factors. Affordability, resource availability and scale of requirements are defining factors for evaluating the alternative energy options of the project. In Nepal, it needs to be proved that the recommended option is sustainable and the most beneficial to the community, the economy and the environment. Because hydropower is internationally considered to be sustainable, and especially because of the large availability of the rivers and the supporting slopes for the construction of the project and non-availability of other resources such as gas, petroleum products and coal, the development of hydropower is the obvious option and probably no alternative options must be thought.

According to the IHA, the criteria presented in Table 6, must be assessed to determine the sustainability of hydropower with respect to other available resources. The elements on the left hand are the key criteria determined by the IHA and the elements on the right hand are the assessment of the key criteria for evaluating the energy options in Nepal. The assessments on the right side are based upon the data provided by various government organizations and the non government organizations, private and public institutions, independent power producers and the hydropower engineers and the journalists, who have direct and indirect relation in the development and the research of Nepalese hydropower.

Table 6: Key criteria to be used in comparing energy options

Key Criteria	**Nepalese Context**
Assess the options in terms of need against supply side and demand-side efficiency measures.	a)Internal demand =1100 MW b)Production =689 MW c)Deficient = 500 MW d)Production Capacity = 83000 MW e)Technical feasibility =42000 MW f) Production =564 MW g)No. of rivers =6000 h)Available other resources =No i)Export Probability =Practically Unlimited
Assess the options in terms of resource depletion	a)No consumption of water b)Water is a Perpetual source, hence depletion is impossible c)Project cost not transferred to future generation d) Project benefit is transferred to the future generation.

Assess the options in terms of energy payback ratio	a)For an assumed lifespan of 100 years, it has the highest payback ratio exceeding 200, (205 for dam projects and 257 for run of river) [15] b)The highest grade means good environmental performance and less energy consumption during production and transmission c) All the impacts arise only during construction. d)Other options are not available in Nepal
Assess the option in terms of economic viability over the life of the facility.	a)Micro hydro plants are main factors for development of rural areas of Nepal b)A privately owned system is financially sound c) Community owned hydropower plants are relatively weak financially, but have been proved to be highly effective in terms of increasing economic welfare of people in rural areas.
Assess the option in terms of the availability and cost of resources over the projected life of the facility.	a)No fossil fuels are available in Nepal b)The rivers are run off and storage type, the origin of which is in the mountains, so there is no possibility of drought c)Water is available free of cost and does not need to be imported d)Other source of energy production process seem highly expensive due to 100% dependence on foreign resources and untimely availability.

Assess the options in terms of the appropriateness of technology, levels of efficiency and service required.	a) Refurbishment and modification of operational regimes, particularly of older power stations, can often result in significant additional energy generation. b)Average technical efficiency of hydropower plants of NEA is around 74% c)Scale efficiency of the plants is found to be 71% d)Overall efficiency is 50% e)Base technical efficiency scores below 90% in terms of sensitivity analysis[16] f)There is a 12% peak load shortage in Nepal g)High efficiency, low maintenance cost and flexibility in the development
Assess the options in terms of additional or multiple use benefits	a)Minimal contribution to global warming b)Cleaner, more stable and secure than other sources with the life up to 100 years c) The potential of sites on already developed rivers is not always fully realized. While consideration of cumulative and other environmental impacts is necessary it is possible to develop new hydro-electric projects on already regulated river systems. Examples include Kaligandaki A and Kaligandaki B are two hydro powers plants being developed from a single river. d)As an agricultural country the water can be diverted for irrigation and also for drinking, therefore increasing the productivity and creating sanitary systems e)Landslide control, flood control, boating and recreational facilities on the water reservoirs are created f)The value should be discounted against any loss of benefits (including environmental costs) associated with the project.

Assess options in terms of poverty reduction through flow of benefits to local communities via employment, skills development and technology transfer.	a)Jobs to local people b)Use of local unskilled and skilled manpower during the construction, operation and maintenance c)Expansion of local skills base d)Technology transfer and self-sufficiency to complete much of engineering, environmental and social work elements and analysis e) No national or international values are ignored or affected by the development of hydropower.
Assess the options in terms of land area affected (environmental footprint) and associated aquatic and terrestrial ecological impact	a) Big hydropower projects like Kaligandaki have severe problems of landslides and sedimentation. b)Impoundment, degradation of the flora and fauna, and water logging change in ecosystem both streams c)In some hydropower projects, some population has been displaced, so comprehensive resettlement and rehabilitation plans must be developed and implemented in consultation with the people affected. Ideas like 'lowering the full supply level of proposed reservoir can help solve this problem easily and has been done in Nepal d) Small hydropower and run of rivers have considerably fewer impacts as no water is stored and no impoundment occurs. e)But trapping of waters in hills and valleys where there are few houses and less cultivated area will be a solution to the above mentioned environmental footprints f) The dam construction proves beneficial during the monsoon as it controls the flow of water and hence landslides and erosion are controlled.

Assess options in terms of carbon intensity and greenhouse gas emissions	a)Carbon emission from hydropower plant is 4-18 g CO2 per kWh where as carbon emission from fossil fuel ranges between 144-3006 g per kWh[17]
Assess the options in terms of waste products (Emissions or discharges to air, water and land).	a)Hydropower plants create no health effects, but these plants are advantageous as they will reduce the dependency on other energy production sources b) In some cases, projects have also posed risks such as waterborne disease and a temporary rise of mercury levels in fish. c)If energy is produced from any other source, there is waste and the final disposal place will be either air or water, which will affect the environment and human health

Also, emission calculator shows that hydropower is the cleanest form of energy. Table 7 compares emissions from various energy sources and shows emission from hydropower is very negligible compared to other energy sources.

Table 7: Comparison of emission from various energy sources [18]

S.N.	Energy sources	Amount	Unit	Emission(kg)
1.	Petrol	1	Liter	2.331
2	Diesel	1	Liter	2.772
3	LPG	1	Liter	1.7
4.	Natural gas	1	kg	0.24
5	Hydroelectricity	1	kWh	1
6	Oil/kerosene	1	Liter	3
7	Biomass	1	Kg	5

Hence, there is reason why hydropower should be promoted as the first choice as the social, economical and environmental benefits seems to support this.

4.2.2 Dam Safety

Dam is the most renowned and important structure in a hydropower project. Its stability ensures the protection of life, property, electricity and the environment whereas its failure may prove highly catastrophic. Nepal has a dam safety management plan which defines the scale, frequency, monitoring and instrumentation required. Planned dams and catchment conditions must be fully assessed from all safety aspect and comprehensive dam safety risk assessments are to be completed for selected sites in any proposed hydropower schemes in Nepal. [19] The statement is a strong supporting factor for dam safety. The design, construction and the practice phase must ensure that the defined safety requirements are met as per the Nepalese and international safety standards.

Dam construction in Nepal requires a high level of expertise from different related areas, problem identification based on the type and the geography, investigations and discussions on the identified problems, problem ratification based upon the discussion, dam safety and emergency response. Regular monitoring as per the instructions of the regulatory authorities, developing an integrated plan of Environment Management Systems (EMS), raising awareness and safety training for downstream and upstream residents are promising dam safety values in Nepal.

