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DRAFT REPORT ON MITIGATION ASSESSMENT OF GREENHOUSE GASES EMISSIONS FOR ENERGY SECTOR IN NEPAL

Project Coordinator:
Mr. Kiran Shankar Yogacharya

Director General
Dept. of Hydrology & Meteorology
Babar Mahal, Kathmandu

Technical Coordinator:
Mr. L. M. Acharya

Dpty. Director General
Dept. of H & M
Babar Mahal, Kathmandu

U.S. Country Studies Program on Climate Change
Nepal

Rural and Industrial Development Associates
Jhamsikhel, P.O. Box 181

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Summary

Nepal is one of the least developed countries of the world depending on an economy that is very much agrarian. The major energy consuming sectors can be clearly disaggregated into domestic, transport, industrial, commercial and agricultural sectors. More than 90% of the energy supply is from traditional sources (fuelwood, agricultural residue and animal waste), the rest is from commercial fuel such as petroleum products and electricity. Domestic sector accounts for more than 95% of the energy consumption, whereas the transport sector consumes most of the commercial fuel i.e. petroleum products. Using the MARKAL model, the total emission of carbon-di-oxide in tons of carbon as well as in Gigagram is estimated to increase from around 770 Gg (209,689 tons of carbon) in 1990 to around 7,590 Gg (2,070,725 tons of carbon) in 2030 for the baseline scenario. For 1990 the IPCC method gives 858 Gg of CO_2.

The petroleum products most widely consumed in Nepal are kerosene and diesel and these two have been found to emit the highest amount of CO_2. During the later years of the study period, LPG is used more and is the major contributor to the CO_2 emission. The total carbon emission for the baseline scenario is 209,689 tons in 1990 and 2,070,725 tons in 2030 of which kerosene accounts for 88,843 tons in 1990 and 461,138 tons in 2030. Similarly the carbon emission from diesel for 1990 is 93,691 tons and for 2030 it is 299,970 tons. LPG which starts off with zero value in 1990 and reaches 1,219,823 in 2030 which is the highest CO_2 emitter.

The per capita GHG emission of Nepal is estimated at 42.6 Kg of CO_2 in 1990 and 220.6 Kg of CO_2 in 2030 which is far below the emission levels of other developing countries. As expected the domestic sector is responsible for most of the GHG gas emission, most of which comes from the use of LPG in later years. On the whole the overall emission level of Nepal is negligible as compared to other developing neighbouring countries. It is quite clear that Nepal's developmental effort will be hampered if energy consuming activities are checked; that is, the development process will be slowed down as energy consuming sectors are the corner stones of its overall development. In particular, industrialization is its key policy objective at present and this will eventually lead to increased use of fossil fuels. The trend towards increased fossil fuel consumption seems almost unavoidable such that any relevant long-term GHG mitigation policy initiatives may be expected to reduce the rate of increase in carbon emissions, but not lower them. Some long and short term measures

such as hydro power development, afforestation programs, and use of energy efficient technology have been recommended to reduce GHG emissions, but it would be very costly as well as detrimental to the country's developmental efforts if strict mitigation measures were to be applied.

1. Introduction

During the 1980's the idea of global warming received much exposure by the media who often presented their stories in association with lurid images of disaster or a climate out of control. This left the public and governments disturbed but not necessarily better informed. In response to this general concern and the lack of clear objective, authoritative statement on the problems on which policy might be based, the World Meteorological Organization (WMO) and the United Nations Environmental Program (UNEP) jointly established in 1988 the Inter-government Panel on Climate Change (IPCC) who was charged with the responsibility of assessment of available scientific information on climate change and the environmental and Socio-Economic impacts and formulation of response strategies.

The IPCC has been remarkably successful in engaging the world's leading experts in various field related to the science of climate and climate change to its impacts, and to possible options for adaptation and mitigation. For instance, the first IPCC scientific assessments submitted to the second climate conference in 1990 a combined contribution from 170 scientists from 25 countries and was reviewed by a further 200 scientists. The number of scientists involved in later IPCC assessment has been even greater. The first IPCC reports of 1990 acknowledges the large degree of uncertainty still associated with the climate change issue. Nevertheless the overall message that many human and natural system are vulnerable to the magnitudes and or rates of climate change likely over the next century added impetus to the negotiation of the UN Framework Convention on Climate Change which was initially signed in June 1992 in Rio De Janeiro, Brazil by more than 150 countries.

The signing of the United Nations Framework Convention on Climate Change (UNFCCC) and the adaptation of Article 4 e.g. All parties taking into account their common but differentiated responsibilities and their specific national and regional development priorities objectives and circumstances shall

- Develop periodically update, publish and make available to the conference of the Parties National inventories of anthropogenic (man made) emissions by sources and removals by sinks of all green house gases not controlled by the Montreal Protocol, using comparable methodologies to be agreed upon by the conference of the Parties;

- Formulate, implement, publish and regularly update national and where appropriate, regional programs containing measures to mitigate climate change by addressing anthropogenic emissions by sources and removals by sinks of all green house gases not controlled by the Montreal Protocol and measures to facilitate adequate adaption to climate change;

- Promote and co-operate in the development, application and diffusion, including transfer of technologies, practices and processes that control, reduce or prevent anthropogenic emissions of green house gases not controlled by the Montreal Protocol in all relevant sectors including the energy, transport, industry, agriculture, forestry and waste management sectors;

At the United Nations Conference on Environment and Development (UNCED) in Rio De Janeiro marked a turning point in international efforts to protect the atmosphere and provided a new focus for the climate related activities of international organizations and nations of the world.

Nepal is joining forces with the world to combat the green house effect. The signing of United Nations Framework Convention on climate change shows the commitment and intense desire to contribute in some way in this respect. In February 1992, the United States announced an initiative to provide funds to help countries to address climate change. The Department of Hydrology and Meteorology (DHM) took a keen interest and initiative for the country study Programma. Out of the four objectives of climate change proposal "To identify and evaluate technical options for mitigating climate change through reducing emissions of green house gases (GHG's) and expanding sinks for these gases" is one of them.

2. Model Description

A need to make substantial future reductions in green house gases emissions actually requires major changes in the energy system. The ability of Nations to respond to this requirement depend entirely on the technology as well as strong policy. To assist policy decisions, the potential of technology and the cost of its applications must be estimated. Sustainable development require consideration of the interrelationship among society, energy, economy and environment as well as technology. Within this context and to the extent practicable, quantitative methods are needed to compare possible national responses. In order to evaluate emission control measures as well as climate changes, the use of simulation models have to be employed. These models make it possible to explore a wide range of alternatives that would be almost impossible to be tested in reality.

The use of one such simulation model called MARKAL has been employed to conduct this study on mitigation of green house gas emissions in Nepal. MARKAL which stands for MARKet ALlocation was developed by ETSAP (Energy Technology Systems Analysis Program, an International research program under International Energy Agency, IEA). ETSAP's main purpose is to provide systems analysis capability to assist the IEA and the member countries in exploring long term energy futures and the role for new energy technologies.

MARKAL builds on the concept of Reference Energy System (RES). A reference energy system is a network diagram showing the flows of energy through the building blocks of an energy system from primary resources through demands for energy services. MARKAL basically consists of software that can represent a wide variety of energy system configurations. The energy system is represented by a set of energy technologies that range from the extraction of important fuels to final consumption by end use devices that meet demands for projected energy services.

MARKAL is provided with a menu of candidate technologies - existing or anticipated - from which it selects those that meet the energy demands at least cost while satisfying such constraints as a limit on carbon-dioxide emissions.

MARKAL results in optimal choice of energy technologies, their total cost, and the marginal cost of constraining factors. With the allowable level of carbon-dioxide emissions restricted, for example, the marginal cost is the increase in cost that would occur if one less ton of carbon-dioxide emissions were permitted. A carbon tax set at this marginal cost would lead to the same restricted level of carbon-dioxide emissions.

MARKAL calculates the technological choices that would best enable a society to reach a desired future. MARKAL identifies the optimal response to external stresses given the assumptions, as opposed to a simulation model intended to predict the future. Ordinarily, a range of scenario assumptions is examined with numerous runs of the model to determine how the choice of technologies changes under different circumstances. In a reference scenario without emission restrictions any "no regrets" technologies that are cost effective in any case could be adopted.

In a typical national MARKAL model, there are several hundred candidate technologies from which the model unambiguously chooses the optimal combination. These include energy sources, conservation measures, generators of electricity and/or heat fuel conversion processes, emission controls, and end-use devices to meet the demands for industrial, residential, commercial and transportation services. Technologies are characterized by their performance, costs, service life, and the maximum rate of penetration. To meet the model requirements each MARKAL user keeps his own database. The advantage of using this model is that "data can be directly comparable from one country to another". MARKAL is now encapsuled in software shell MUSS, the MARKAL User Support Systems used by the ETSAP participants and MARKAL users around the world on 486 computers. MUSS automates the activities needed to prepare data and analyze the results of MARKAL run, thus greatly increasing the productivity of the analyst.

MARKAL a bottom up linear programming energy model was chosen for this study to generate scenarios mainly for the following three reasons :

- Firstly, large number of international community have been using this model therefore results and findings of the various countries can be easily available for comparison purposes.

- Secondly, MARKAL being an engineering model, it yields not only information about the abatement costs but also technological details about how mitigation targets can be obtained.

- Thirdly, MARKAL can also be an useful analytic tool to policy makers for least cost planning and integrated resource management.

MARKAL behaves as if it had full knowledge of the past and present; it uses existing facilities most efficiently and can plan ahead for new investments. MARKAL is used internationally to analyze national, state or province, and local energy systems. It was originally written as a main frame computer model (Fishbone and Aleilock, 1981). A standardized PC version is now available (Goldstein, 1991).

