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Biofuel: Potential and Prospects in Nepal as an Alternative to Fossil Fuels

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Abstract *– Though a tenth of Nepal's energy requirement, especially in the urban sector, is met with petroleum products; the external dependence on it has caused irregularity in the supply and hampered economic growth of the country. Moreover; the dependence of more than 80% of Nepal's rural population on traditional biomass and/or fossil fuel for energy has always been the reason for health problems and has stopped them from moving out of their woe towards economic development. One of the ways to get rid of this external dependence and to improve the national economy is to find alternative,s and biofuel could be a better option to substitute fossil fuels as compared to other energy resources such as hydropower or solar energy that need expensive infrastructure and more time to develop. The abundance of resources such as molasses, plant species producing inedible oil, fat and resins could support the intervention of biofuel such as ethanol, biodiesel, un-esterified plant oil and turpentine in various applications ranging from urban vehicles to rural requirements of operating irrigation pumps, agro-processing mills, electric generators, cookers and lamps. Initiations for the use of biofuel started in Nepal long back with various action research activities by different sectors and this needs to be continued by developing infrastructures, building technical capacity of stakeholders and formulating policies that are favorable for harnessing energy from the abundantly available resources.*

Keywords – Bio-ethanol, biofuel, economics, substitution.

1. INTRODUCTION

Energy is one of the vital inputs to socio-economic development of any country. Types of energy resources available, energy used and ways and amount of energy used also indicate the economic development status of a country. From this perspective, "energy poverty" of Nepal is causing economic poverty and leading to overall poverty [1]. Energy consumption by fuel type in Nepal consists of traditional fuel 86.8%, commercial fuel 12.66% (petroleum products – 9.02%, coal – 2.01% and electricity – 1.63%) and renewable 0.54% [2]. About 80% of population living in rural areas of Nepal depends on traditional fuel like wood fuel and biomass for cooking [2]. These people are mostly comprised of socio-economically deprived indigenous and marginalized communities and have very hard living.

Nepal is fully dependent on imported fossil fuels like petrol, diesel, kerosene and LPG for running vehicles or stationary engines and cooking and lighting. Annually, about 40% of Nepal's earning on foreign currency goes to buy the fossil fuels [3]. The price of petroleum products are increasing day by day and the supply management of fossil fuel is becoming very crucial and critical as the number of motor vehicles and fossil fuel consuming areas are increasing. This will have great impact on national economy. The prevailing situation in Nepal could be improved to a large extent, if the energy requirements could be met by some kind of renewable energy that is locally available and sustainable. Nepal being a rich country in biodiversity, especially biomass based renewable energy sources, can harness locally available and sustainable energy for multi-purpose uses and thus preventing the drainage of reserved hard currencies and helping in reducing the country's trade imbalances to some extent. Nepal has varieties of biomass resources, wild fruits and different types edible and non-edible oil plants. Bio-fuel is one of the clean fuels that can be used for cooking, lighting and to propel the vehicles or generate power from stationary engines. Although edible oil has more economic value for domestic consumption where as; largely available non-edible oil can be used for several activities that are relying on fossil fuels or animated energy.

From Nepalese perspective there are two types of bio-fuels that can be promoted in short terms: Bio-diesel either after esterification or directly used after extraction of oil and fats and Bio-ethanol. In Nepal, in short term, the bio-diesel can be produced from mostly non-edible oil plants like Jatropha (Jatropha curcas L.), Soapnut (Sapindus mukorossi), *Dhaka* (Aregmone mexicana), *Nageswhor* (Mesua ferrea) etc. Bio-ethanol can be mainly produced from molasses that is by-products of sugar mills. Likewise, Khote Salla (Pinus roxburghii) is abundantly available in the hilly areas of Nepal and it can be used to produce turpentine oil as a substitution for petrol [4].

2. PROJECTION OF POTENTIAL

Bio-diesel

Potential of locally available non-edible oil plants and seed production as well as oil and fat production is not simple to estimate. However, rough estimate can be drawn based on the types of non-edible plants available, their

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productivity and land suitable for the production. Some 286 oil bearing plants and nuts are found in Nepal and more than 23 plants have oil content more than 30% and in some cases it is as high as 80% [5], [6]. As per Boswell [7], from the climatic condition's perspective, around 30% of Nepal's area is favorable to produce Jatropha Curcas L. plants, which contains 30 to 50% oil by weight [8]. A rough estimation based on the secondary data as well as in [6] shows that Nepal has 12% (1,764,285 ha) wastelands that are suitable for Jatropha plantation. Considering the average oil yield about 1,000 liter/ha/year based on average seed yields of Jatropha plants, compare with [6][1], the total oil production that can be achieved from suitable waste land in Nepal is about 1,764 million liters.