Historical flow of the river and the assumption of that the catchment flow will have the same characteristics future are the major design criteria for dams. Since, global warming has changed the hydro geological conditions, for example increased flood caused submergence, and changed the precipitation pattern which, in turn, has increased the risks of dam. In addition, Nepal lies in

the Earthquake zone; there is always a high chance of earthquake at any time. If there happened an earthquake of reasonable magnitude probable more than six (6) on the Richter scale, the people living downstream of the dam may not survive. Thus, due to global warming and the geographic location, dam-building in the Himalayan Republic of Nepal is proving to be investing billions of dollars in high-risk and non-performing assets.

Also, the burst of glacial lakes is the next serious concern. Due to global warming, ice can melt that can create a risk of forming glacial lakes which can burst with enormous energy of the water of nature. These moraine dams collapse and millions of cubic meters of water are released resulting in massive flash floods because they cannot be stopped by dams of lower flood design value than the catastrophic value. [20]

Thus, safety design of safe dams is not a problem in the Nepalese republic, but the impact of the global warming and the earthquake risk may turn the safe dams of Nepal to catastrophic ones. However, the earthquake is a natural event; and cannot be assumed all the time. If dams are designed on modern technology with consideration of the global warming effect, they prove to be sustainable elements in the hydropower sector in Nepal.

4.3 Environmental Aspects

The factor Environmental Aspects involves the overall and the integrated environmental issue of the impact of hydropower projects. The environmental issues may arise because of many factors and at various stages of time. There are many environmental issues that must be analyzed during analyzing the sustainability criteria. The IHA suggests the following basic and important elements of the environment factor to be assessed: Environment Impact Assessment (EIA) procedure, water quality, sediment transport and erosion, downstream hydrology and flow, rare and endangered species, construction

activities, health issues, flora and fauna. The most important environmental sustainability factors for the Nepalese hydropower are described briefly in the following paragraphs.

4.3.1 Environmental Impact Assessment (EIA)

EIA is an assessment conducted to inform decision makers of the projects of the positive and negative effects of a project upon the environment and help in developing the associated mitigation measures against the effects. The environmental impacts of hydropower project are considered during the planning, construction, operation and demolition time of the project and may vary with time as it must be carried under various clues and directives.

EIA determines project impact by virtue of its nature, size, location, codes of practice, interested group's participatory approach, environment protection and factual information from the local level and from the government level.[8] Transparent and collaborative decision making, true and factual information collection creates a good EIA report. In Nepal, the developers consult with local and national resource agencies first to get assistance in the environmental issues to be addressed and to clarify the timelines that apply. [7] Authorities need the following information for approval in a specified and timelines. [21]

- Project Description
- Objectives, targets and success indicators definitions
- Existing environment of the proposed area
- Project justification and evaluation of project alternatives
- Economic, social and environmental considerations
- Mitigation measures environment impacts
- Transparent communication and consultation with stakeholders

EIA reports measure the performance against the targeted objectives and the proposed indicators of the project and suggests the mitigating solutions for the conflicting issues. The best way of mitigating the public conflicts is by the negotiations with the public for anonymous or at least majority public acceptances.

The Nepalese government's EIA Guidelines of 1993 and the Environment Protection Act of 1997 are the basic guidelines for carrying out EIA in Nepal. [21] 'Formulation of Environment Protection act 1997', 'Establishment of Ministry of Environment', 'development of EIA guidelines', 'Considerations of environment concerns in Hydropower Projects' have helped a lot to enforce EIA procedures in Nepal[25] during project proposal and enactments. Simultaneous consultation of Professional Development Programs (PDP) Nepal's regulations and user-friendly manuals with local expertise can be used during the EIA procedures of hydropower and distribution lines that will help to take together the national guidelines and the local conditions. EIA and EMP are needed for every unit of the hydropower projects such as electricity sub-stations, switching stations and rehabilitation of power plants regardless of the type of fuel used. [21]

Ministry of Water Resources (MoWR), Ministry of Environment Science and Technology (MoEST), DoED, and Nepal Electricity Authority (NEA) are the official bodies that evaluate and approve the EIAs of hydropower projects in Nepal. According to them, the EIA process in Nepal must contain the following units:

- *Project Environmental Screening*

Screening evaluates if the proposed project needs to carry out EIA or not. According to the sections of 1 and 2 of (EPR), 1997(NG/MoLJPA 1997) power projects with the following qualifications are required to carry out the EIA. [21]

- Hydropower projects with an installed capacity of more than 5 MW
- Thermal power projects with an installed capacity of more than 1 MW
- Installed 132 kV transmission line projects
- Projects around national parks, wildlife sanctuaries, or conservation areas, regardless of the size of the project

There is also a rule of thumb in hydropower projects: The bigger the project, the bigger is the impact and vice versa. Projects below 5 MW are almost beneficial with minimal impacts, and their effects are outweighed by the intensity of their benefits. Thus, generally EIA reports for the projects below 5 MW are not needed in Nepal as their benefit suppresses the impacts.

- *Scoping*

Scoping helps to identify the significant issues of EIA and to develop the Terms of Reference (TOR) document. This will analyze all the impacts, the alternatives and the BAT for the project. Scoping in Nepal involves the following tasks: [21]

- Involvement of all stakeholders
- Identification of significant issues to be considered
- Selection of BAT and development of TOR

With the above mentioned considerations, the proponent publishes a public notice in a national daily newspaper requesting concerned people for suggestions and views on TOR and BAT within 15 days of the date of publication. The aims of scoping in Nepal are: [21]

- Identify the key issues in EIA
- Analyze alternative and help choose the BAT
- Determine the assessment methods

- Identify all the stakeholders
- Public agreement and consultation on the project related issues
- Establish TOR for the EIA study

An integrated scoping process is the spirit of decision making process in project EIA because it contains the following components: [21]

- Project information
- Hearing on affected people, group, communities interest
- Identifying major issues of public concern
- Evaluating of project issues on the basis of available information
- Establishing priorities for environmental assessment
- Developing a strategy for addressing priority issues
- Public Involvement

The project proponent does the scoping as their responsibility on the basis of the guidelines provided by the regulating body of Nepal. It makes EIA scoping in Nepal an open and participatory exercise as it contains multidisciplinary experts, local leaders, and special interest groups to encourage the participation during the implementation monitoring and evaluation. [21]

- *Terms of Reference (TOR)*

TOR defines the outlines for conducting EIA. It carries out all the outlines to determine the impacts, and to look for more possible alternatives during the planning, construction and the implementation phase.

