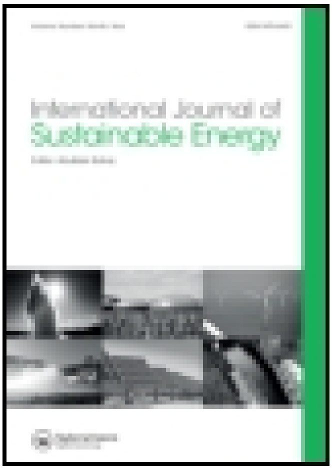

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Integrated MAED–MARKAL-based analysis of future energy scenarios of Nepal

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This paper employs an integrated model for analysis of energy demand and MARKet ALlocation modelling framework for assessing different pathways for the development of energy systems of Nepal. Four energy scenarios are analysed with the time horizon from 2010 to 2030. With high electrification and energy efficiency and demand-side management, the analysis reveals that all three major goals of sustainable energy for all can be achieved by 2030, but that the total discounted systems costs required account for three times the costs of the reference scenario. In the policy scenario, net fuel import costs and greenhouse gas emissions will decline by 20% and 35%, respectively and the share of renewable energy will increase from 3% in 2010 to 22% in 2030. The analysis provides insights for selecting a better pathway for the sustainable energy development and energy security of the country.

Keywords: dependence on fossil fuels; MAED–MARKAL modelling; hydropower resources; energy security; energy sustainability

Introduction

Nepal, an agrarian economy, is situated between two giant emerging economies – India and China (Figure 1). Nepal's GDP per capita at purchasing power parity (GDP PPP/capita) was US$1370 in 2010, and its economic structure has undergone significant change in recent years, and the contribution of the agriculture sector, though the population is predominantly dependent on agriculture, has declined to 35% from 47% in 1990 (MOF 2012; ADB 2013). Nepal's population was 26.5 million and there were altogether 5.6 million households in 2010. Eighty three percent of the population lives still in rural areas (CBS 2012).

In the year 2010, the total primary energy supply (TPES) was 420 PJ (based on WECS, 2010; MOF 2012). Traditional solid Biomass energy accounted for 83%, and the shares of commercial energy such as fossil fuels and electricity were 13% and 3%, respectively, in the TPES. Modern renewable energy such as biogas, solar home systems and briquettes supplied about 1% only (WECS 2010; Bhandari and Stadler 2011; Gurung, Ghimeray, and Hassan 2012; MOF 2012; NEA 2012; NOC 2012; Malla 2013). In recent years, the imports of LPG were increasing at a constant annual growth rate of 17%, whereas total petroleum products were growing at the average annual rate of 5% in the period of 1995–2010 (NOC 2012). Table 1 presents the energy balance of Nepal in 2010.

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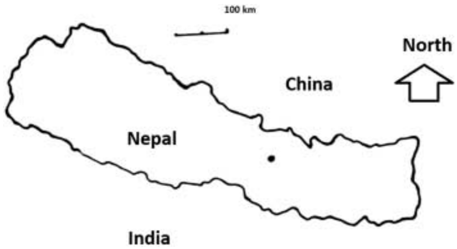

Figure 1. Map of Nepal.
Source: Author's own elaboration.

Table 1. Energy Balance of Nepal in 2010 in PJ (based on WECS 2010; MOF 2012).

Particulars	Petroleum products	Coal	Hydro	Electricity	Biomass	Modern renewables	Total
Primary supply							
Indigenous production	0	0	12	0	349	3	365
Imports	40	11.975	0	2	0	0	54
Exports	0	0	0	(0)	0	0	(0)
Stock changes	0.23	0	0	0	0	0	0
Total primary supply	40	12	12	2	349	3	419
Transformation							
Inputs	–	0	(10)	0	0	0	(10)
Electricity generation	0	0	0	12	0	0	12
T & D losses	0	0	0	(3)	0	0	(3)
Other losses, own-use, etc.	–	0	(2)	0	0	0	(2)
Net supply to consumers	40	12	(0)	11	349	3	415
Final Consumption							
Industry	2	12	–	5	2	–	20
Residential	5	0	–	4	346	3	357
Commercial	3	–	–	1	2	–	6
Transport	21	–	–	0	–	–	21
Agriculture	3	–	–	0	–	–	3
Others	–	–	–	1	0	–	1
Total	33	12	–	10	349	3	408
Statistical error	7	–	(0)	0	0	–	7

Note: There was a supply of 7 PJ of petroleum products that were used for captive generation of electricity by the private sector and the households.