3. Scenario Assumptions and Input Data

3.1 General Scenario Assumptions

Macro Economic Background: Nepal is one of the least developed countries of the world with a per capita income of less than 200 US dollars. It has a predominantly agrarian economy with majority of its population depending on agriculture and living in rural communities with very small land holdings. As a small, mountainous and landlocked country, Nepal's development efforts are circumscribed by her geographical location along with other socio-cultural factors. Despite planned development efforts of 40 years, Nepal remains as one of the poorest countries of the world with more than half of the population living below the poverty line. The country is facing severe development challenges on account of diverse factors like stagnating agriculture, the mainstay of the economy, growing population at a higher rate of 2.1 percent, social indicators remaining well below the average for South Asian region, underdeveloped infrastructure facility - mainly irrigation, electricity and transportation - and deteriorating environment and ecological balance. A country with poor natural endowment, Nepal has to import not only fuel and capital goods but also primary and consumption goods. Disadvantages generated by geography and other factors make it difficult in maintaining international competitiveness and hence an edge in the export market due to high transportation cost. The insulation of employment opportunities and protecting domestic industries against competition from Indian products is virtually difficult. To top it off, the long open border with India has circumscribed country's independent economic policies related with labour, trade, interest rate, pricing and exchange rate.

Real GDP growth stood on average, at 5.0 percent in the 1980's and the first half of 1990's as compared with just 2.0 percent during 1970's. The introduction of structural adjustment measures in the later 1980's did not show marked improvement in the GDP growth rate, it stood at 4.8 percent during 1986-90 compared with 5.0 percent during 1981-85. The growth rate, stagnated to 4.9 percent during 1991-95 as well.

Agricultural sector performed an average growth rate of less than 3 percent during the last decade. Nevertheless, the growth of some of the subsectors remained encouraging. The price signals emanating from deregulation as well as exchange rate incentives worked to some extent to promote the production of those items.

Agricultural production is growing at a very low rate reducing per capita availability of foodgrains. Nepal has recently turned into a food deficit country from surplus and food items constitute about 10 percent of total imports. Agricultural productivity level is, on an average, below that of two decades back. Planned development efforts have failed to increase production and productivity in the agricultural sector, despite that each and every plan laid first priority to agricultural sector either through budgetary provision or through policy orientation. More than three-fourths of the arable land is still rain fed and even the provision of irrigation facility to about 25 percent of the arable land is not effectively served because of underutilization of most large scale iirigation, poor maintenance, and weak institutional support for managing irrigation investments. Energy use of the agricultural sector is critically low, equivalent to 466 TJ in 1990. This accounts for just 0.2 percent of the total energy use of the country.

The country has witnessed massive deforestation in the 1980's resulting in soil erosion and environment degradation. Human as well as livestock population pressure on forest for search of cultivable land, energy, fodder, agricultural tools, and pastures has reduced forest cover from more than one-third in the 1970's to less than one-fourth of the land area. Institutional support for forestry development has also remained weak due to frequent nationalization-privatization moves.

The industrial sector remained highly protected till the end of 1980's. High custom duty, additional charges, sales tax, overvalued exchange rate, and various tax and non-tax concessions to domestic industries resulted in a high effective rate of protection. Consequently, the country witnessed proliferation of assembly type industries which enjoyed highest protection due to high tariff for final goods and low tariff for raw materials and capital goods.

Despite liberalization of foreign investment policy, the inflow of direct foreign investment has been low, worth Rs 8.6 billion so far. Manufacturing sector has so far been able to provide employment opportunity to a very small number of people and its share on GDP has remained less than 10 percent. The industrial base is weak but is picking up, very slowly. The level of industrialization is self evident from the magnitude of energy use by this sector equivalent to 2294 TJ of energy in 1990. This accounts for just 1 percent of the total energy use in 1990. Power shortage, load shedding and other barriers to smooth supply of energy is also partly responsible for poor performance of the industrial sector.

Liberalization of the economy and restructuring has had marked effect on services sector. Transport and communication, trade, restaurants and hotels, and financial & real estate observed more than five fold increase in nominal terms during the last decade as compared with agricultural sector growing by les than four fold. Particularly, liberalization of the economy showed encouraging signs in civil aviation, road transportation, financial sector expansion, and other services. The effect has been a growing share of services sector to GDP, mentionably from 36 percent in 1981 to 49 percent in 1995. This may be attributed to the liberal policies adopted in the process of restructuring and adjusting the economy.

The policy reforms in the external sector were the most extensive and fastest among all the sectoral reform measures in the economy. Starting from imports liberalization and more flexibility in the exchange rate policy in mid-1980's, Nepal attained full convertibility of the NRs in the current account in early 1993 and set free the determination of the exchange rate of NRs vis-a-vis convertible currencies by market forces. However, trade liberalization has not substantially changed the structure of imports. In 1985, Nepal's imports consisted of 16.2 percent of food items, 14.5 percent of intermediate goods, 13.2 percent of fuels & lubricants, 18.1 percent of machinery and transport equipments and the rest 38 percent of manufactured goods. In 1990, the share of food items and fuels slightly came down to 12.6 percent and 8.3 percent respectively whereas the share of intermediate goods, and machinery & transport equipment increased to 23.9 percent and 20.6 percent respectively. But the trend again reversed after 1992. By 1995, the share of both intermediate goods, and machinery & transport equipment in total imports declined to 17.6 percent and 12.7 percent respectively whereas the share of manufactured consumer goods increased to 43.6 percent. Import of petroleum products which stood at 22 percent of total exports value in 1974/75 increased to 29.2 percent in 1984/85 and further to 30 percent in 1994/95. For fossil fuel, Nepal is solely dependent on imports. Imports of such fuel is swelling up due to expanding transportation services and gradually picking up industrial activities.

External sector liberalization has failed to reduce trade deficit. This is because even with a sharp depreciation of the NRs by about 70 percent during the last decade, imports increased, on an average, by 24 percent in rupee terms and by 12 percent in dollar terms during 1986-96 as against the growth of exports by 23 percent and 10.2 percent respectively. As a result, trade deficit increased from 10.7 percent of GDP in 1995 to 12.7 percent in 1990 and further to 21.5 percent in 1995. Such a huge trade gap is obviosly unsustainable and is posing a heavy pressure on current account balance.

After a few years of completely opening the current account, the balance of payments situation has shown unhealthy sign. This is mainly because of poor export performance followed by higher imports in high trade and current account gaps. As trade deficit has increased from 10.7 percent of GDP in 1985 to 24.5 percent in 1995, service and transfer earnings are unlikely to match this deficit in the foreseeable future. Thus, the sustainability of the country's external sector balance has come under question. The huge deficit in current account (8.4 percent of GDP in 1995 excluding grants) and shy nature of long term capital inflow signals that the country's balance of payments may not remain favourable if corrective measures are not immediately taken up. Exports of the country have remained highly vulnerable due to concentration of export trade to a few commodities and limited market. The structure of imports has remained almost unchanged with high share of manufactured consumption goods in total imports.

The growing resource gap in the public sector has been the major problem in macro economic management. Fiscal deficit (defined as total resources minus total expenditure) has been widening and has been reflected in current account gap in the external sector of the economy. The resource gap in the public sector stood as high as 7.0 percent of GDP, on average, during 1990's so far. The underlying factor behind such a resource gap is low tax effort. Tax GDP ratio in Nepal is one of the lowest in South Asian countries. In the expenditure front, there are too many projects with poor implementation. The quality of investment program is quite low because of poor implementation, weak project screening, poor monitoring, financial reporting and budgetary control. Most of the development projects face time and cost over runs due to delay in aid mobilization because of lack of counterpart fund for aided projects and delay in completing administrative procedures for launching the projects. Low aid absorptive capacity has dampened the development prospect of the country along with increasing unnecessary financial burden.

External debt of the country has increased to 51 percent of GDP in 1995 from less than 20 percent in 1985. Including domestic debt, total debt of the government stood at 65 percent of GDP in 1995. Debt service problem is also emerging as one-third of regular budget has to be earmarked for principal and interest payments. The problem is likely to exacerbate in the near future as more of the long term borrowing is getting matured in that course.

One resource that Nepal is blessed with is the abundance of hydropower potential. Ironically, the country faces acute power shortage and industrial activities suffer due to frequent power interruptions and load shedding. At present only about one percent of the total economically viable hydro-potential has been utilized and it is likely to remain unutilized unless foreign/ private participation in hydro power sector takes place. The Government is serious about developing this national resource and is encouraging even independent power producers participation in its developmental efforts.

In the transportation sector, Nepal has less than ten thousand kilometers of roads, only one third of which is black-topped. It has virtually no railways and navigation and very few airports. Road is the main mode of transport and petroleum the major source of energy in this sector. Some of the problems faced by the transport sector are insufficient budgetary provisions for maintenance, weak implementation of projects resulting in low quality construction and high cost of road construction due to difficult hilly terrain. The East-West highway, the only road integrating the country's east to west borders is under construction for the last 35 years. Feeder roads to East-West highway are either of low quality or not developed at all. There are still many places which can only be accessed by many days of trekking along foot trails. Low quality of fuel, poor maintenance of vehicles, absence of stringent anti-pollution laws and plight of low quality vehicles in the street has caused heavy air pollution in the growing cities in general and the capital city Kathmandu in particular.

Tourism is Nepal's major source of foreign exchange earnings. It was equivalent to 44 percent of her total foreign exchange earnings from merchandise exports in 1994/95. An industry based on natural endowment, tourism in Nepal has recently been thwarted by the deteriorating environmental factors, mainly the pollution in big cities and trekking routes.

Major sources of traditional energy in Nepal are fuelwood, agro by products and animal products. The share of such source in total energy supply has marginally declined from more than 95 percent in the 1980's to a little more than 90 percent in the 1990's. The commercial sources of energy - petroleum, coal and electricity - contribute less than 10 percent of the energy consumption. Of the traditional sources of energy, fuelwood shares more than three-fourths whereas agricultural and animal waste products contribute less than one-fourth of the energy consumption. Of the commercial sources of energy, petroleum contributes more than three-fourth's whereas coal and electricity contribute the rest. The share of electricity in commercial energy source has slightly increased from 9 percent in 1984/85 to 12 percent in 1994/95, whereas the share of coal has declined from 32 percent to 12 percent during the same period. The foregoing discussion reveals that Nepal is still heavily dependent on traditional sources of energy and commercial energy has very little contribution to total energy supply. Also, of the commercial energy, the share of electricity is just one percent of the total energy consumption. Traditional sources of energy are mainly used in household consumption like cooking, lighting, heating and processing agro-products. The commercial sources of energy are used mainly for industrial, transport and domestic sectors with negligible use in the agricultural sector. This is because agriculture in Nepal is yet in a subsistence level; it is still highly labour intensive with insignificant mechanization. In the industrial sector also, cottage industries are highly labour intensive as are carpet, garments and handicraft industries. Heavy use of energy is thus concentrated in large industrial establishments such as cement, iron and steel, plastic, and metal industries.