- *EIA*

EIA is an integrated package of all the information obtained, analysis, and interpretation of results. It is the baseline for the impacts identification on the basis of which the mitigation measures against the impacts are suggested in the Environment Management Plan (EMP). The principles of *transparency* and *stakeholder involvement* are crucial for maximizing project benefits and minimizing negative impacts. The proponent submits the reports to the DoED. After the review and comments it will go to the MoWR, the MoPE and then to the RRC respectively. If NEA is the hydropower project proponent, it submits a specific number of copies of the EIA report to the DoED or the MoWR directly for approval. The report is reviewed hierarchically by the DoED and the MoWR for the following two legal requirements: [21]

- Public hearing about the proposal in the affected area for the collection of comments and suggestions
- Submission of the recommendations of the concerned authority

After the review, the reports are submitted to the DoED, the MoWR and then MoPE in a row with possible comments. When it passes all levels, the MoPE publishes a public notice, inviting the concerned public and stakeholders to provide comments on the report in the same manner as scoping for a minimum of 30 days. The public then provides comments within the time deadline, and if some constructive and critical comments are obtained, the MoPE may instruct the proponent to address them. [21]

- *SIA Framework*

SIA provides compensation and takes mitigation measures against losses for the affected people and the community as a part of socio corporate responsibility. [21] This involves everything from the risk assessment, calculation of the area under severe influence; calculation of the compensation to be paid and the rehabilitation to be made. The SIA framework is made according to the

intensity of effects, affected area, effect criteria, valuation and the identification of the affected groups and areas.

The EIA framework in Nepal is a complex and a long process as described by the Figure 3. Scoping, BAT, EIA, Cost and benefits ratio and all the process are clearly identified in the EIA process of Nepal.

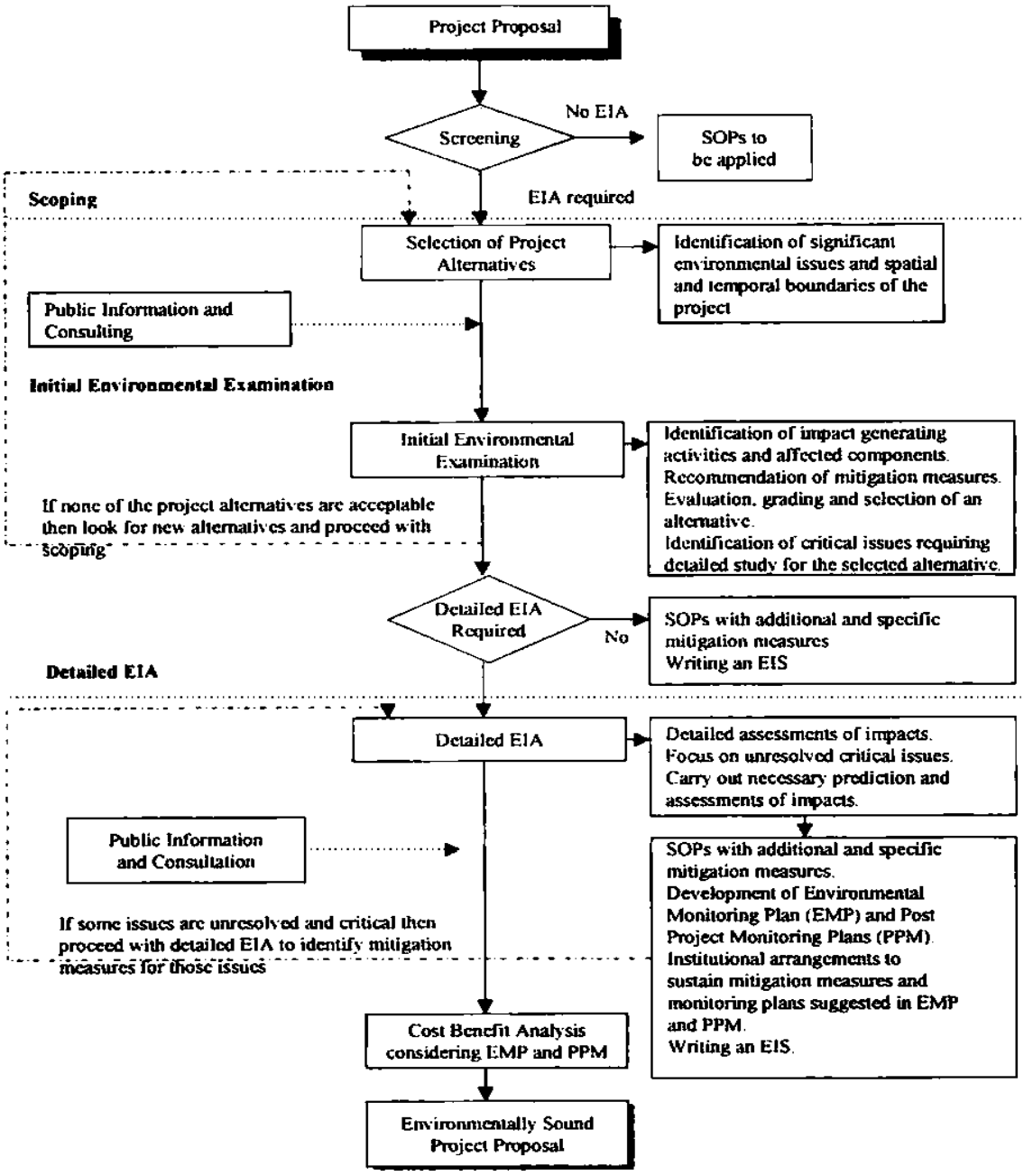

Figure 3: EIA principles and process in Nepal [22]

EIA is taken as a holistic approach in Nepal due to the people's consciousness, the demand of projects and the avoidance of legal and economical crisis. Nevertheless, there are some major steps to be taken to strengthen the system and the capability of conducting EIA. The various approaches that need to be upgraded and updated or improved inside the EIA process in Nepal are as follows: [9]

- Improving the quality of EIA reports
- Processing EIA report within stipulated time
- Creating accurate baseline data
- Ensuring quality of the consultant
- Building the human resource capabilities.

Hence, the implementation of EIA in Nepal is of very high standard; this approach has been an example for the world and has been regarded as one of the best EIA practice in the world. This is an indication that the approach in Nepal in terms of EIA is holistic and from this point of view the sustainability of Nepal is at an extremely good level.

4.3.2 Water Quality

The bathymetry, climate change, and the changed river flow pattern due to dam construction, have led many places to undergo impoundment. This in turn has resulted to water quality change both upstream and downstream of the storage type of hydropower projects. Because the water remains stagnant for a long time, green plants, and organic material will die and then undergo anaerobic decomposition creating lots of methane. Also, because the landscape of Nepal is sloppy, the mountain soil and the hilly soil eroded can contain some sorts of phosphoric, sulfuric and nitric components, which in turn raise the nutrient content of the pond. Because of the increased nutrient content,

eutrophication will increase, thereby alternating the water quality of the impounded area.

Others factors involve reduced oxygenation, temperature, stratification potential, pollutant inflow, propensity for disease proliferation, nutrient capture, algal bloom potential and the release of toxicants from inundated sediments. Water quality change is and must be identified during the EIA process. The increased chemical concentration of carbon dioxide in water can produce carbonic acid, sulphates can react with calcium hydroxide to form compounds with higher volumes, sulfides react to water to form sulfuric acid, and various sulfuric, hydrochloric, nitric and organic acids will be formed and they reduce the strength of the concrete dams. The carbonic acid formation is as:

$$CO_2(aq) + H_2O \leftrightarrow H_2CO_3(aq) \quad (4)$$

Hence, the safety of the dam is also in risk due to the changed water quality. Before starting any hydropower project in Nepal, information on water quality must be collected as shown in the Appendix 3 of this thesis. It is considered that the removal of impounded vegetation is impossible, but the improvement of the catchments areas is a promising idea to maintain or improve the quality of water.