In 2010, the residential sector consumed 87% of final energy, whereas productive sectors like transport, industry, commerce and agriculture in totality had lower shares in the final energy consumption. Nepal is totally dependent on imports of petroleum products for its energy requirements. The nation spent approximately 126% of its earnings from commodity exports in 2011 on import of petroleum products which was just 27% of the exports earnings in 2001 (MOF 2012). On the other hand, Nepal has indigenous energy resources, such as hydropower, solar, wind and other renewable energy. The hydropower potential is 83,000 MW and out of it the commercially viable potential is 42,000 MW (Shrestha 1965; WECS 2010). However, Nepal has harnessed only 3% of its commercially viable hydropower resources till now. The nation spent 0.3% of its GDP in the energy sector which is low compared to other developing countries (WB 2012).

In the regional context, Nepal's energy consumption in 2010 was 14 GJ/capita compared to its neighbouring countries such as India (25 GJ/capita), Pakistan (21 GJ/capita) and China (76 GJ/capita). Similarly, Nepal's electricity consumption per capita was 93 kWh compared to those of the other South Asian countries such as Bangladesh (279 kWh), India (644 kWh) and Pakistan (457 kWh) in 2010 (IEA, 2012). Energy poverty is prevalent in rural areas with 80% of its population spending more than 10% of their income on energy procurement (Bazilian et al. 2010; Banerjee, Singh, and Hussain 2011). The country currently has power cuts of more than 12 hours a day in winter and 6 hours a day in summer (NEA 2012).

The Literature indicates that many studies are conducted on the energy demand projection in Nepal. Pokharel (2007) and Nakarmi and Banerjee (2007) used econometric approaches for forecasting energy demands till 2012 and 2015, respectively. Malla (2013) employed the long-range Energy Alternatives Planning System (LEAP) modelling framework for developing scenarios to study household energy consumption patterns till 2040. Several studies were also conducted on the status and assessment of renewable energy in Nepal (Pokharel 2003; Gewali and Bhandari 2005; Katuwal and Bohara 2009; KC et al. 2011; Parajuli 2014). In the context of greenhouse gas (GHG) emissions, Shrestha and Rajbhadari (2010) studied energy and environmental impacts due to emissions from 2005 to 2050 in the Kathmandu valley using MARKAL (MARKet ALlocation) modelling framework. Similarly, Shakya, Kumar, and Shrestha (2012) and Shrestha and Shakya (2012) analysed also co-benefits and benefits of carbon emissions in Nepal for the periods from 2005 to 2050 and 2100, respectively.

Overall, the current energy consumption pattern in Nepal indicates an unsustainable trend with poor harnessing of indigenous renewable energy, increasing dependence on imported fossil fuels, increasing power crises and inefficient usage of the biomass energy in the country. Against this backdrop, it becomes essential to analyse the economic implications for alternate energy development. This paper analyses future energy scenarios integrating the Model for Analysis of Energy Demand (MAED) and the MARKAL modelling framework.

Data and data sources

Economic and demographic data were obtained from the Ministry of Finance (MOF), Government of Nepal; the Asian Development Bank (ADB); and Central Bureau of Statistics (CBS), National Planning Commission (NPC), Government of Nepal (CBS 2012; MOF 2012; ADB 2013). Energy-related data were obtained from energy Synopsis reports from the Water and Energy Commission Secretariat (WECS), Government of Nepal; the Nepal Electricity Authority (NEA); Nepal Oil Corporation (NOC) and the International Energy Agency (IEA) (CBS 2004, 2011; WECS 2006, 2010; NPC 2010; IEA 2012; NEA 2012; NOC 2012). Disaggregated end-use energy data for different economic sectors were collected from various energy surveys conducted by the WECS at different periods and other governmental agencies (MOFSC 1987; WECS 1997, 2000, 2001, 2005). Data for conversion technologies and import costs were obtained from the Customs Department, Ministry of Finance, corporate plan of the NEA, and costs for grid and off-grid technologies from the World Bank publications (NEA 2005; ESMAP 2007; Department of Customs 2008). For data on demand technologies, primary survey was done in Kathmandu, Nepal in April–September 2007 and other unavailable data from the survey were obtained from the publications (US Congress 1992; ESMAP 1993; Department of Customs 2008; IEA–ETSAP 2010; RITES/SILT 2010). Furthermore, other energy-related data in the similar developing countries were also collected from the publications in the international journals and reports (Bose and Srinivaschary 1997; Ale 2001; Dhakal 2003; Pokharel 2004; Singh and Michaelowa 2004; CES/IGIDR 2005; IPCC 2006).