In order to assess the mitigation options for the energy sector, the following assumptions have been made for modelling the energy system of Nepal:

In engineering optimization model like MARKAL, the model itself provides a numerical assessment and comparison of different policies. This model is a linear programming energy model in which the most basic criterion is total cost of providing economy- wide energy services under different scenarios; when this criteria is used the structure of this type of model as used in mitigation analysis can be represented schematically as

Minimize total cost of providing energy and satisfying end use demand subject to:

- energy supplied >= energy demanded
- end use demands satisfied
- available resource limits not exceeded

The validity of the results depends very much on the following assumptions:

- future prices of fuels
- useful energy demands (projected)
- Technological characteristics

Technological characteristics means the rate of emission of carbon- dioxide, costs, efficiency, the upper and lower bounds on market penetration.

The key assumptions used in the baseline and mitigation scenarios are:

- Growing education level and literacy, provision of family planning services, changing attitudes towards boy or girl child, economic development and social security provisions are likely to reduce the fertility rate in future course of time. Based on these assumptions the population is projected to grow at the rate of 1.9% per annum in the 1990's, by 1.7% in the 2000's, by 1.5% during 2010's, and by 1.3% during 2020's. Accordingly, total population of the country is estimated at 21.9 million in 2000 A.D., 26.0 million in 2010 A.D., 30.2 million in2020 A.D., and 34.4 million in 2030 A.D. (Table 3.1).

- Based on past performances the national GDP is projected to grow, on an average by 5.0% per year till 2000 A.D., by 4.5% till 2015 and by 4.0% thereafter (Table 3.1). The growth of non-agricultural sector is expected to pickup in the coming years. But for the agricultural sector, as the size of arable land holding is limited with very slow growth of extension and support services, the growth rate is expected to stabilize in the long run.

- By 2030 all district headquarters will be electrified and about 50% of the population will have access to electricity by then.

- In future the existing thermal plants will be retired and be replaced by hydro electric plants.

- Petroleum prices have witnessed large volatility during the last two decades and a half. After touching 35 US$ per barrel in 1980, it stabilized at less than 20 US$ per barrel during the 1990's. Assuming no serious supply shock and sudden shift in the demand, the crude POL prices is projected to increase by a modest rate of 1.5 percent per annum through the review period. The crude oil price change is assumed to be fully reflected in domestic supply price of refined POL products. Assuming depreciation of Nepalese currency at a rate of 3-4 percent per annum. POL prices in domestic market is projected to grow by about 6 percent during the same period.

- Indigenous renewable resources (wind, solar and biomass) will be tapped but their contribution is negligible.

- For the mitigation scenarios a 10% and 20% reduction in GHG emission from the baseline level is considered.

- The national inventory of GHG emission considers that the net balance of emission from traditional fuel source is zero.

- The discount rate taken into consideration in the projections and cost calculations was mostly the inflation rate. Particularly for deriving electricity cost of production at 1990 prices, an inflation rate adjusted for exchange rate depreciation and foreign price rise was taken into account. For deriving real GDP and its components, GDP deflector was taken as the discount factor.

- Projection of major macroeconomic variables is done with the help of time series regression analysis. Projection of international prices, domestic prices, real GDP and its compostion, supply prices of energy was done with regression techniques using the explanatory variable (s), the trend variable dummies wherever necessary. For many of the projections, the time period taken into consideration was 1966 through 1995. For a few projections like that for fuelwood, the sample period was quite short (1985 through 1995).

- Assuming the aforesaid growth in real income and population, energy demand is projected to increase from 5.6 million tons of oil equivalent in 1990 to to 19.5 million tons of oil equivalent in 2030 A.D (Table 3.1). This exhibits a growth rate of energy demand at 3.0 percent per annum.

Table 3.1: Projection of Energy Demand and Population Growth

Year	Real GDP (MRs)	Population (Million)	Energy Demand ('000 TOE)
1990	56151.00	18.10930	5622.000
1991	59768.00	18.49000	5824.000
1992	62531.00	18.84131	6133.000
1993	64586.00	19.19930	6356.000
1994	69282.00	19.56408	6517.000
1995	71695.00	19.93580	6701.000
1996	76095.00	20.31458	6873.280
1997	79899.75	20.70056	7084.235
1998	83894.73	21.09387	7304.650
1999	88089.47	21.49465	7534.976
2000	92493.95	21.90305	7775.688
2001	96656.17	22.31921	8005.911
2002	101005.70	22.69863	8241.447
2003	105551.00	23.08451	8486.616
2004	110300.80	23.47695	8741.834
2005	115264.30	23.87606	9007.537
2006	120451.20	24.28195	9284.180
2007	125871.50	24.69474	9572.237
2008	131535.70	25.11455	9872.205
2009	137454.80	25.54150	10184.600
2010	143640.30	25.97571	10509.970
2011	150104.10	26.41729	10848.870
2012	156858.80	26.81355	11197.090
2013	163917.40	27.21576	11559.900
2014	171293.70	27.62399	11937.940
2015	179001.90	28.03835	12331.870
2016	186162.00	28.45893	12701.040
2017	193608.50	28.88581	13084.020
2018	201352.80	29.31910	13481.340
2019	209406.90	29.75888	13893.570
2020	217783.20	30.20527	14321.290
2021	226494.50	30.65835	14765.110
2022	235554.30	31.05690	15220.070
2023	244976.50	31.46064	15692.240
2024	254775.60	31.86963	16182.310
2025	264966.60	32.28394	16690.980
2026	275565.30	32.70363	17218.980
2027	286587.90	33.12878	17767.070
2028	298051.40	33.55946	18336.040
2029	309973.40	33.99573	18926.700
2030	322372.40	34.43767	19539.920

It is obvious that the results are very much dependent on the assumptions used, therefore when the assumptions are modified or changed then the results too get changed accordingly.

Data Used in the Analysis

For the study of mitigation options of Green House Gases (GHG's) Emissions the following data have been used :

- Base year for the energy supply and demand data is taken as 1990. In both supply and demand sector data of non - petroleum products (e.g. fuelwood, agricultural residue, dung and electricity) as well as data of petroleum products viz. LPG, ATF, kerosene, high speed diesel, light diesel, fuel oil etc. have been used.

- Similarly, total output or value added or physical units (e.g. tonnes) produced with regard to measures of industrial output, 1990 GDP, expected GDP growth rate, current population including projected growth rates, expected changes in residential energy demand, expected changes in per capita transportation demand, labor force (1990 size, expected growth rates and expected changes in labor productivity) commercial activity (measures of current activity, expected changes) also has been used in the mitigation analysis.

- Likewise, electricity generated from existing major hydro projects and diesel power stations including the 1990's actual generation by power plant has been used.

As said earlier the MARKAL energy model is built on the concept of Reference Energy System (RES). The reference energy system of Nepal is illustrated in Figure-3.1. The RES is "a network diagram showing the flows of energy through the building blocks of an energy services".

Figure-3.1 depicts the useful energy demand of the Nepal Reference Energy System. The energy demand has been split into four main categories requiring the energy services namely Industry, Residential/ Commercial, Transport and Agriculture. The right side of the figure shows the types of the imported energy while the various forms of energy carriers are shown on the lines with arrows. The demand technologies which uses the energy carriers for providing the final energy services is shown as a dot (.) in the figure. Also this figure shows the four main demand sectors divided into 25 demand categories. The final energy demand has been projected from the base year (1990) to the year 2030 for each of the categories. Note that a dot not seen in Figure-3.1 could appear at a later year indicating the use of new technology. Seventeen different types of energy carriers have been shown in this figure.

3.2 Projection of Energy Intensities

It is obvious that energy demand is determined by several factors like the growth and structure of gross domestic product, choice of techniques of production, technological changes, population growth and the pace of urbanization and modernization. The Nepalese economy has been gradually transforming from subsistence, agricultural to industrial and modern economy; and techniques of production has also been shifting from labour intensive to capital intensive. Along with this, rapidly growing population, expansion of residential areas and urbanization, and advanced level living conditions nhas led to higher demand for energy in the country. This is reflected in the growth of energy consumption in relation to GDP growth. During the last decade, real GDP grew at a compound rate of 4.8 percent whereas energy consumption also went up at a compound rate of 2.8 percent. The quantity of energy consumption which stood at 4.9 TJ (114 TOE) equivalent per each one million rupee GDP in 1984/85 declined to 4.2 TJ (100 TOE) equivalent per one million rupees worth of GDP in 1989/90 and further to 3.6 TJ (94.5 TOE) equivalent in 1994/95. This implies a less than unitary elasticity of energy consumption to GDP. Such a declining intensity of energy consumption to GDP indicates that demand for energy in Nepal would increase less than proportionally with the growth in national income. The present trend shows that intensity to decline to 2.1 TJ per one million rupees worth of GDP in 2010 and further to 1.2 TJ in 2030 A.D.

Such inference has, however, to be taken with caution. The above analysis implicitly assumes that demand for energy is inelastic to price changes and the market for energy is in equilibrium implying that consumption demand for energy is identical to supply. If supply is constrained due to availability factor and/or demand suppressed by price factor, then the above statement might give incorrect inference about energy demand with respect to economic growth.

3.3 Description of Technologies and Energy Resources

Energy Resources

Nepal is endowed with a vast hydroelectric potential, however only a fraction of this potential has been tapped so far. Nepal is not so fortunate in terms of other sources of energy as it has no known natural gas, petroleum and coal reserves.