Thus, water quality is not so demanding factor for hydropower sustainability in Nepal, as many of the hydropower projects are ROR type and the change in water quality is unlikely to occur. History stands as proof of no significant water quality change.

4.3.3 Sediment Transport and Erosion

The changed river morphology due to the creation of the reservoir also changes the hydraulic and sediment transport characteristics of the river. This will in

turn lead to increased sedimentation content in the reservoir. Although there is always a provision of flushing, sedimentation load proves to be a design and environmental challenge. Unbalanced sedimentation load downstream can change geomorphic processes, thus creating environmental hazards.

In Nepal, most of the projects get affected by this problem of sediment transport and erosion. Especially during in monsoon, due to heavy rainfall, the sediment gets deposited in the reservoir and the water carrying the volumetric capacity of the impound decreases whereas in downstream a reverse phenomenon occurs. The magnitude of the sediment transport depends upon the environment properties, shape, size and mineral component of the sediment. The sediment deposition rate is directly proportional to the magnitude of the hydropower project; the larger the project is, the larger the impoundment is and the larger the deposit as shown by the figure 4.

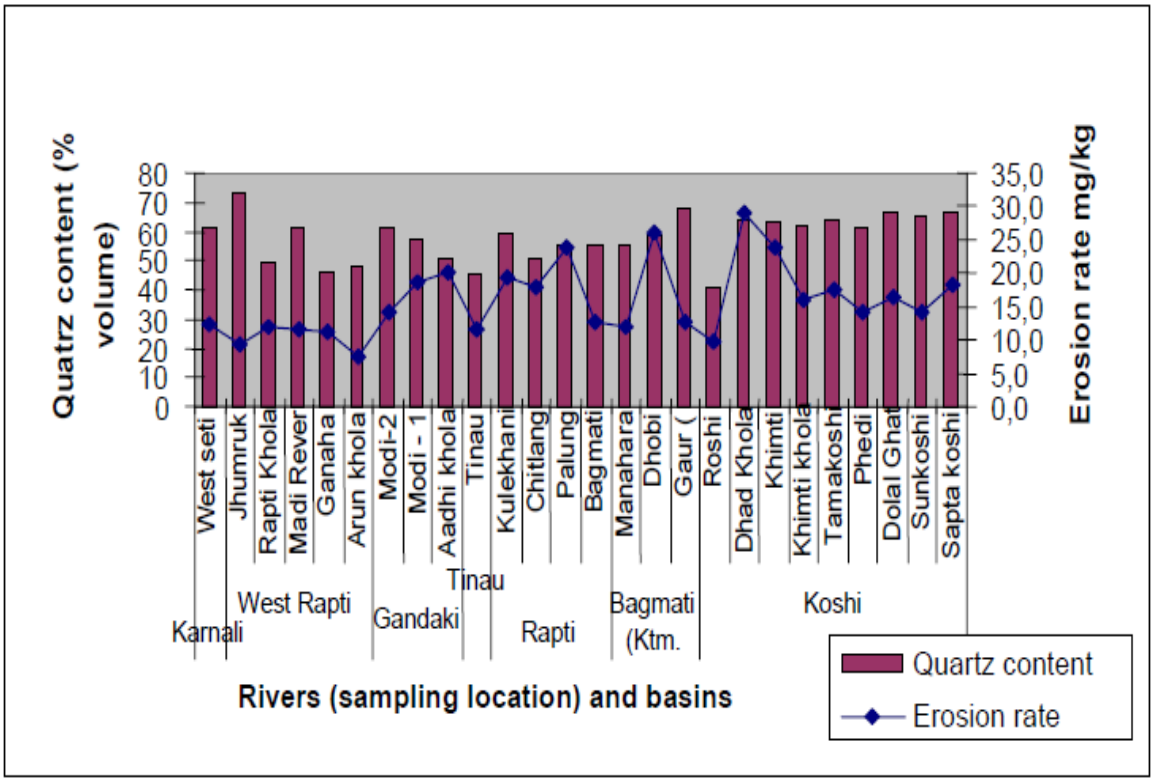

Figure 4: Quartz content from mineral analysis and erosion rate from laboratory test from corresponding sand samples [23]

In Nepal, larger hydropower plants with high head and production capacity seem to get mostly affected by the problem, because of large catchment area and the erosion that the catchment area contains. Examples include the high deposition and erosion in the catchment of Khimti and Kaligandaki A Project. The deposition concentration in reservoirs upstream of many hydropower plants is presented in the Figure 4. The data have been obtained by experimental analysis conducted in many rivers of Nepal.

It is clear from the graph that the main and the big rivers have a high rate of erosion and a high value of sediment transport. Thus, the main concern and interest of the power developer must be to reduce reservoir sedimentation. This issue must be addressed clearly in the EIA report because the improvement of the catchment area against soil loss can be minimized by terracing, reforestation and bioengineering techniques. Load minimization by flushing off deposited sediments from the settling basin is the next alternative. Also, designing a large catchment and a dam if possible, and pre-thinking of the operational, physical mitigation measures to reduce erosion downstream must be considered for both the proposed and the existing development projects.

Hence, because of the geology and soil strata of Nepal, sedimentation and erosion are permanent issue but their effects can be minimized. Hence, sedimentation and erosion do not affect the sustainability parameter as sediments can be flushed off and erosion can be minimized.

4.3.4 Downstream Hydrology and Environmental Flows

The change in river hydrology after the construction of a dam affects the people, land, biodiversity on the downstream of the river. It is always a recommendation of the Nepalese government and the international associations to maintain a certain minimum value of the downstream flow. Nepal has maintained a standard of the downstream flow for the existing projects and for

the projects under construction. In spite of the challenging hydrology for example gradient, feed type and glaciered flow, Nepalese hydropower plants have minimized the adverse environmental and social impacts of the project. The new Hydropower policy of 1992 emphasizes the need for a minimum flow of 10% of the minimum monthly average discharge or a flow equal to the discharge to the downstream flow. Also, because Nepal's area downstream is agricultural land; therefore, a certain value of flow is needed to serve the lower level for the irrigation, food production and other relevant purposes. To maintain sustainable fish life, downstream animal and flora life, and to prevent the conditions from deteriorating by flood, drought or changes in geomorphology, the above stated flow criteria has been made compulsory in Nepal. None of the hydrological aspects mentioned above can neither be prioritized nor be ignored during the project. They are always addressed in the EIA study of the hydropower projects of Nepal.

In case of Nepal, because of the higher availability of water, it is not a problem and all the plants that are in operation are capable of letting the minimum requirements downstream. Hence, Nepal has no problems in allowing and enforcing natural flow of the river downstream, which is extremely sustainable.

4.3.5 Rare and Endangered Flora and Fauna

Dam construction is a serious danger to nationally and internationally threatened and endangered terrestrial and aquatic species because of habitat loss, impoundment, disturbance upstream and the downstream flow patterns and the mutation due to the changed conditions of life. The endangered species for example Bengal tiger and the rock python, many phytoplankton and other micro-organisms and the Himalayan flora may be adversely affected by the construction of hydropower plants.