Methodology

Energy scenarios provide a framework for exploring future energy perspectives and strategies, including various combinations of technology options and their implications. Besides, a scenario

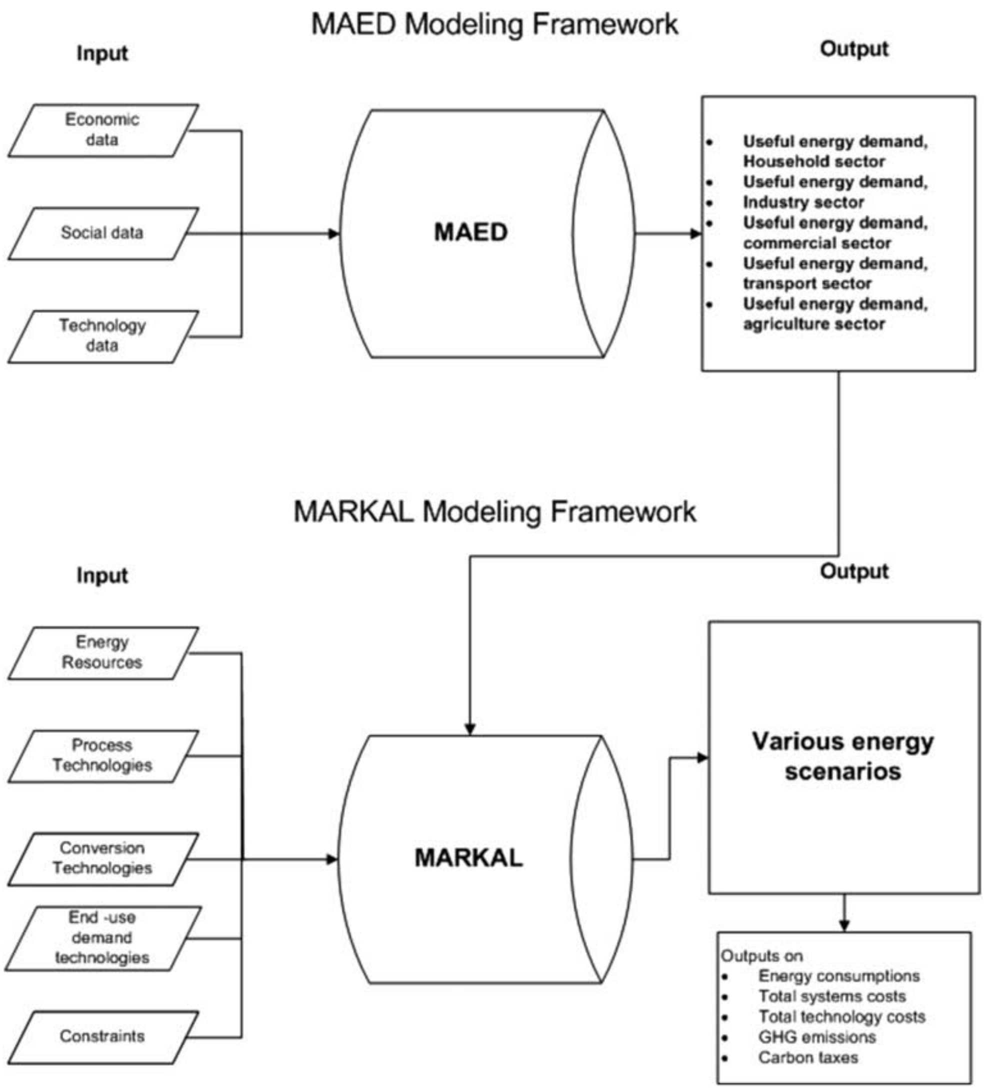

Figure 2. Diagram of the integrated MAED–MARKAL model for energy systems analysis.

analysis can provide insights into future energy trends that may be beyond the scope of existing forecasting techniques (Ghanadan and Koomey 2005). An integrated approach with MAED for energy demand and MARKAL for the supply system is used in this study and it is the first attempt to analyse energy scenarios for assessing various policy pathways combining these modelling frameworks (Figure 2).