The ever growing energy demand in Nepal by its various sectoral activities has been so far catered through internally available energy resources as well as those imported from outside. Nepal's traditional indigenous energy resources are:

- fuelwood
- biomass: agriculture residue and animal waste

Apart from these traditional sources Nepal has a vast potential for electricity.

Since Nepal does not have its own deposits of the following fuels it imports them in order to meet the demand from various end-users:

- fossil fuels: diesel, gasoline, kerosene, liquified petroleum gas (LPG)
- mineral fuels: coal, coke

Nepal's sources of supplying energy is predominantly from traditional energy sources which account for nearly 95% of the total supply whereas electricity on the other hand accounts for not even 1%. The energy supply for 1989/90 are shown in Table 4.1. Regarding the consumption of energy, domestic sector accounts for an overwhelming 95.68% of the total, followed by transport sector 2.2%, industrial sector 0.98%, commercial sector 0.89% and agricultural sector 0.19%. The detailed breakdown of the national energy demand for 1989/90 is shown in Table 4.2.

Description on energy resources of Nepal will not cover the imported fuels. In the following paragraphs attempts are made to present the brief descriptions on the status of the domestic energy resources.

I) Fuelwood:

Fuelwood had been the perennial source of energy from time immemorial for heating, cooking, and lighting purposes. This resource is still predominant over the others and the growing energy demand of Nepal is currently being met by over-exploiting indigenous forest resources for basic household cooking needs as well as industrial and commercial fuelwood requirements. It provides 71.69 % of the total energy used in Nepal. Over 70 % of fuelwood comes from accessible forests, shrubs and grasslands, over 20 % from non-cultivated inclusions, and the remaining from farmland. Total accessible forest area (located within a radius of 3 km by road/trail) for fuelwood supply in 1990 was estimated to be 4,634 thousand hectares, with a sustainable yield of 7.49 million tonnes against annual consumption of about 11.2 million tonnes.

During the past decade, the persistent efforts of HMG to better manage the forest through various projects with assistance from donor agencies have brought the forest depletion rate to an all time minimum. However, the population growth and associated proportional growth in demand for fuelwood, unless shared by other substitutes, remain a threat to the country's economy and its environment.

II) Agriculture Residue:

The second major source of energy in Nepal comes from agriculture residue from major crops (paddy, sugarcane, maize, wheat and jute) which yielded about 11 million tonnes in 1990 of which about 3.2 million tonnes is used as fuel. Among the residues, rice husk is also used to produce briquettes. Bagasse, the residue from sugarcane processing, is used as fuel for boilers in the sugar factory.

III) Animal Waste:

Families who do not have access to an adequate supply of fuelwood and crop residue use animal dung as fuel. The use of round-shaped hand made dung cakes and stick-shaped dried dung mixed with straw for cooking food is common in lower hills and terai respectively. The total amount of dung available as fuel is estimated to be 4.4 million tonnes in 1990. It is partly used for the production of biogas.

IV) Electricity:

Hydropower is the main source of electricity in Nepal. Although electricity accounts for less than 1 % in the overall energy balance of the country in 1990 it is expanding at a fast rate as more and more electrification schemes are being carried out throughout the country. With no other long-term viable resources available in the country, hydropower is no doubt, the energy of the future in Nepal. The theoretical potential of the river systems of Nepal for generating electrical power is estimated to be over 83,000 MW based on average river flows as follows :

	River Courses		
River basin	Major (*)	Small(#)	Total
Sapta Kosi	18,750 MW	3,600 MW	22,350 MW
Sapta Gandaki	17,950 MW	2,700 MW	20,650 MW
Karnali & Mahakali	32,680 MW	3,500 MW	36,180 MW
Southern Rivers	3,070 MW	1,040 MW	4,110 MW
Total:	72,450 MW	10,840 MW	83,290 MW

NOTE:(*) with catchment area above 1000 sq.km.

(#) with small catchment area

For the sake of comparison of the hydro potential available and the actual installed capacity, in 1990 the peak electricity demand was 176 MW and the available energy was 773.842 GWh. The total installed capacity of the plants generating electricity (hydro + thermal) was 150 MW. In the same year the total sales was 548.069 GWh.

Energy Supply Technologies

So far Nepal has adopted the conventional methods of producing the energy she is endowed with. Unlike in other developed countries, no complicated and sophisticated energy extraction processes are involved here.

In the following paragraphs the modern technologies employed in the production of electricity, fossil fuels, etc. are described in terms of investment costs, variable and fixed operation & maintenance costs, efficiency, emission coefficients, maximum market penetration rates, installed capacity, etc.

As the main source, fuelwood, is being supplied in traditional way i.e. it is readily available in unrestricted quantities close to points of consumption, it has no direct cost other than the time and effort spent in collecting it and it requires no major capital investment nor advanced technology in its exploitation and use.

Electricity is the only natural resource Nepal is bestowed with in abundance. Modern day technology is involved in harnessing the hydropower potential.

Installed capacity: By the end of 1990, the total installed capacity was 150 MW of which 140 MW was contributed by 7 medium sized hydropower plants and 20 small sized ones and 10 MW was from diesel plants. Furnace oil fired multi-fuel plant came into operation only in post 1990. There is one photo voltaic (solar) station and one wind power plant, the combination of which can produce maximum 500 kW of electricity.

Most of the hydropower plants are of the run-of-river type. For load management as well as for seasonal peaking purposes the national integrated grid system has so far only one storage type hydropower station.

Market penetration rate: In the fiscal year 1989/90 the total number of electricity consumers in the country was 290,015 which implies that about 10 % of the population had access to electricity. As far as the consumption of electricity is concerned it encompasses more than 50 districts covering all types of terrain. In order to benefit the maximum population, the electrification schemes adopted in Nepal is usually to start first from the urban areas and the district head quarters and then to slowly cover the other outlying areas.

In order to assess the real penetration of electricity use in different sectors a breakdown of the consumers by their categories and their respective consumption levels has been done. For the year 1989/90 the category-wise consumer and consumption are shown as follows:

Consumer category	Consumer (no.)	Consumption (MWhr)
- Domestic	274,921	231,396
- Non-commercial	4,506	47,433
- Commercial	1,758	33,712
- Industrial	7,482	178,321
- Water supply	112	11,928
- Irrigation	382	11,965
- Street light	517	7,295
- Temporary supply	123	403
- Transport	9	2,060
- Temple	205	270

Based on the previous 5 years' data the growth rate of consumers is about 10 % and that of consumption is 15 %.

Investment costs: Regarding the investment costs of various hydropower plants it is difficult to come to a figure because some of them were built under grant projects, some were constructed many years before, small hydropower plants were constructed in different topographical areas. Also, hydropower development is very site specific as well as it depends on the design parameters (tunnel length, geological conditions, transmission line length, run-of-river or storage etc.). The proper benefits from the projects have to be assessed rather than going by only the investments required.

Variable and fixed O&M costs: Variable operation and maintenance costs are attributed to the fuel consumption in the thermal power stations. The consumption of fuel depends upon the actual thermal generation. In Nepal in order to avoid the import and dependence on petroleum products the use of thermal power stations are only made during the peak demand time and during the dry months when it is not possible to get the full output from the run-of-river hydro plants. For the study the annual variable operation and maintenance cost is taken as 2.6 $/MWh.

Fixed operation and maintenance costs, both in hydro and thermal plants, comprise of salary, wage, allowance, operation and administration. In general these constitute about 5% of the total capital cost for thermal plants and about 1.5% for hydro plants. The costs taken for the study are 63.6 $/kw/year for thermal and 25.2 $/kw/year for hydro.

Efficiency: The overall efficiency of the diesel plants operating in Nepal grid is taken to be 60 % whereas that of the hydro plants are considered to be operating at more than 85 %.

There exists a potential for solar powered generation as the country has a lot of sunshine throughout the year except for the monsoon months. Solar powered generation plants could be set up in areas where it would be difficult to take transmission lines and to populated remote areas. However due to lack of efficient technology in this field there has been very little success in the use of solar energy. Only in the urban areas there is limited use of solar energy for water heating purposes. The harnessing of wind power has also not proved very successful so far.

4. Scenario Definitions

4.1 Baseline Scenario

The reference scenario corresponds to the least cost planning without carbon-dioxide (CO_2) emission constraints. On the basis of the assumptions and the final energy demands MARKAL finds an energy system that leads to the least discounted total system cost. This linear programming optimization model also determines the optimal fuel mix and the set of technologies to be used for each period based on the relative cost competitiveness of fuels and energy technologies. The CO_2 emission trend of this optimal energy system is calculated by the IPCC methodology.

As mentioned earlier the energy demand and supply structure of Nepal is such that it is met mostly by fuelwood, however the indiscriminate use of this fuel source has lead to deforestation which is causing ecological imbalance in many areas. The use of fuelwood would decrease as it is becoming more and more difficult to obtain it, also the government is taking steps to discourage the indiscriminate collection of wood from the forest and shrublands. As Nepal lacks other energy resources it is foreseen that electricity will play a vital role in the development of the nations's economy and that it will become the main source for the energy supply sector. The hydro potential of the nation is almost inexhaustible as far as its needs are concerned, however, it needs a lot of capital for investment and it will take some time before such development will materialize. To some extent solar and wind power could be utilized for energy supply, but this is not expected to amount to much.

The development of the base line scenario for analyzing GHG mitigation options within Nepal's energy supply and demand system is started with the proper understanding of the energy network whereupon the flow of energy from primary resources to useful energy demands in end-use sectors is traced. The demand side represents all the major end-use sectors which are residential, commercial, non-commercial, industrial, transportation, agricultural and exports. The network diagram for the generalized energy of system of Nepal is presented in the following Figure-4.1.