There is a trend in Nepal to prepare a Biological Assessment (BA), which is a part of EIA, and is focused on the endangered species. It is submitted to the agencies responsible for the conservation of the endangered species. The panel's experts check this BA and then develop a Biological Opinion (BO) which gives the information about the details of the project requirement to the conservation of the endangered species. [24] The shift of the animal's habitat or the change in the plan of the project may be advised according to the instruction of the BA. But, structurally and politically large and important projects are difficult to be halted. Major mitigation cost must be a part and parcel of the project, if impacts are severe and unavoidable practically.

> In the US, mitigation for lost endangered species habitat is often compensated by the requirement of acquisition and long-term protection of similar habitat in adjacent areas. Ratios are such that the loss of one acre of endangered species habitat requires more than one acre of compensatory habitat. Multinational corporations are used to complying with agency regulations and mitigation issues, so Nepal should not allow itself to accept any less. For good or bad, this is part of the business climate that must be factored into 'successful' project design, construction and operation [24]

The same principle is followed in Nepal. It is till today not known that any of the species became extinct or was severely affected because of the hydropower projects. EIA identifies the species and must treat them lawfully not to cause extinction. In Nepal, the species have been relocated in many cases as there is identical environment available for the species to adapt to. Hence, the sustainability factor due to this element is really appreciable.

4.3.6 Passage of Fish Species

Fish breed in the rivers and they require the hydrosphere for their life time. The construction of hydropower acts as a barrier for the fish to move from either the upstream or the downstream. Normally, the Nepalese are not dependent on the fishing profession, but still there are many types of fish that are only found

in the Nepalese republic and are an important factor of the Nepalese Himalayan ecosystem.

Nepalese rivers contain mostly the migratory fish, and, hence, in almost all the completed hydropower projects this issue has been addressed and mechanisms for their transfer such as fish ladders, mechanical elevators, guidance devices and translocation programs have been constructed. Also, some other mitigation measures have been taken in big hydropower projects for example trapping and hauling, constructing trash racks, louver systems and hatcheries, ramping and monitoring. But, all the above measures cannot be realized due to the constructional practice, and the emphasis on other impacts rather than this impact. Still the adverse impact to the fisheries is possible, if not probable.

Nepalese project developers are assumed to construct passage for fish according to the EIA rule; this has already been done in completed projects. Hence, this practice ensures the sustainability under this element.

4.3.7 Health Issues

Health issues are important factor to determine the sustainability analysis. Human health effects due to disease, hydrologic conditions and the changed water quality are the most important considerations. The hydropower developers must make a public health plan and implement it in the precautionary phase. The implementation of this plan during the hazard crack phase may create a problem of project continuality. All the completed projects have succeeded in achieving the success in health issues because they address the health issues that may arise during the life cycle of the project. Also, the establishment of hospitals, the improvement of health service and the provisions of the ambulance services in the affected areas automatically help to minimize the health risk arising from hydropower development. Effective monitoring plans, health issues and monitoring tasks must be relevant to

ensure the affected person of the potential health benefit. Risks and uncertainties must be the first priority to be addressed as the breakdown of the plant may cause a catastrophic hazard. As a preventive measure, the improvement in water supply, economical improvement and flood control measures can be used as a tool to address the health issues.

In Nepal, the occupational health and safety legislation is of low standard also among the South Asian Association for Regional Cooperation (SAARC) countries. In such a case, the health and safety of the people in the area cannot be assured. It all depends upon the project proponent's rationale and the activeness of the people living in the area of the project. Health practices and the proposed location of the project are also a defining factor to analyzing the sustainability analysis of the hydropower projects.

4.3.8 Environment Management of Existing Hydropower Schemes

Continual improvement by review, audit and gradual changes is the aim of the environment management of the existing hydropower schemes that can be controlled or influenced. [25] Despite some contradictions in the scenes, Nepal has provided the investors with all relevant laws, policies, permits, agreements and codes of practice for the jurisdictions in which they must operate. The basic laws and standards for hydropower comply with the following Hydropower policies along with the internationally accepted ISO 14001: [22]

- Electricity Act 2049
- Water Resources Regulation act 2050
- Energy Regulatory Commission Act
- Environment protection Act 1997 (EIA and emission regulations from the existing projects)
- Conservation and threatened species legislation

- Nepal Company Act 1964 (Guide for the national or international investors to establish, transfer shares, merge or transfer the project to the new people or company)

EMS refers to the continual improvement of operational practices through a formal Environmental Management System (EMS). There is a provision in Nepal for power operators and manufacturers of hydro-electric equipment, to adopt internationally recognized environmental management systems (such as ISO 14001). The implementation of EMS is made compulsory in Nepal for the following reasons: [25]

- Environment ethics and socio corporate responsibility in business
- Environment management responsibility
- Acceptance of environmental sustainability goal by Nepal
- Accountability and responsibility on environmental impacts
- Corporate recognition of employees initiating environmental improvements.

Documentation, controls, emergency operational procedures need to be implemented in the projects to achieve the goal and also to make a continual improvement on the resettled goals. Training, monitoring, measuring, reviews and audits will help to gain this target. But sometimes the lack of practical policy application of the company handling the hydropower project, applicable international policy, services and the location of the project determine the intensity of the use and application of hydropower.

The presented Figure 5 is the universally accepted way of determining continual improvement of the management system and it has been used in Nepal since the introduction of this type of management system in the world.

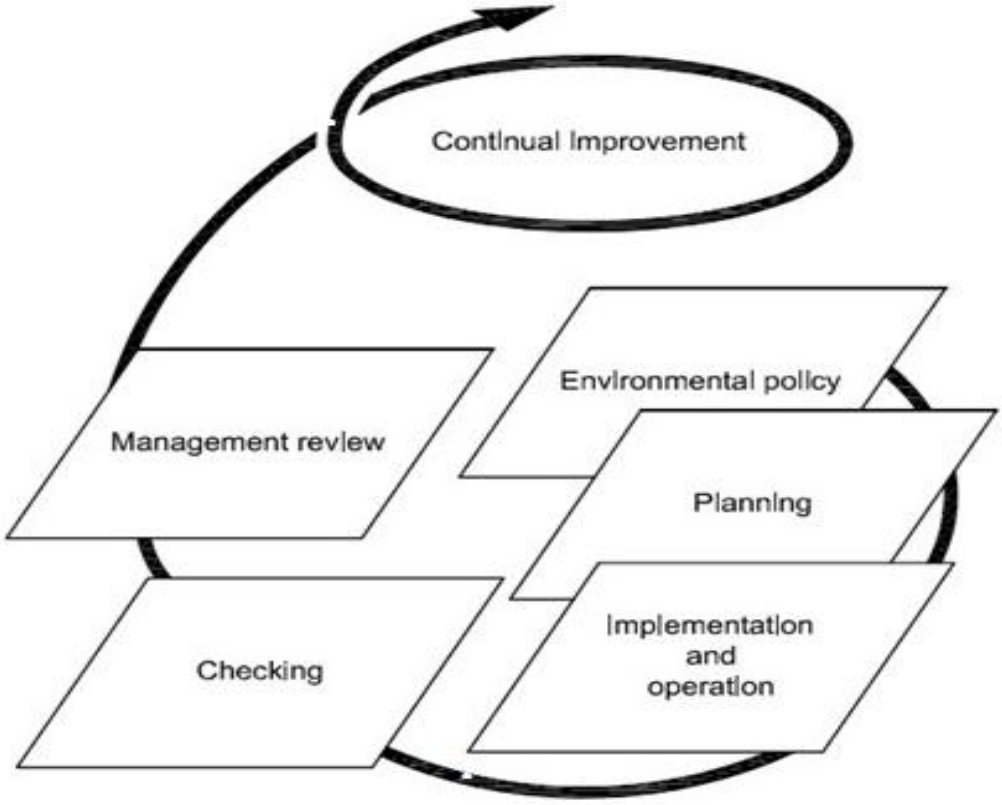

Figure 5: EMS model accepted by ISO 14001 [25]