Table 1. Land Use Data in Nepal, Source: [9]

S.N.	Description	Land Used in %
1	Natural Forest	37
2	Shrub land	12
3	Grass land	12
4	Tree covered land adjacent to farms	4
5.	Cultivated land	21
6.	Others (settlement, rocky areas, perennial ice snow, lakes and rivers)	42

A good amount of waste fat is available in Nepal although exact data on it could not be found. Buffalo fat is collected and is used for other sectors like soap making, etc but isolated and small scale initiatives have been started by few NGO and institutions to produce biodiesel. Apart from this, pine resin is also abundantly available in Nepal, which could also be utilized for bio-diesel production. As per available data in FY 2006/07 about 13,600 kL of resin and turpentine was produced by 12 industries and Nepal said to have about 27,214 kL of annual potential. Part of these resources could be utilized for bio-fuel in Nepal.

So potential of non-edible oil plants and other resources for bio-fuels depends on the areas available and suitable for cultivation and yield rate per year per unit area as well as economies of scale and commercial viability. Rough estimate shows that about 1 billion liter of diesel can be replaced by bio-diesel in Nepal per year.

Bio-ethanol

Although ethanol can be produced after hydrolysis or fermentation from different forestry and agriculture residues, organic municipal waste, woody perennials, starchy foods and fruits, at present the most potential sources of bio-ethanol production in Nepal is from molasses that is by-product of sugar mills. About 25 sugar mills are registered in government agency in Nepal however, currently only eight are operating [10]. In FY 1985/6 around 98,461 MT sugar was produced which is about 42% of installed capacity. In FY 2005/6 about 2,462,574 MT of sugarcane was produced in Nepal and productivity of sugarcane was 39.862 MT/ha, which was 24.265 MT/ha in FY 1985/86. In 1985/86 about 23,010 ha was used to produce sugarcane whereas in 2005/6 about 62,058 ha was used to produce 2,462,574 MT. About 43,760 MT of molasses as a by-product of sugar mills was produced, which is only 46.38% of total production capacity currently available in Nepal. Interestingly only about 56% of sugarcane produced in Nepal is being brought to sugar mills and the rest is utilized by domestic and informal small-scale industries to produce different products.

In FY 2005/6, out of eight operating sugar mills in Nepal, only four claim to have the capacity to produce ethanol. Three claim that they can produce ethanol by the cracking method and one already has the facility of dehydration plant through the molecular sieve technology. Except one, all sugar mills are relying only on sugar molasses to produce ethanol. The total potential of ethanol production in Nepal, at present is about 20,000 kL per year and the biggest sugar mill is having the production capacity of about 30 kL per day. The quality of anhydrous ethanol that can be produced by a biggest sugar mill is 99.8% V/v from the feedstock of rectified spirit 95%V/v. However, there are 40 distilleries registered with government agency, are consuming ethanol. The supply of ethanol for fuel also depends on the demand of ethanol by these distilleries.

From these figures it can be seen that there is a good future and resource potential to produce bio-ethanol from the existing sugar mills in Nepal. Once the utilization of ethanol becomes popular in practice, utilizing other bio-products, which are financially and economically feasible without having impacts on food security and environment, will automatically increase the supply side of ethanol.