Fig.- 4.1 : Energy Network in Nepal

```
--------  ----------  --------  ----------  ---------  ------
Domestic  Commercial  Non-Comm. Industrial  Transport  Export
--------  ----------  --------  ----------  ---------  ------
   |          |          |          |           |        |
   |          |          |          |           |        |
-------------------------------------------------------------
                        DISTRIBUTION
-------------------------------------------------------------
      |                                         |         |
      |                                         |         |
-------------                               ----------    |
 Electricity                                Conversion    |
 Generation                                 Process       |
-------------                               ----------    |
      |                                        |      |   |
      |                                        |      |   |
-----------------------------------------------   -----------
  DOMESTIC                          RESOURCES       IMPORT
-----------------------------------------------   -----------
```

1) Energy supply in base year 1990:

In the base year 1989/90, the energy supply as shown in Table 4.1 has gone into the above energy network for the fulfilment of the national energy demand in that year. According to Table 4.1 the basic energy requirement is fulfilled through the domestic resources as well as import. In the domestic resources Nepal has mostly non-commercial type of energy namely, fuelwood, agriculture residue, and dung. The only commercial form of energy Nepal produces on its own is electricity. All the other commercial energy such as coal, motor spirit, ATF, kerosene, HSD, light diesel, fuel oil, and non-energy are imported into Nepal.

Table 4.1: Energy Supply for Nepal, 1989/90

Resource	x1000 GJ	Percent
Fuelwood	171,796	71.45 %
Agriculture residue	34,000	14.14 %
Animal waste	21,328	08.87 %
Electricity	2,696	01.12 %
High speed diesel	4,700	01.95 %
Light diesel	32	00.01 %
Motor spirit	561	00.23 %
Kerosene	4,487	01.87 %
ATF	453	00.19 %
Coal	312	00.13 %

Fuel oil	1	00.00 %
Non-energy	75	00.03 %
TOTAL	240,441	100.00 %

2) Energy consumption in base year 1990:

The summary of energy consumption for each sector and the percentage of energy consumption by each demand sector are shown in the following Table 4.2. It is evident that the domestic sector overwhelms all the sectors in consuming the energy (95.68 %). The next energy consuming sector is transport which consumes 2.20 % of the total available energy for consumption. The other energy consuming sectors namely industrial, commercial and agricultural sectors together contribute less than 3% of the total energy consumption. This energy consumption pattern shows what an early stage of development Nepal is really in, in fact it is rated to be one of the least of the least developed countries of the world.

Table 4.2: Energy Consumption for Nepal, 1989/90

Consumption sector	x1000 GJ	Percentage
Domestic	229,271	95.68 %
Industrial	2,339	0.98 %
Commercial	2,127	0.89 %
Transport	5,280	2.20 %
Agriculture	466	0.19 %
Others	76	0.03 %
Non-energy	75	0.03 %
Total	239,633	100.00 %

Electricity demand: The demand of electricity is forecasted by the concerned line agency, NEA, as shown in Table 4.3. According to this forecast, the peak demand of the NEA system including the compulsory export to India increases annually by 9.5 % on an average over a 20 year period from 1996 to 2015, resulting in the peak demand growing from 281 MW in 1996 to 413 MW in 2001 and 676 MW by 2006 within a span of ten years.

Table 4.3: NEA Load Forecast

FY	Required Generation (GWh)	Load Factor %	Peak Load (MW)
1996	1272	51.7%	281
1997	1392	52.4%	303
1998	1530	53.3%	328
1999	1688	54.4%	354
2000	1860	55.5%	383
2001	2047	56.6%	413
2002	2261	57.1%	452
2003	2500	57.3%	498
2004	2767	57.5%	549
2005	3065	57.4%	610
2006	3392	57.3%	676
2007	3757	57.3%	748
2008	4153	57.5%	824
2009	4593	57.7%	909
2010	5081	57.9%	1002
2011	5617	58.1%	1104
2012	6216	58.4%	1215
2013	6879	58.6%	1340
2014	7641	58.8%	1483
2015	8487	59.0%	1642
2016	9427	59.3%	1815
2017	10471	59.5%	2009
2018	11632	59.5%	2232
2019	12921	59.5%	2479
2020	14353	59.6%	2749

Various generation expansion plans are being conducted by the Nepal Electricity Authority (NEA) a government undertaking responsible for the generation, transmission, distribution and development of electrical power. Least cost generation expansion plans have been carried out for a period upto the year 2015. The expansion plans for electricity are based on the demand for electricity which is growing with an average rate of around 10%. The demand for electricity is mainly in the domestic and industrial sectors. The load forecast for the electricity demand as supplied by NEA is presented in Table 4.3. It should be noted that the forecast has been prepared taking in view that not enough supply is available to meet the demand, we thus have a situation where the demand is suppressed. If enough capital could be raised and if the demand for electricity was left to grow at a natural rate then the actual demand would probably be much higher this is because only around 10% of the population is having access to electricity. The growth in electricity demand will thus be very high in the initial stage of its development. The generation expansion plan as envisaged by NEA is provided in Table 4.4. It should be noted that several studies are being conducted to identify more attractive hydro projects thus the generation expansion plan will be updated as better and cheaper projects are found.

<u>Expansion plans for electricity generation:</u> Generation addition of 29.5 MW during the plan period (1991/92-1996/97) were as follows:

Jhimruk	-	12.0 MW
Trishuli-Devighat Refurbishment	-	12.5 MW
Smaller hydro plants	-	5.0 MW

The expansion plan of capacity additions to match the supply with the forecast demand is a challenging task for NEA. Because of the financial resources constraints NEA has to look for the private participation in the hydropower development. To this end there has been some positive development already achieved; for Khimti HEP (60 MW) and Bhotekosi HEP (36 MW) power purchase agreements (PPA's) have been signed between NEA and concerned parties.

In order to determine the least cost generation expansion plan numerous combinations of generating plants in conjunction with the existing ones are to be examined. Because of technological limitations of the present system, future generation options are limited to hydro, multifuel, and gas turbine plants only. The resulting plan is subjected to various sensitivity tests to assess its robustness to changes in important input parameters such as load forecast, delay in implementation of critical projects, cost overruns, etc.

The envisaged generation expansion plan is shown in Table 4.4, but is subject to change as better and cheaper projects will be included as further studies are carried out:

Table 4.4: Electricity Generation Expansion Plan

FY 1996	-	30 MW Import from India
FY 1997	-	13 MW Multifuel Plant
FY 1998	-	Puwa HEP (6.2 MW) + Chilime HEP (20 MW)
FY 1999	-	Modi Khola HEP (14 MW)
FY 2000	-	Khimti I HEP (60 MW)
FY 2001	-	Kali Gandaki A HEP (144 MW)
FY 2002	-	-
FY 2003	-	Bhotekosi HEP (36 MW)
FY 2004	-	Upper Marsyangdi HEP (43 MW)
FY 2005	-	3 x 12.5 MW Gas Turbines + Chamelia HEP (30 MW)
FY 2006	-	Upper Karnali HEP (240 MW)
FY 2007	-	-
FY 2008	-	1 x 12.5 MW Gas Turbine
FY 2009	-	Arun-3 Phase I HEP (201 MW)
FY 2010	-	-
FY 2011	-	Upper Arun HEP (335 MW)
FY 2012	-	-
FY 2013	-	Arun-3 Phase II HEP (201 MW)
FY 2014	-	1 x 12.5 MW Gas Turbine
FY 2015	-	West Seti HEP (360 MW)

4.2 Mitigation Scenarios

Two scenarios were studied for mitigation, these are 10% and 20% reduction in carbon emission by the year 2030.

5. Results

5.1 GHG Emissions

Based on the assumptions and definition of baseline scenario of the energy consumption during the period 1990-2030 the levels of GHG emission from the various types of energy used in different sectors are ascertained in this section. Since only the actual use of energy, both indigeneous and imported, contributes towards the evolution of GHG e.g. CO_2 gases the primary production levels, exports & bunkers, stocks, and losses are not considered separately. Using the IPCC convention for emissions associated with the types of fuels the following Table 5.1 shows the would-be-trend of GHG emission levels by commercial fuel types from 1990 through 2030. Figure 5.1 also shows the total emission level for the study period.

Table 5.1: Baseline Emission Levels by Commercial Fuel Types (Tons of Carbon)

Year	Kerosene	Coal(LS)	Coal(HS)	Gas	ATF	Diesel	LPG	Total
1990	88843	3985	3704	10496	8970	93691	0	209689
1995	65111	24390	5875	13395	9000	121222	93556	332549
2000	85962	7663	7663	14840	9515	154485	205784	485912
2005	81680	8514	9791	15636	9104	178732	365484	668941
2010	201529	9365	11920	29938	9955	202980	434173	899860
2015	208500	10217	14048	33680	10578	227227	630860	1135110
2020	340174	11068	16177	37422	11130	251475	756727	1424173
2025	433449	11920	18305	41164	11407	275722	936366	1728333
2030	461138	12771	20434	44906	11683	299970	1219823	2070725
TOTAL	9831928	499448	539575	1207318	456707	9027517	23213866	44776359
Emission Rate (tons of Carbon per TJ)								
	19.8	25.542	25.542	18.71	19.8	19.998	17.028	

Note: 1. Total emission includes the emission during the intervening years too.
2. Emission from electricity and traditional fuels is assumed to be zero.

As seen from the above Table 5.1, maximum emissions in tons of carbon will be contributed due to the consumption of LPG (23213866) and least is from ATF (456707). The GHG emission contribution from kerosene, diesel, gasoline, and coal will be 9831928, 9027517, 1207318, and 1039023 respectively. Hence, the total level of GHG emitted from the commercial fuels for the study period of 40 years will amount to 2070725 tons of carbon. In the base year 1990 GHG emission level is 209689 tons of carbon and then it grows annually at the rate of 12.28 %. The national inventory of GHG emission considers that the net balance of emission from traditional fuel source is zero.

Table 5.2: Baseline Emission Levels by End-Use Sectors

Year	Domestic	Commerc.	Industr.	Transpo.	Agricul.
1990	66627	22216	8328	104314	8459
1995	129456	29211	30584	120265	7366
2000	253216	38530	15325	133393	6433
2005	401200	45965	18305	139714	5499
2010	579977	55725	21285	146178	5999
2015	776665	62695	24265	156834	6499
2020	1025841	71060	27245	166597	6999

2025	1289461	80355	30225	175704	7332
2030	1590847	90114	33205	182337	7665

As expected, the energy consumption pattern for the baseline study period shows that the domestic sector is responsible for contributing the most GHG emission as it consumes more than 95% of the total energy consumption. The GHG emission from the transport sector is next followed by the commercial sector and only then by the industrial sector. Although the share of agriculture in GDP is more than any other sectors taken individually the GHG contribution is far low due to less involvement of energy consuming activities in this sector.