Hydropower operators in Nepal are involved in the transparent consultations with the stakeholders to enhance longer-term relationships and continual improvement of the assumed environment policy project handler. The companies must do internal audits and try to find the government new policies and the management steps that they must take to make a safer environment that is compatible with the international standard.

4.4 Social Aspects

Hydropower schemes must have significant role in poverty alleviation, and raise the economic standard of the society. Electricity approach, children and woman empowerment and the infrastructure development are the positively influencing factors for making the society welcome the project. Multiple benefits such as fresh drinking water and irrigation water, flood control, fishing profession development has convinced the people on the positive side of hydropower

development in Nepal and many places have seen the uplifting of the overall social status. The main ensuring issue of the hydropower sustainability is based on the motto that 'All individuals of the affected communities must benefit in one way or the other'. Important social elements of this factor are presented in the following subsections.

4.4.1 Managing Social Impacts

Known as *Boomtown Effect,* managing social impacts is a collective set of the socio cultural impacts and the treatment and address of the impacts that must be done in same way. For example, in the construction of the Kaligandaki Project, 1468 families lost 208.68 ha of land due to project structures. Also the 21 local fishermen were affected by their profession and the religious site named 'Setibeni Seela' was submerged with the stoppage in white water rafting. [26]

These impacts were mitigated by offering the cash compensation for those who lost their land, house and property. Alternative indirect mitigation measures were also taken in the projects including the rehabilitation of the affected families, providing the replacement land and house and providing the job in the project according to their skill and qualification. Also the introduction of the microcredit revolving fund, profession oriented skills and various other things have kept the social harmony with the projects and some of them have become the examples projects in the world. [26] This is the trend in Nepal and till today almost all the displaced people are rehabilitated. Nepalese are socially conscious people and know the rules and national and international provisions that the project must make to the society and what they must contribute to the projects to make the hydropower projects more sustainable.

Hence, the cooperation of people and society with the hydropower developers is always positive, which is the best factor suggesting the sustainability of the hydropower projects.

4.4.2 Outcomes for New Developments

Mostly proactive during the planning phase, the element involves the following considerations to ensure the sustainability of the project:

- Improved life conditions
- Improved health conditions
- Direct or indirect project benefits distributions
- Information and economics transparency

As per the above mentioned considerations, the hydropower development has contributed to the development and establishment of new hospitals and health care centers in many parts of the hydropower developed areas. This has created a positive output to the new developments in those areas. It can be concluded that the hydropower development has brought many new development opportunities in the areas.

The new outcomes such as jobs, infrastructure, education, health care and electricity can always be considered as the supporting tips to advocate the sustainability of hydropower project in Nepal.

4.4.3 Strategies to Achieve Proposed Outcomes

The project proponent may promise many advantages and benefits with the society, but making a promise is not important, the implementation of the promises is the main thing. Therefore, the strategies should be made in such a way that adequate consultation and decisions at all levels are made to gain the

best possible impacts during the planning, designing and the implementing phases. This can be done by the direct representation of the affected party in the different stages of project development. Generally, Community acceptance of a project, particularly in its early phases, will greatly assist in the successful implementation of that project.

This has been the strategy of major hydropower projects in Nepal. Therefore, the projects are almost conflict free during the life stage of the operation. But there are also some examples where the project proponent has not taken their promise seriously and the local people also sometimes change the way of dealing their priority with the project holders. But as a rule of thumb, Exception is not an example.

4.5 Economic Aspects

The factor Economic Aspect means the seen and the unseen monetary aspects during any stage of the project. In the case of hydropower projects, almost all the investment comes at the start of the project. All the mechanical, electrical and civil engineering construction has to be done at the start of the project. It looks expensive at the first glance. But, after the initial investment, it doesn't need any investment except for a nominal O&M cost. Also, the PPA is always carried out in the forehand of the project completion; hence the whole project has not any concerns from inflations and market prices. Instead, a good payback period has empowered hydropower not to be decommissioned.

Continuity, reliability and flexibility are the mechanisms that help in the multipurpose development activities. Also, the good electricity market and the good price of the produced electricity are motivating factors that determine the sustainability of hydropower in Nepalese land and rivers. Table 8 gives the PPA values of the Nepalese hydropower projects. The PPA value has been determined according to the value of the electricity produced during the time of

the year. The table presented below clarifies that the electricity produced during the dry season valued more than during the wet season, due high demand and low supply during that time.

Table 8: PPA rates with Nepal government (**esc=escalation**) [27]

Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Wet Season (May-Dec) ($/kWh)	0.05/	3% esc	6% esc	9% esc	12% esc	15% esc	18% esc	21% esc	24% esc	27% esc
Dry Season (Jan-April) ($/kWh)	0.0875									
Income Tax								**20%**		

Table 8 shows that an electricity payment of 0.05 dollar per unit kWh is a good value for hydroelectricity. Also, there is the concept of short-term financing and almost zero O&M cost in the direct and hidden costs of the, which ensures the economic sustainability of the project in Nepal. The following subsection presents the economic elements that are examined the economic sustainability is analyzed.

4.5.1 Institutional Framework

Hydropower in Nepal not only interests the Nepal government, the public and the private sectors of Nepal, but also many foreign people and companies who both have direct and indirect interest and invests in this sector. With almost 100 years of Foreign Direct Investment (FDI) history, bilateral and multilateral funding has entered the Nepalese hydropower sector. [22] Mostly the Indian and

Nepalese companies are actively investing in hydropower projects due to their resonance on the socio economic culture and their low overall cost.

Nepal's hydropower policy is confusing in some ways but there are some institutional special features such as the 'policy of economic liberalization' that draws the investors' attention to hydropower in Nepal. Various other steps to ensure the hydropower investors' confidence in the investment is the main priority of the available legal frameworks of Nepal.[25] Nevertheless, the institutional framework in Nepal is seldom available at its best or in an integrated approach; instead there are individual approaches. If all the individual approaches could be integrated with clear good governance and transparency, the development of hydropower would increase geometrically.

Hence, institutional frameworks are neither good nor bad. The sustainability is assured by the liberal socioeconomic features.