MAED was developed at the International Atomic Energy Agency (IAEA) and is EXCEL[1] based (IAEA 2006) and MARKAL was developed in a cooperative multinational project over a period of more than two decades by the Energy Technology Systems Analysis Program (ETSAP) of the International Energy Agency (Loulou, Goldstein, and Noble 2004). The sectoral disaggregation in the model for all the sectors is shown in Figure 3.

At first, useful energy demand for all the sectors and the subsectors disaggregated for end-use services were obtained from the MAED modelling framework where the input parameters

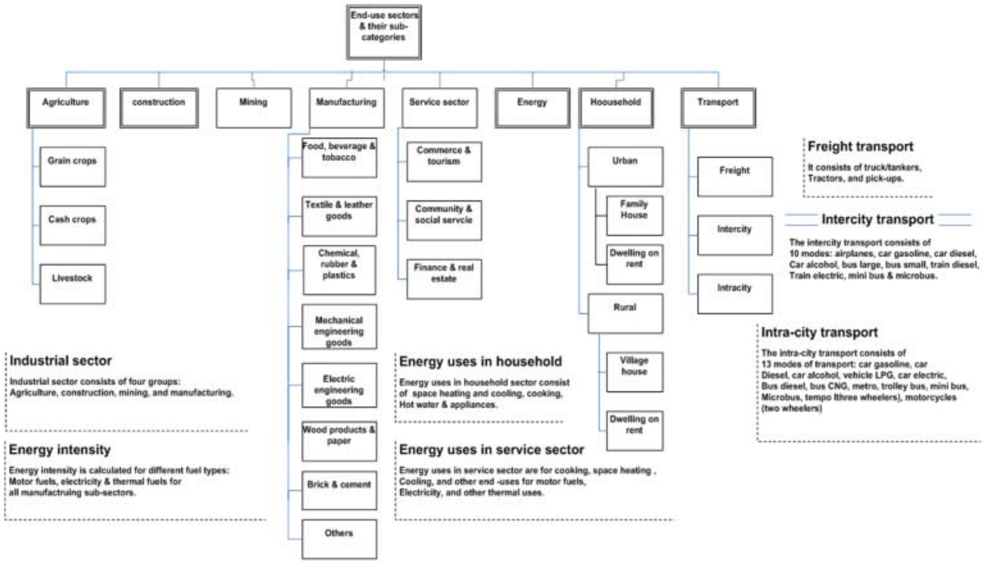

Figure 3. Sectoral demand disaggregation in the MAED Model for Nepal.

were national income disaggregated to sectoral gross value added (GVA), energy intensities and technology penetration rates in various end-use processes.

Sample relationships for the calculations of the useful energy demand for cooking in rural households and thermal energy in the manufacturing sectors are given by the following equation (IAEA 2006):

$$\text{CKRH} = \text{TRDW} * \text{CKRDW} * \frac{\text{CF}}{1000}, \tag{1}$$

where, CKRH – useful energy demand for cooking in rural households (TJ), TRDW – total number of dwellings in rural areas (million) and CKRDW – dwelling factor for cooking in rural areas (kWh/dwelling/year).

The dwelling factors for cooking in urban and rural areas were calculated based on survey reports (WECS 1997; CBS 2004, 2011).

CF – Conversion factor from TWh to TJ.

Similarly, useful energy for other end-use services is calculated accordingly.

For instance, useful thermal energy in manufacturing is calculated on the basis of

$$\text{USMAN}(i,j) = \text{EI} \cdot \text{TU} \cdot \text{MA}(i) * \text{YMA}(i) * \frac{\text{PUSIND}(i,j)}{100} * \frac{\text{CF}}{1000}, \tag{2}$$

where, USMAN(i,j) – useful thermal energy in manufacturing in i subsector for jth end-use services in TJ, EI·TU MA(i) – specific useful energy for thermal uses in manufacturing i subsector, kWh/Rs, YMA(i) – gross value added (GDP) of ith manufacturing subsector (million Rs), PUSIND(i,j) – % share of the thermal energy for the jth end-use service of the ith manufacturing subsector and

CF – conversion factor from TWh to TJ.