For the mitigation scenario 10% and 20% reduction in GHG emission from the baseline level is targeted.

5.2 Impact on Energy Use

The impact of the mitigation programs on uses of primary and final (useful) energy including electricity shall be more visible when compared with the would-be-usual trend of energy uses in the baseline scenario. Therefore, the sectoral consumption by final energy type are also dealt in detail in the baseline scenario before the levels of use of those energy are ascertained during the various mitigation scenarios.

Primary and Final Energy:

It will be appropriate to reiterate the list of primary energy that has gone into the reference energy system of Nepal as follows:

- Fuelwood
- Agriculture residue
- Animal waste
- Hydro
- Solar
- Wind
- Coal
- Gasoline
- Aviation turbine fuel
- Kerosene
- Diesel oil
- Fuel oil

In Nepal except for fuel oil and agriculture residue (bagasse and rice husk) all the other primary energy go into the process directly as useful (final) energy. Fuel oil, bagasse and rice husk are sometimes used even as primary energy for boiler to produce steam to generate electricity which in turn is used for other end-use activities. But the amount of primary energy converted into secondary energy is negligible. Therefore, the pattern of only the final energy consumption by each sector is analysed in the following paragraphs.

Residential Fuel Use: For domestic purpose the fuels used as its end-use are fuelwood, agriculture residue, animal waste, kerosene, electricity and LPG. Evidently the bulk of energy consumed is supported by fuelwood. In the base year 1990, the residential sectoral consumption is broken down as fuelwood (75.27%), agri-residue (14.9%), dung (9.44%), kerosene (0.02%), and electricity (0.37%). Therefore, much of the energy demand is met through traditional form of energy. Electricity is negligibly small. Throughout the study period fuelwood remains the most dominantly used energy among all.

Table 5.3: Residential Fuel Use

Year	Fuelwood	Agri-residue	Dung	Kerosene	Electricity	LPG
1990	170103.00	33686.00	21328	50.00	833.00	0
1995	178730.29	37662.50	24250	50.00	713.94	5494.2
2000	177900.37	40875.00	27500	50.00	598.18	12085.0
2005	177470.38	44062.50	28750	50.00	489.00	21463.7
2010	177028.31	47250.00	31000	50.00	533.46	25497.6
2015	176719.88	50437.50	33250	50.00	581.59	37048.4
2020	176380.81	53625.00	35500	50.00	635.87	44440.1
2025	176041.74	56812.50	37750	50.00	679.28	54989.8
2030	175702.60	60000.00	40000	50.00	727.10	71636.3

Until some drastic measures are taken up commercial form of energy will not be in the position to replace the traditional one in a substantial manner. Unlike kerosene the other commercial energy, electricity, will be growing even in the rural residential areas because of some efforts towards rural electrification. The above Table 5.3 shows clearly that a lot of room for improvement is left for electricity to penetrate into the realm of traditional energy. This will be one of the challenges into the next century.

Commercial Fuel Use: As a commercial fuel kerosene (1122 TJ) tops in the list in the base year 1990 whereas electricity (335 TJ) even trails behind the fuelwood (620 TJ). Agriculture residue, considered to be traditional form of energy, is still used by the commercial sector with annual consumption of 50 TJ. In 1995 the use of both the bio-mass, fuelwood and agriculture residue, have dropped to respective halves and from 2000 onward they are not used at all. This is the indication of the shift to the commercial form of energy completely for the commercial sector consumption. Because of the limitation of the supply of the commercial energy and the pre-dominance of the traditional energy in the Nepalese society the earlier years see the use of later even in the commercial activities e.g. cooking in the rural hotels/shops and lodges. From the beginning of the next century onward it is assumed that for commercial activities traditional fuels shall be completely replaced by commercial fuels. Electricity and LPG shall replace fuelwood for cooking in the lodges and restaurants with the assumption that by those years all the commercial areas (specially district head quarters) in all the region shall be electrified. For lighting purpose kerosene shall pervade. Therefore, it is seen, in the following Table 5.4 that the consumption of electricity and kerosene have grown steadily. As is normally expected the growth of indigenous electricity is faster than imported kerosene.

Table 5.4: Commercial Fuel Use

Year	Electicity	Kerosene	Ag.Residue	Fuelwwod
1990	335.00	1122.00	50.00	620.00
1995	637.13	1475.28	25.00	310.00
2000	1095.88	1945.95	0.00	0.00
2005	1593.80	2321.47	0.00	0.00
2010	2281.91	2814.37	0.00	0.00
2015	2880.52	3166.42	0.00	0.00
2020	3624.57	3588.89	0.00	0.00
2025	4221.32	4058.33	0.00	0.00
2030	4847.80	4551.20	0.00	0.00

Industrial Fuel Use: For the industrial purpose final energy used are fuelwood, electricity, coal, and diesel oil. In the base year 1990, the consumption stays at the levels of 1319 TJ, 642 TJ, 301 TJ, and 32 TJ of fuelwood, electricity, coal, and diesel oil respectively (Table 5.5). In this sector also fuelwood is consumed at its maximum. Even though modern industries (large, medium, and small) do not employ fuelwood as their inputs but the wide spread rural and cottage industries still rely on fuelwood until they are replaced by other commercial energy in the process of adopting new technology. As is obvious, electricity is going to be used in all spheres of industrial activities in the years to come. Therefore, the demand of electricity as the final energy is ever increasing in intensifying and replacing the other energy in the industrial sectoral consumption. Electricity will be exclusively used by all the modern industries except cement industries whereby coal/coke will also be used. The consumption of electricity by this sector shall grow steadily from 642 TJ in 1990 to 2593.6 TJ in 2030. Diesel oil shall be phased out from 2000 onward. Coal will reach at the level of 1300 TJ by the year 2030 whereas fuelwood shall still remain the main input of rural and cottage industries and they shall consume 4347.3 TJ in 2030.

Table 5.5: Industrial Fuel Use

Year	Electricity	Diesel	Coal	Fuelwood
1990	642.00	32.00	301.00	1319.00
1995	915.37	16.00	1184.88	983.46
2000	1188.73	0.00	600.00	2127.13
2005	1458.90	0.00	716.67	2560.87
2010	1729.07	0.00	833.33	3006.69
2015	1945.20	0.00	950.00	3318.87
2020	2161.33	0.00	1066.67	3661.69
2025	2377.47	0.00	1183.33	4004.51
2030	2593.60	0.00	1300.00	4347.30

Transportation Fuel Use: Barring kerosene, light diesel, and non-energy fuel all the other petroleum products imported in Nepal in the base year 1990 are consumed by the transport sector alone. This sector hardly uses the traditional energy. Only a fraction of its energy demand is met through electricity because of limited technologies which employ electricity as their driving fuels such as ropeways and trolley bus system. For 1990, 99.26% of what this sector demands as its end-use energy is petroleum products. In this year the transport sector consumes high speed diesel (80.07%), gasoline (10.62%), ATF (8.57%), electricity (0.55%), and coal (0.19%). During the entire time horizon of baseline study i.e. 1990-2030, no new technology is envisaged to be introduced in this sector therefore, the pattern of end-use consumption shall remain unchanged. Even in 2030 high speed diesel will be used the most (6444.8 TJ) and coal the least (18 TJ). There is not much increment in ATF (590 TJ) whereas the rate of consumption of gasoline (2208 TJ) and electricity (118 TJ) is growing faster than others.

The consumption of the final fuels by transport sector from 1990 through 2030 are shown in Table 5.6.

Table 5.6: Transport Fuel Use

Year	Diesel	Gasoline	ATF	Electricity	Coal
1990	4230.04	561.00	453.02	29.11	10.00
1995	4879.97	715.86	454.56	36.72	11.01
2000	5445.60	784.07	480.56	45.01	12.00
2005	5750.59	816.57	459.79	53.77	13.00
2010	5352.05	1541.18	502.79	63.28	13.99
2015	5690.70	1714.08	534.22	73.99	15.00
2020	5992.08	1882.85	562.13	86.65	16.01
2025	6278.35	2047.46	576.11	102.42	17.00
2030	6444.80	2208.00	590.00	118.00	18.00

It is clear from above Table 5.6 that most of the GHG emitting fuels are consumed by transport sector. Therefore, this sector is at the centre of focus to be addressed most in view of any future action of GHG mitigation.

Agriculture Fuel Use: As the electrical infrastructure is not built in many parts of terai, the agriculture base in Nepal, energy consuming activities in the agriculture sector still use high speed diesel instead of electricity. Diesel pumps, thrashing machines and tractors using diesel are employed across this part of the country. Only in some parts irrigational facilities are associated with electricity. In the base year 1990, 423 TJ of high speed diesel and 43 TJ of electricity are consumed in this sector. It is assumed that in the years to come terai will have electrical distribution networks installed in many parts such that agricultural equipments will use electricity more and more even by replacing diesel driven motors. Therefore, by 2030, electricity has steadily grown to 189.2 TJ whereas by that year diesel has finally dropped to the level of 383.3 TJ. It is interesting to note in the following Table 5.7 that in the first half of the study period diesel consumption by this sector has drastically been cut down in spite of the growth in this sectoral GDP leading to the conclusion that fuel switching might have taken place in favour of electricity. Then in the later half the development pace in this sector just could not be matched enough by electricity alone such that diesel persistently remains as motive power.

The consumption of the final fuels by agriculture sector from 1990 through 2030 are shown in Table 5.7.