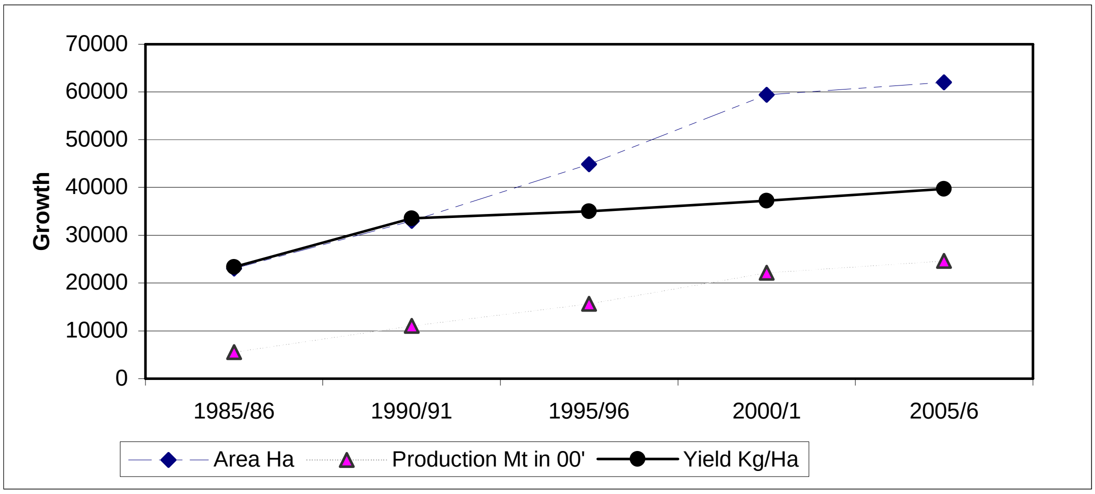
3. INITIATIVES TO USE BIOFUELS IN NEPAL

There are no visible commercial applications of bio-diesel in Nepal although isolated adaptive research and development activities were carried out since 1990s. Even oil extracting expeller were designed and produced locally in Nepal [5], [6]. Research Center for Applied Science and Technology (RECAST) has done some research and development activities on diesel engine to use un-esterified bio-diesel and simultaneously plantation of Jatropha in western Nepal. An initiative was also started to use Jatropha plant oil in pressurized kerosene stoves in 1997-98 by Rural Energy Development Program but could not be materialized. Currently, few I/NGOs are exploring the possibilities of promoting non-edible oil as bio-diesel either to feed directly to the diesel engine or produce bio-diesel after esterification. However, no commercial application is available in Nepal yet.

In case of bio-ethanol, Thapathali Campus, Institute of Engineering started adaptive research on ethanol as an automotive fuel in 1997. In the year 2002, the Government of Nepal had decided to blend 10% ethanol in petrol however the decision could not be materialized due to several reasons. Alternative Energy Promotion Centre (AEPC) has carried out a study in 2007 to assess

[1] [6] indicated that in Madagascar about 2400 liter/ha/year and Nicaragua 1630 liter/ha/year and in Mali 200 liter/ha/year. So average figure, comparing the climatic condition of Nicaragua with Nepal 1000 liter/ha/year is a realistic figure.

the economic, technical and environmental aspects of using petrol-ethanol blend in automobiles in Nepal. The study has come up with positive findings and recommendations and showed that financially, commercially, economically and environmentally; the use of bio-ethanol from molasses of sugar mills will be beneficial to Nepal. The Government of Nepal in November 2007 has again decided to blend 10% ethanol in petrol and a committee is working on modality and approaches to implement the government's decision.



Graph: Trend of sugarcane cultivation area, production and productivity in Nepal, Compiled from [17], [3]

4. ECONOMICS OF BIOFUEL USE IN NEPAL

Jatropha Curcas L. is an indigenous plant; found growing at most places in Terai and lower hills. About 60% of Nepal's economically active people are involved in agriculture. About 39% of GDP is contributed by agriculture sector alone. Most people are farmers and own land. Most of the poor farmers live in marginal, low-grade land where hardly any thing can be grown. Jatropha and other non-edible plants grow on poor barren lands and can also be planted in long margins along 15905 km of black topped roads, newly constructed green roads and countless trails and rivers where food, fruits and vegetable cannot be grown [7].

At present no standard market price for non-edible oil seed is available in Nepal. However, as per [7], if a household plants 250 Jatropha Curcas L. in marginal land, then it can at least on average produce 250 kg of oil seeds per year. On a win-win situation, 68 liters of oil can be extracted which can be used directly to diesel engine or can be sold at least at 50% price of the available diesel. Various private and public sectors have shown interest to purchase Jatropha seeds and few have started collection in the Mid Western Terai region of Nepal. Nepal Salt Trading Corporation is also interested to buy Jatropha seeds. Jatropha seed collection could be adapted from the concept of milk collection centers which are operated by co-operatives in Nepal and it will make possible for poor farmers to find market opportunity for their small scale production. Local level expelling of non-edible oil seeds is also possible with cost effective *sundhara* oil expeller that is designed and manufactured locally and also technically and financially viable in Nepal [11]. Economic analysis of bio-diesel or bio-fuel (direct use of oil from non-edible seeds) use is still premature because of the absence of market and its application in the practical field in Nepal but Indian experience shows that it could be economically feasible in Nepal also.