4.5.2 Identifying Costs and Benefits

Cost and benefits analysis include the income and outcome of the hydropower projects. An approach of cost and benefit analysis must be made during the construction, operation and the maintenance of the project to know the benefit or the loss obtained by the project implementation. The cost of the hydropower projects may be the cost due to land acquisition, environmental and social mitigation cost, maintenance of the civil engineering structure while the benefit can be the payback from the project.

Along with the payback, benefits such as the quantitative measurement of greenhouse gas emission cutting and income of the carbon tax from the other polluters, job creation, recreation, tourism, water supply and irrigation must be taken as the benefits of the project. The following extract from the 'Nepal Monitor, FDI in Nepal's hydropower sector: A focus on the product' indicates

that the cost benefit of hydropower projects reflecting the cost and benefit ratio of hydropower:

- Recipients of FDI often gain employee training in the course of operating the new businesses, which contributes to human capital development in the host country. If we harness 10,000MW hydropower, in the process, every year 132,000 people (13000 persons on construction phase and 32000 in operation phase, assuming 2000 person for 750 MW) can get employment.

- FDI allows transfer of technology— particularly in the form of new varieties of capital inputs— that cannot be achieved through financial investments or trade in goods and services. FDI can also promote competition in the domestic input market.

-Profits generated by FDI contribute to corporate tax revenues in the country.

- India's demand for power would grow to 200,000 MW by 2018. If Nepal could fast-track projects to generate just 10,000 MW in ten years, consume 2,000 MW itself and export the rest to India, it could earn $2.7 billion a year.

-According to Nepal Oil Corporation (NOC), in the fiscal year 2005/06, NRs 2.45 billion has been spent to import petroleum products. If the same amount of money were spent for developing hydropower, we could generate 29.9 MW hydropower electricity (for instance, in Chilime Hydropower Project, 1 KW production cost = $1550 = NRs.108500) [26]

This extraction indicates that Nepal has very good benefit to cost ratios in hydropower development thereby boosting the sustainability.

4.5.3 Allocation of Benefits

Nepal is a highly democratic country with the concept of capitalistic market. The construction of the hydropower project ensures the infrastructure development i.e. health care, education and the electricity becomes available to people of all caste, creed and race. It creates jobs and local transformation which results in cash flow at the local level and raises the life standard of the people. Thus, this clean energy will not only generate the green and clean energy, but will also

transform the country as a whole, and the benefits reach all the aspects of life. The only requirement for this is the transparency, regular audits and the feeling of the socio corporate responsibility on the project developers.

In Nepal, the benefit is allocated in two ways. One is the capitalist way; the more you have taken the risk, and the more will be your benefit. This applies specially to the direct investment. But if the project is of general interest and all parties have an equal share of the investment or the risk, then the benefit is given to all of them in a solidary system. Hence, the allocation of benefit is very systematic and rational, so that everyone on the project area are neither left over nor repeated for proper allocation of the hydropower projects benefits.

5. Discussion

The elements of the sustainability factors are not proportional in terms of their positive deviation towards sustainability. Some elements show strong reasons why hydropower is the most sustainable while others strongly oppose the sustainability attitude. The analysis of the elements of sustainability pointed four main directional deviations named strength, weakness, opportunity and threat. The SWOT analyses of the results in table 9 show that the strength of hydropower development has dominance over the weakness and threat from the hydropower project development. There are also various opportunities and fewer threats. The weakness is solely due to economic and social factors that can be changed with good governance and social corporate responsibility.

Table 9: SWOT analysis table for the hydropower in Nepal

Strength(S)	**Weakness(W)**
Economics	
Low O&M cost with high life	Heavy Primary Investment
Reliable to cope peak demand	Performance dependent on hydrology
Multipurpose use	Conflict in water use
Employment opportunities	Foreign investment required
Energy independence	Long term planning required
Social	
Capacity building	Resettlement
Resource and manpower mobilization	Competence in water management
Improve living standard	May create social imbalance
Environmental	
Environmental	
Totally green and clean	Damage to land and animals
Prevents fossil fuel depletion	Water quality may alter
No consumption of resources	Sedimentation and erosion

Opportunity(O)	Threats(T)
Economics	
Make the money and service	Investment may fail
Raise the living condition of people	
Social	
Social influence and harmony	Society may demand unreliable things
Environmental	
Greenhouse gas reduction	Natural disasters
Carbon tax income	Dams failure

After the analysis of the IHA's guidelines for hydropower sustainability in Nepal, the scores were provided to the each of the determining factors as shown in Table 10. The net value of the sustainability is the average of all the values.

Table 10: Score table of sustainability parameters

S.No.	Aspects	Score
1	Government stability	1
2	National and regional energy policy	3
3	Policy inconsistencies	2
4	Planning deficiencies	2
5	Licensing anomolities	3
6	Strategic assessment	3
7	Climate concerns in energy related projects	5
8	Evaluation of alternative energy options	5
9	Safety issues	4
10	Environment impact assessment	5
11	Water quality	4
12	Sediment transport and erosion	3
13	Downstream hydrology	4
14	Rare and endangered flora and fauna	5

15	Passage of fish	5
16	Health issues	3
17	EMS of hydropower projects	4
18	Management of social impacts	4
19	Outcome for new development	4
20	Strategies to achieve proposed outcomes	3
21	Institutional frameworks	3
22	Cost and benefits ratio	5
23	Benefit allocation	3
Average		**3.61**

The average of all the elements determining the sustainability of hydropower projects in Nepal was 3.61. Any value below three (3) would be unacceptable because such a low value represents risk rather than sustainability. Nevertheless, the average value was above three (3), which represents the confidence level in the hydropower sustainability in Nepal. Thus, it can be said that the sustainability of hydropower projects in Nepal is at good level.

6. Conclusions

The discussion and the overall result value of 3.61 out of 5 shows that Nepal's hydropower is at a sustainable level. It is to be considered that the score of Nepal was drawn down only because of the political and the governmental factors. Hydropower is welcomed and supported by the local people as a beneficial project. If Nepal gets good and stable governance with reduction in red tape politics and bureaucracy, the score will surely rise over 4 out of 5. Although the sustainability score is above the accepted level, Nepal needs to develop many sustainability measures and continuous sustainability management so that it can reach a most satisfactory level of sustainability.