Table 5.7: Agriculture Fuel Use

Year	Diesel	Electricity
1990	423.00	43.00
1995	368.33	75.26
2000	321.67	105.52
2005	275.00	135.78
2010	300.00	148.13
2015	325.00	160.47
2020	350.00	172.81
2025	366.65	181.04
2030	383.30	189.20

Electricity Generation: Even in the baseline scenario latter years have seen the gradual replacement of diesel and multi-fuel plant by the hydro plant. This is very understandable because of the fact that Nepal has enormous hydro potential as well as large number of big and small candidate projects are ready to be undertaken. It is customary to introduce the thermal and multi-fuel electricity generation for two reasons: i) when the immediate supply and demand gap has to be met and ii) when the peaking is failed to be addressed by the combination of hydros. NEA has envisaged, in its least cost generation expansion plan, to utilize the combination of big and small hydro power plants and also to construct the hydro plants with storage facility. This will lead to a minimum use of thermal generated electricity. Phasing the thermal plants out is a national dictum as the importation of fuel means the sinking of hard earned foreign currency reserves.

Therefore, much effort is given to introduce hydros in the mitigation scenarios above and all for the following reasons:

- meeting the needful energy demand through clean source of energy;

- rate of depletion of forest, the important sink for GHG emissions, is slowed down when the demand of fuelwood for domestic consumption is substituted by hydro generated electricity to a greater extent in lighting, cooking and heating;
- substitution of petroleum products, the main source of GHG emissions;
- indigenous source of energy.

The annual electricity production for 1990 shows that out of a total of 773.842 GWh, hydro accounts for 712.312 GWh, while thermal generation is a mere 0.858 GWh with 60.672 GWh coming from imports. With the demand for electricity increasing at a rapid rate and with little hydro additions in the last decade there has been more contribution from thermal plants, even then hydro still accounts for 75% of total generation in 1995. It is expected that hydro will contribute more and more to the total generation in the future with thermal generation used only in emergency peak load conditions when hydro generation is insufficient to meet the demand.

There is a power ecchange agreement with India whereby upto 50 MW can be exchanged between the two countries. Between 7% and 10% of Nepal's electrical energy is met by importing energy from India, but at the same time Nepal also exports energy to India during its off peak time, these exports amount to 25-85 GWh per year. There is a large potential for export of electrical energy as India is facing large power and energy shortage.

5.3 Cost of emission abatement

Regarding cost of emission abatement, a projection of relative costs per unit of different sources of energy is made (Table 5.8). Table 5.9 shows the projection based on specific assumptions regarding international (import) prices, exchange rate, and domestic prices revealing the cost of coal to increase from Rs 49 thousand per TJ in 1990 to Rs 232 thousand per TJ in 2030. Similarly, the cost of imported petroleum is projected to increase from Rs 90 thousand per TJ in 1990 to Rs 966 thousand per TJ in 2030. Alternative scenario gives the petroleum price at Rs 565 thousand per TJ in 2030. The price of fuelwood is estimated to increase from Rs 132 thousand per TJ in 1990 to Rs 1240 thousand in 2030. The past trend, however, indicates that by 2030 A.D., the price of fuelwood may be as high as Rs 11028 thousand per TJ. Regarding the cost of hydro-power, the average supply price is supposed to increase by 7 percent per annum. The cost is estimated to be Rs 10.97 million per TJ of electricity in 2030 from Rs 283 thousand in 1990. The projection of emission level reveals that from 209689 tons of carbon in 1990, the emission level would rise to 2070725 tons in 2030. A 10 percent reduction in carbon emission would require reduction in either 10458 TJ of kerosene, or 10355 TJ of diesel, or 12161 TJ of LPG or 8107 TJ of coal. To make up this energy loss, either hydro-electricity (which is non-carbon emitting source of energy) has to be added up, or fuelwood which is assumed to have zero balance emission has to be supplied in additional amount. The cost involved in such a substitution is, however, exorbitantly high particularly in case of kerosene or LPG replaced by electricity. As domestic supply price of electricity is conservatively estimated to increase at a rate of 7 percent, the net cost of electricity for a 10 percent reduction in carbon emission (through reduction on kerosene use) would be as high as Rs 105 billion in 2030. Similarly, for a 20 percent reduction in carbon emission, the net cost for electricity is Rs 209 billion. If emission abatement is to be adopted by substituting electricity for LPG, the net cost involved would be Rs 122 billion for 10 percent reduction in carbon emission and Rs 243 billion for 20 percent reduction.

Table 5.8: Specific Cost of Energy by Sources

Year	Coal	POL1	POL2	Fuelwood1	Fuelwood2	Hydro
1990	1229.23	3238.04	3238.04	2211.78	2211.78	1020
1995	2133.65	4393.02	4393.02	3765.21	3765.21	3700
2000	2462.74	5903.85	5414.69	7589.71	4805.47	5189
2005	2842.54	7924.29	6751.38	12920.30	6133.13	7278
2010	3280.84	10663.02	8418.05	21994.81	7827.61	10208
2015	3786.66	14330.21	10496.16	37442.72	9990.22	14318
2020	4370.38	19258.59	13087.28	63740.46	12750.34	20082
2025	5043.97	25881.94	16318.05	108508.20	16273.02	28165
2030	5821.27	34783.16	20346.38	184718.30	20768.95	39503

CPIN--> 7%

Note:

Coal= Projection of coal prices on past trend basis (Rs/MT)

POL1= Projection of POL prices based on an assumed international price rise of 3% for crude oil (Rs/'000 lt)

POL2= Projection based on past trend of price increase (Rs/'000 lt)

Fuelwood1= Projection of fuelwood based on past trend (Rs/MT)

Fuelwood2= Projection of fuelwood based on assumed price rise of 5% (Rs/MT)

Hydro= assumed electricity price rise of 7% per year.

Table 5.9: Cost of Energy by Sources in MRs/TJ

Year	Coal	POL1	POL2	Fuelwood1	Fuelwood2	Hydro
1990	0.049	0.090	0.090	0.132	0.132	

						0.283
1995	0.085	0.122	0.122	0.225	0.225	1.028
2000	0.098	0.164	0.150	0.453	0.287	1.442
2005	0.113	0.220	0.188	0.771	0.366	2.022
2010	0.131	0.296	0.234	1.313	0.467	2.836
2015	0.151	0.398	0.292	2.235	0.596	3.977
2020	0.174	0.535	0.364	3.805	0.761	5.578
2025	0.201	0.719	0.453	6.478	0.972	7.824
2030	0.232	0.966	0.565	11.028	1.240	10.973
Factor of Conversion (Heat Content)	25.1236	36	16.75		16.75	3.6

Table 5.10: Emission Abatement Cost (Case A)

Case A: Kerosene replaced by Electricity
Reduction by : 10%

Year	Reduction Level (TC)	Kerosene Reduced(TJ)	Reduction Cost (MRs)	Addition Cost (MRs)	Net Cost (MRs)
1990	20969	1059	95	300	205
1995	33255	1680	205	1726	1521
2000	48591	2454	402	3538	3135
2005	66894	3378	744	6831	6087
2010	89986	4545	1346	12887	11541
2015	113511	5733	2282	22801	20519
2020	142417	7193	3848	40123	36275
2025	172833	8729	6276	68293	62017
2030	207073	10458	10105	114760	104655

Table 5.11: Emission Abatement Cost (Case B)

Case B: LPG replaced by Electricity
Reduction by : 10%

Year	Reduction Level (TC)	LPG Reduced(TJ)	Reduction Cost (MRs)	Addition Cost (MRs)	Net Cost (MRs)
1990	20969	1231	111	349	238
1995	33255	1953	238	2007	1769
2000	48591	2854	468	4114	3646
2005	66894	3928	865	7943	7078
2010	89986	5285	1565	14985	13420
2015	113511	6666	2654	26512	23859
2020	142417	8364	4474	46654	42180
2025	172833	10150	7297	79410	72113
2030	207073	12161	11750	133441	121692

Table 5.12: Emission Abatement Cost (Case C)

Case C: Kerosene replaced by Electricity
Reduction by : 20%

Year	Reduction Level (TC)	Kerosene Reduced(TJ)	Reduction Cost (MRs)	Addition Cost (MRs)	Net Cost (MRs)
1990	41938	2118	191	600	410
1995	66510	3359	410	3452	3042
2000	97182	4908	805	7075	6270
2005	133788	6757	1487	13661	12174
2010	179972	9089	2692	25775	23083
2015	227022	11466	4564	45601	41037

2020	284835	14386	7696	80246	72550
2025	345667	17458	12551	136586	124034
2030	414145	20916	20209	229519	209310

Table 5.13: Emission Abatement Cost (Case D)

Case D: LPG replaced by Electricity
Reduction by : 20%

Year	Reduction Level (TC)	LPG Reduced(TJ)	Reduction Cost (MRs)	Addition Cost (MRs)	Net Cost (MRs)
1990	41938	2463	222	698	476
1995	66510	3906	477	4014	3538
2000	97182	5707	936	8227	7291
2005	133788	7857	1729	15885	14156
2010	179972	10569	3131	29971	26840
2015	227022	13332	5307	53025	47718
2020	284835	16727	8949	93309	84360
2025	345667	20300	14594	158820	144226
2030	414145	24321	23499	266883	243383

5.4 Contribution of Technology Options to GHG Abatement

Generation of electricity is mainly from hydro electric power plants. Thermal plants are pressed into service only during the peak load hours (between 6:00 pm to 8:00 pm) when supply from hydro plants are insufficient to meet the demand. Energy is also imported from India to supply some border towns. For 1990 the total supply of electrical energy was 773.842 GWh of which hydro power supply was 712.312 GWh, thermal supply was only 0.858 GWh and 60.672 GWh was from imports.

6. Macroeconomic Impacts

The demand for energy derived through the MARKAL model indicates that energy intensity of economic growth will be declining in future course of time. This implies that technological advancement, cost effective use of various energy sources and higher productivity of the factors of production including energy will lead to higher output growth per unit of energy used. But the relationship between economic growth and energy use is not unidirectional as projected in this study. Increased supply of energy will definitely enhance the rate of economic growth, although such a feedback is not very much strong in the present context. But in future course of time, energy will be one of the major determinants of growth due to these reasons: (i) gradual shift of economic activities from agricultural to industrial ones would require more energy, as energy intensity of industrial activities is higher than that of agricultural activities, (ii) in the process of modernization and mechanization of farm activities, demand for energy even by the agricultural sector will go up, (iii) foreign investment in large industries will come only if there is prospect for sufficient power supply, and (iv) enhanced power supply will help automation, mechanization and hence increased productivity of other factors of production leading to higher economic growth rate. The present study, however, being based on empirical results derived from standard model cannot capture the effects of energy shocks to the economy in general. Although a separate causality analysis could be done by using econometric tools, absence of historical data for a relatively longer period has constrained such study as well.