Regarding ethanol, interestingly, sugarcane farming seems to be relatively lucrative compared to rice and other regular crop plantation in plain areas of Nepal as number of hectare used for sugarcane farming is increasing every year. On other side, as per [10], Nepalese Rupees (NRs.) 6 per liter (1 US$ ≈ NRs. 63) only is the excise duty to anhydrous alcohol (above 99%). Local development tax and VAT has to be added to this. In FY 2002/3, price of bio-ethanol (anhydrous) submitted to NOC by private companies was said to be NRs. 38.56. However, current price as per sugar mills is about NRs. 50 per liter after including all taxes. The price can be competitive once there is open market for all sugar mills and market opportunity to the sugar mills.

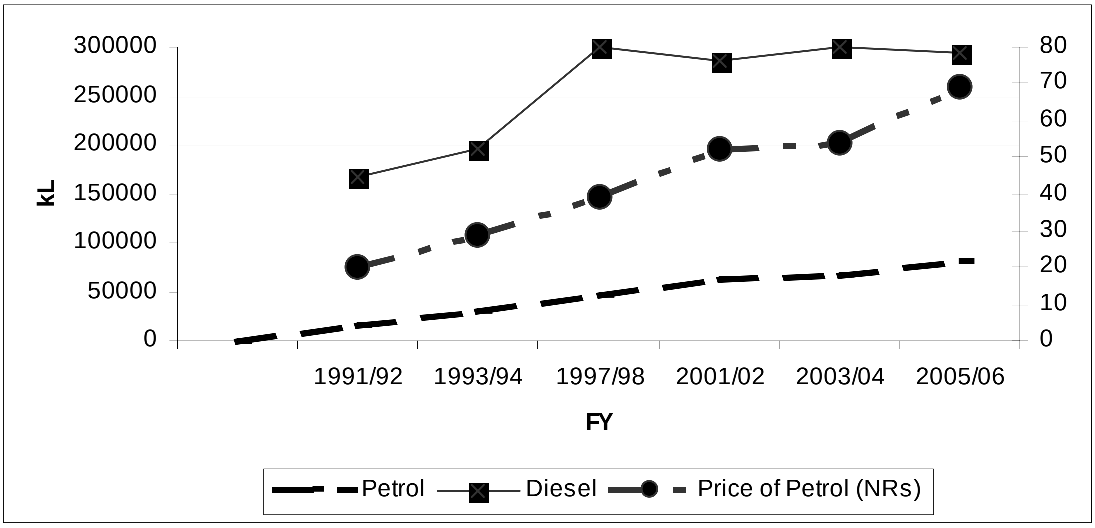
Comparing with the current price of petrol in Nepal, which is NRs. 80 per liter, the available price of ethanol is cheaper. As in AEPC [12] study has shown that blending 10% ethanol to petrol brings positive results and the price of 10% ethanol blended petrol will be NRs. 77 with significant environmental and national economic benefits. Use of E10 can prevent import of 7,300 kL of petrol in Kathmandu valley alone annually. Nepal's fossil fuel supply is still being controlled by state-owned entity – Nepal Oil Corporation (NOC) and it is on huge debt. Promoting ethanol will certainly give some relief to financial crisis of the NOC and reduce trade deficit.

However, economics of producing ethanol from other resources has to be analyzed, especially from cash crops and starchy products. As Nepal is having food security problems in high hills and remote areas, the use of such food items should be avoided.

5. FUEL SUBSTITUTION POSSIBILITIES IN NEPAL

Biofuels could be important substitution of fossil fuels in Nepal in both urban and rural applications. There is a good prospect for producing ethanol from molasses that is abundantly available as a byproduct of sugar mills [10] and biodiesel from Jatropha and other inedible plant seeds [13], [14]. The possible sectors for substitution are both petrol and diesel operated vehicles together with other applications using diesel fuel such as diesel power plants, irrigation pump sets and generators and cooking and lighting applications in rural areas. However, immediate implementation possibilities of replacement is petrol with ethanol blending in mass scale.

The demand of petroleum products is growing in Nepal at a rate of 12% each year, which is the highest in South Asia [15]. About 446,749 kL petroleum products were sold in fiscal year 1993/94 and it has grown up to 222,984 kL in the fiscal year 1998/99 which has tremendously increased and reached to 777, 843 kL in FY 2004/5. Kathmandu valley alone has a daily consumption of 200 kL of petrol.