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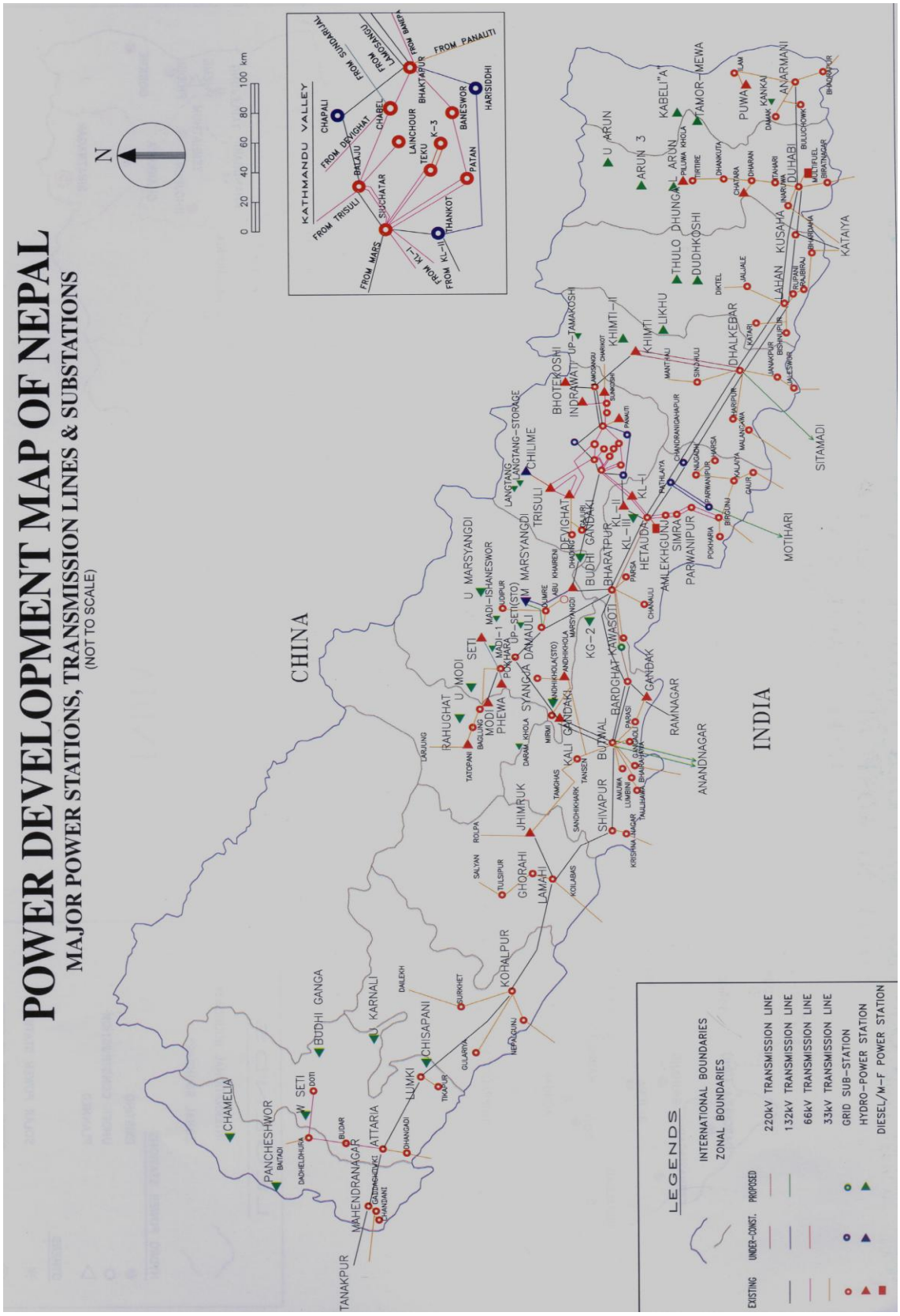
Appendix 1: Power Development Map of Nepal [28]



Appendix 2: Hydropower Plants and Transmission Lines in Nepal [3, 5]

HYDROPOWER PROJECTS			
S.N.	**Hydropower Type**	**Capacity (MW)**	**Number of plants**
1	Existing major H.P	459.159	11
2	Existing small H.P.	472.994	16
3	Existing isolated H.P.	4.536	23
4	Existing diesel plants	53.41	2
5	Undergoing major H.P.	500.4	4
6	Planned and proposed H.P.	1422	8
7	IPP Projects connected to INPS	158.315	19
8	100% private owned plants	16.436	6
9	PPA concluded projects	87.508	25
10	Identified H.P.	21253	20
11	Unidentified and undeveloped	58572.2	--
	Total	***83000***	

TRANSMISSION LINES			
S.N.	**Type**	**Length (km)**	**Circuit type**
1	Existing 132 kV	1562.9	14 single, 5 double
2	Existing 66 kV	354.72	12 single, 4 double
3	Under construction 220 kV	147	1 single, 1 double
4	Under construction 132 kV	157.5	1 single, 1 double
5	Planned and proposed		
	220 kV	540	5 double
	132 kV	674	1 single, 6 double
6	Inter-country joint venture	45	1 double
7	Planned trans-boundary	59	3 double
	Total	***3540***	

Appendix 3: Water Quality Parameters Associated with Hydropower Developments [31]

Parameters	Pre-Construction	Construction	Operation	Audit
General Monitoring				
Water Temperature	Y	Y	Y	
Air Temperature	Y	Y	Y	
Dissolved Oxygen	Y	Y	Y	
Conductivity	Y	Y	Y	
Total Suspended Sediments	Y	Y	Y	
Total Dissolved Solids	Y	Y	Y	
PH	Y	Y	Y	
Assessment Monitoring (As Recommended During Consultation)				
Nitrate-Nitrogen	Y	Y*	Y*	Y
Ammonia-Nitrogen	Y	Y*	Y*	Y
Total Phosphorus	Y	Y*	Y*	Y
Heavy Metals (Fe, Hg, Mn, As, Pb, Cd, Na, K, Cr)	Y	Y*	Y*	Y
Biochemical Oxygen Demand	Y	Y	Y*	Y
Chemical Oxygen Demand	Y	Y	Y*	Y
Total Coliform Bacteria	Y	Y		
Fecal Coliform Bacteria	Y	Y	Y*	Y
Alkalinity (as $CaCO_3$)	Y		Y*	Y
Hardness (as $CaCO_3$)	Y		Y*	Y
Chloride	Y	Y	Y*	Y
Sulfates	Y		Y*	Y
Oil and Grease	Y	Y	Y*	Y
Pesticide Scan	Y		Y*	Y
Dissolved CO_2	Y		Y*	Y
Chlorophyll a[1]	Y		Y*	Y

[1] Y* = short duration monitoring, with quarterly sampling

Appendix 4: Kali Gandaki A Hydropower Project, A story

The 144MW Kali Gandaki-A hydro project in Western Nepal was commissioned in 2002 and is owned by the Nepal Electricity Authority (NEA). As well as an Environmental Impact Assessment (EIA), an Acquisition, Compensation and Rehabilitation Plan (ACRP) and a Mitigation Management Plan (MMP) were prepared. The social mitigation program ensured that proper measures were taken to assess and compensate people affected by the hydro project. Government-issued regulations were used to rate families affected by the project. 263 households were rated as severely project-affected families, losing their house, more than 60% of their income or more than 50% of their land. 1,205 households were rated as project-affected families, losing part of their land.

To determine compensation, each of the affected settlements formed advisory committees consisting of local community leaders and representatives of the affected families. These committees conducted a community consensus valuation of land and these values were presented to landowners for discussion and approval at public meetings. NEA set compensation rates above government minimums and compensation was also given for standing crops damaged during construction. Skills-training and employment were provided for at least one member of the severely project affected families. The income generated by this was about 10 times greater than income foregone from lost agriculture production.

In addition, a micro-enterprise fund was set up to provide money for project-affected and severely project-affected families to support local income generating activities, such as pig, goat or vegetable farming. NEA committed 1% of net project revenues to electrification of villages surrounding the project.