The macro-economic impact of emission mitigation program will depend upon what type of energy substitution we opt for mitigation purpose. If emission reduction has to be done through replacement of fossil fuel by electricity, heavy additional cost will have to be bourne, as discussed earlier provided that the electricity generation requires import of machinery and plants and also foreign technology, the foreign exchange involvement would be substantially high. Increased use of indigenous technology and local machinery would, however, reduce the foreign exchange involvement. Further, if residential demand for energy is met through increased use of fuelwood for kerosene and LPG, and if afforestation program is operated effectively, the country could even save foreign exchange involved in financing the import of kerosene and LPG. Assuring that consumption of fuelwood is made up by new plantation, the addition to emission level will supposedly be zero. This would be the most cost-effective emission abatement strategy which has no foreign exchange involvement at all.

Regarding bio-mass sources of energy, the expected declining share of agricultural sector to GDP implies that the supply of agro-byproducts will also be limited in futurecourse of time. Dung, a major source of traditional energy would not be sufficiently available for this purpose in future because of the heavy opportunity cost involved. As the price of chemical fertilizers is likely to shoot-up due to government policy not to keep on subsidizing it, in the long-run, dung is very likely to be used as substitute for chemical fertilizers. In this perspective, it can be inferred that even if cattle population does not decline not much dung would be available for energy purposes. Hence, the need for an alternative source of energy arises.

7. Policy Options

Prior to deciding what types of mitigation policy option should be adopted for Nepal it will prudent to first look at the options available:

- Emission Reduction Targets: CO_2 emission levels are pre-set for various years such that these targets are at reduced level by certain percentage of the baseline level of the respective years.
- Options up to a Certain Cost per Ton of Emissions Reduction: This type of scenario is the "bottom-up" equivalent to a "top-down" carbon tax scenario. In the bottom-up approach, all technology and policy options that are expected to cost less than or equal to a given cost per tonne of emissions reduction would be entertained.
- "No Regrets" Scenario: This scenario is a common variant of the previous type of objective, where the screening threshold is essentially zero cost per tonne of GHG reduced. In other words, such a scenario would include only those options that appear economic or otherwise desirable.
- Specific Options or Packages of Options: Examples of this type of scenario might be a "natural gas" scenario, a "renewable energy" scenario, or a "nuclear" scenario.

Nepal is one of the least developed countries and its energy consuming developmental activities are very low. Consequently, its share of global GHG emissions is also negligible. The comparative total CO_2 emissions of some of the representative countries of Asia are as follows:

Table -7.1: CO_2 Emissions of Some Asian Countries

	Total Emissions	
Country	tons of Carbon	CO_2
Nepal	0.210 million ton	771 Gg
Japan	320.000 million ton	1,173,000 Gg
Vietnam	98.117 million ton	359,762 Gg
Republic of Korea	69.900 million ton	256,300 Gg
Mongolia	5.325 million ton	19,524 Gg
Fiji	0.203 million ton	743 Gg
Bangladesh	4.004 million ton	14,680 Gg

It is quite clear that Nepal's developmental effort will be hampered if energy consuming activities are checked and slowed down as energy consuming sectors are the corner stones of its overall development. In particular, industrialization is its key policy objective at present and this will eventually lead to increased use of fossil fuels. The trend towards increased fossil fuel consumption seems almost unavoidable such that any relevant long-term GHG mitigation policy initiatives may be expected to reduce the rate of increase in carbon emissions, but not lower them.

Therefore, the second objective - the "top-down" carbon tax and its "bottom-up" equivalent - is not suitable at all in the Nepalese context. However, the government will have to formulate a proper plan as it will have to consider the peoples affordability and willingness to pay such taxes. This possibility should be explored in depth to assess the benefits.

As far as the fourth objective is concerned, only "renewable energy" scenario is relevant and other two scenarios are of distant possibilities. Substitution of fossil fuels by clean and indigenous renewable resources is the potential policy option for Nepal.

"Emission reduction target" objective is relevant to Nepal.

1. Long-Term Promising Mitigation Options

Hydropower Generation: Unarguably the cleanest source of energy is the hydro-generated electricity, fortunately Nepal is richly endowed with this form of energy. Harnessing this hydro-energy to its fullest extent will be the most attractive and promising mitigation option from CO_2 emission point of view. HMG should give top most priority for electricity generated from hydro-energy among all the other energy sources in its future five year plans. In order to stop the outflow of hard earned foreign currency through import of fossil fuels and to reduce the GHG emissions led through burning of these fuels substitution of them by electricity can be obtained particularly in industrial and transport sectors. By providing cheaper (cross-subsidized electricity tariff) and reliable electricity to the industries spread across the country will help reduce the fossil fuel consumption. Having established a national transport network supplied with electricity (such as electric trolley bus in most part of Kathmandu valley, electricity run railways along the East-West highways, ropeways in difficult hilly terrain, battery driven vehicles, etc.) the GHG emission will definitely drop down because the transport sector alone consumes substantial portion of the fossil fuels.

Afforestation: Expanding the emissions sink base is also equally important as far as CO_2 emission is concerned. It is achievable through afforestation program. For the last few decades a lot of forest area had been encroached by growing population and improper forest management. In the baseline scenario, the fuelwood consumption is significantly used by the rural population for domestic purpose. Hence the cutting of trees will continue even in FY 2030 in spite of the expansion of electrical networks in the country. In order to countermeasure the emission of CO_2 due to burning of fuelwood plantation of trees by some amount will result into a definite absorption of CO_2.

2. Short-Term Promising Mitigation Options

Energy Efficient Technology: By employing the energy efficient equipments instead of ordinary type of equipments in the existing as well as new system the CO_2 emissions will be reduced to some extent although this measure does not form a part of a climate change country plan. The use of compact flourescent lamp (CFL) which is much more energy efficient than the general incandescent lamp will help reduce the total energy demand and therefore, will eventually reduce the consumption of diesel by thermal power stations.

Improved cooking stoves (ICS) have a potential to save fuelwood uses for household cooking in Nepal. At present, 90% of total 11 million metric tonnes of fuelwood is burnt in cooking alone. Theoretically, it is possible to reduce the fuelwood consumption for cooking by 90%. ICS have an efficiency in the range between 15% and 30% compared to traditional mud stoves whose efficiencies vary between 3% and 15%.

Briquettes are compacted form of the rice husk and saw dust prepared under the technique of mass densification with or without pyrolization. The density of these briquettes is more than 1000 km/m3 and gross calorific value is about 4000 kcal/kg which is comparable to that of air dried fuelwood. Briquettes can produce a maximum temperature of 500 degree C at 6% moisture content. The shape, calorific value, and maximum burning temperature of briquettes are favourable to be a substitute for fuelwood. Thus the use of briquettes will somewhat help in slowing the deforestation process.

Improved vehicle efficiency for automobiles, light and heavy trucks, and buses will also be a mitigation option for the transport sector. Improving the efficiency of vehicle fleets or switching fuels (for example "Safa Tempo") require long lead times to have substantial effect, but they are much more likely to persist in their impact. Even if economic growth leads to an increase in the amount of transportation, emissions will be lower if the vehicle stock has higher fuel economy, or if it uses cleaner fuels than present petroleum fuels. In general, the following five (5) broad categories of mitigation options encompass a large number of specific actions in this sector:

- Improve vehicle technical efficiency
- Switch to fuel systems with lower emissions
- Improve system efficiency
- Encourage shifts toward modes with lower emissions

- Manage transport demand

3. Possible Barriers

Some of the major problems associated with the mitigation option analysis are : Country's lack of resources and its poor economic conditions; very unstable political situation (four governments in just five years); and limited reliable data.

Also, the investment in the hydro-electricity generation is very capital intensive and to make matters even worse the capital outlay is heavily/unevenly required in the starting years. The problem is further compounded by the fact that the plants and machineries are not produced in Nepal and have to be procured from outside resulting in a financial resource crunch.

As the initial capital investment for compact fluorescent lamp (CFL) is much higher the market price can be made competitive by lowering the custom duty charged on it and with some incentive schemes to consumers for switching to CFLs.

The expansion of sink by forestation has certain difficulties as follows:

- long gestation period
- limitation of land for forestation because of cultivation and habitation for ever growing population
- lack of awareness of GHG emission problem
- limitations on government resources to carry out large scale afforestation programmes.

From the discussions it can be concluded that Nepal, no doubt understands the implications of global warming and the effects of greenhouse gases emissions on our environment and thus is committed towards combating the polluting effects of these gases. It has started anti-pollution drives specially in the urban areas and all developmental projects have to have an environmental impact assessment study done before they can be taken up for implementation. However, at present, the reduction of carbon-di-oxide is not a matter for serious concern for Nepal (as it is a very minor contributor). It is still struggling with its efforts for developing its overall economic conditions and is lagging far behind the rest of the world. The government is hard pressed with more urgent matters such as economic development, infrastructure development (roads, educational, health, and irrigation facilities, etc.), reducing unemployment, improving trade deficits thus improving foreign exchange situation, and in general improving the quality of life of its people.

On the whole the overall emission level of Nepal is negligible as compared to other developing neighbouring countries. It is quite clear that Nepal's developmental effort will be hampered if energy consuming activities are checked; that is, the development process will be slowed down as energy consuming sectors are the corner stones of its overall development. In particular, industrialization is its key policy objective at present and this will eventually lead to increased use of fossil fuels. The trend towards increased fossil fuel consumption seems almost unavoidable such that any relevant long-term GHG mitigation policy initiatives may be expected to reduce the rate of increase in carbon emissions, but not lower them. Some long and short term measures such as hydro power development, afforestation programs, and use of energy efficient technology have been recommended to reduce GHG emissions, but it would be very costly as well as detrimental to the country's developmental efforts if strict mitigation measures were to be applied.

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