Graph: Petroleum product sales growth [3]

According to Nepal Oil Corporation, petroleum products of worth NRs 33.31 billion was imported in 2007 while products of NRs 40.41 billion would be imported in 2008 if the demand increases by 12% as in the previous years. Out of the total import in 2007, NRs 3.96 billion has been spent for petrol (gasoline) while NRs 12.86 has been spent for importing diesel. These figures are for overall Nepal. It would require 535 MW of hydro-electricity to replace the consumption of LPG and kerosene for the consumption made in the year 2006, which is not possible at the present installed capacity of just over 600MW and installation growth rate of hydropower projects [16]. The biomass energy resources are dwindling while per capita energy consumption is quite low in Nepal. So the dependence on petroleum products will remain to grow. Bio-fuel in long term and bio-ethanol immediately could provide best option for partial replacement of fossil fuels.

6. EMISSION REDUCTION BY SUBSTITUTION OF FOSSIL FUELS BY ETHANOL FUEL

Anhydrous ethanol, i.e. 99% pure ethanol can be blended at different proportions in petrol up to hundred percent (E100) and used in petrol engines to reduce air pollution. The presence of oxygen molecule in ethanol compound increases the octane rating of blended fuels and it helps in proper combustion. Various international experiences have shown that the use of E10 and E20 does not require modification in existing engines. Almost 75% of transport fuel in Kathmandu is petrol and it is responsible for 62% of transport related PM10 emissions [14].

One of the objectives of the study conducted by AEPC in 2007 on ethanol blended petrol was to find out the environmental effects of using the blend. The experiment focused on the emission of carbon monoxide (CO), hydrocarbon (HC) and carbon dioxide (CO2). Tests were made on five cars and four motorcycles of different engine capacities. Results show that there is a huge environmental benefit of using ethanol blended petrol with significant reduction in CO up to 36.6% for E10 to 90% for E20 and HC up to 45 ppm and 46.62 ppm for E10 and E20 respectively. The saving is higher for E20 as compared to E10 and is significant for HC emissions.

7. CONCLUSION

There are no proven reserves of petroleum fuel in Nepal and hence Nepal is a net importer of such. Other energy resources such as hydropower, solar, biogas are either expensive to generate or a lot of infrastructure development is necessary to harness them for energy in order to substitute the end use of petroleum. Liquid biofuel can replace the use of petroleum sooner than others. Moreover, intervention can be made by the use of plant oil for cooking or lighting purpose to replace the use of 87% traditional fuels, especially biomass comprising mostly of fuel wood, that cause indoor air pollution and degradation of forest. In a country like Nepal where scattered settlements make electricity transmission and distribution very expensive, it would be wise to develop stand-alone power generators; bio-diesel processed from locally grown Jatropha seeds and locally developed *sundhara* expeller could be a viable alternative. Likewise, agricultural applications such as agro-processing mills, irrigation pumps and other processing facilities in the rural areas that presently use diesel engines could be substituted with plant oil impelled from locally grown seeds. This will save the expenses of processing biodiesel from plant oil but maintenance work could be increased since the injector nozzle needs to be cleaned more often.

Policy wise, Rural Energy Policy – 2006 of Nepal has given a clear indication that for the enhancement of rural livelihood, biofuel has to be promoted. AEPC is promoting biofuels adaptive researches collaborating with other institutions and stakeholders.

Table: Experiments with different fuels and their pollutant emissions on cars [12]

Brand Name and Type	Capacity (CC)	Fuel Type Used	Carbon Monoxide (CO) % by vol.	Hydrocarbon (HC) Parts per million (ppm)	Carbon dioxide (CO2) % by vol.
Maruti – Sujuki	800	Petrol	1.498	429	11.89
		E 10	1.203	342	12.31
		E20	0.201	229	12.74
Toyota- Corolla	1300	Petrol	2.779	466	6.49
		E 10	0.222	337	12.67
		E20	0.132	250	12.24
Maruti Sujuki Alto	1100	Petrol	0.846	306	14.92
		E 10	0.126	293	14.37
		E20	0.045	176	15.61
Hyundai Santro	1100	Petrol	0.418	260	11.87
		E 10	0.265	245	11.53
		E20	0.386	155	11.53
Kia Sephia (GTX)	1600	Petrol	1.125	248	14.68
		E 10	0.399	205	14.92
		E20	0.138	179	14.98
Nepal Mass Emission Standard		3% by Volume of CO		Less then 1000 ppm of HC	

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