Equations (1) and (2) are samples and similar equations were used for other sectors also. Their details of calculations are given in the user manual of MAED (IAEA 2006).

Input variables for the calculation of useful energy for sample end-use processes and energy carriers in different sectors used are given in Table 2.

Table 2. Input variables in the energy used in end-use processes in various economic sectors.

Economic sectors	Energy use by end-use process (sample)	Input variables
Household	Space heating	Number of households; % of dwelling required for space heating; household size; specific heat transfer rate by household type; degree-days for households; % share of technology used for space heating
Industry	Furnace/direct heat	Subsectoral value added; energy intensity; % share of energy carrier
Transport	Intracity passenger transport	Intracity passenger transport volume; % share of the mode of transport in intracity transport; number of passenger in unit mode of transport; specific fuel consumption of unit mode of transport
Commerce	Thermal uses	Subsectoral value added; energy intensity; % share of energy carrier
Agriculture	Motor fuels	Subsectoral Value added; energy intensity; % share of energy carrier

MARKAL is a generic model tailored by the input data to represent the evolution over a long period of time for a specific energy system at the national, regional, state or province, or community level. Useful energy demands for all sectors after calibrations from the base year 2010 were fed exogenously into the MARKAL systems modelling which consists of different energy resources, imports, process and supply technologies and their costs, and at the end constraints prevalent in the energy systems. MARKAL is a partial equilibrium model and the objective in this model is to minimise the total cost of the system discounted over the planning horizon from 2010 to 2030 under various user-defined constraints, such as resource bounds, price bounds and other bounds. Each year the total cost includes the following elements (Loulou, Goldstein, and Noble 2004):

(1) annualised investments in technologies;
(2) fixed and variable annual operations and maintenance costs of technologies;
(3) cost of fuel imports;
(4) revenue from exports from energy; and
(5) taxes and subsidies with energy sources, technologies and emissions.

The generalised equation is given by

$$\mathrm{NPV} = \sum_{t=1}^{t=NPER} (1+d)^{NYRS\cdot(1-t)} \cdot \mathrm{ANNCOST}(1,t)\cdot \{1+(1+d)^{-1}+(1+d)^{-2}+\ \ldots\ldots + (1+d)^{1-NYRS}\}, \tag{3}$$

where, NPV – the net present value of the stream of annual costs incurred in each year of the time horizon and ANNCOST(*1*,*t*) – total annual cost for period *t*.

The total annual cost is the sum of the all technologies, all demand segments and all input fuels, namely annualised investments, annual operating costs, including fixed and variable technology costs, fuel imports costs minus revenue from exports of energy carriers.

d – discount rate, *NPER* – number of periods in the planning horizon, *NYRS* – the number of years in period *t*.

Scenarios were developed in MARKAL modelling framework at dynamic energy balances at different periods at the least costs of energy systems discounted at the discount rate of 10%.

Scenario descriptions and assumptions

Four scenarios for analysis were developed with this integrated modelling framework – (i) REF0: reference case with the constant annual growth rate (CAGR) of GDP at 5.5% and the population growth rate of 1.4% (NPC 2010; CBS 2012) as business as usual case during the study horizon, (ii) REFPLUS: reference case with income and demographic growth rates as in (i) but with increased demand in the modern energy in the current household energy consumption, (iii) REFPLUSHH: reference case with increased demand in the household sector but with energy efficiency and demand-side management measures in lighting and cooking and (iv) REFPLUSALL: case with energy efficiency and demand-side management measures in other economic sectors like commercial, industry, agriculture and transport and supply from solar photovoltaic energy apart from the hydropower resources, in addition to REFPLUSHH. The scenarios and their assumptions are presented in Table 3.

Results/Discussions

Among the four scenarios developed for analysis, scenario REF0 shows an energy pathway at business as usual without any policy intervention and the technology mix in 2010 is expected to be same in the whole study period. Scenario REFPLUS describes an alternative pathway for enhanced demand for modern energy in the household sector and no policy intervention and no change in the technology mix are envisaged in the study horizon. In the enhanced demand scenario, per capita household consumption of modern energy reaches 70 kWh in rural and 860 kWh in urban areas, respectively, in 2030. For the urban area, the consumption meets the threshold of energy access to modern energy, but in rural areas it is lower than the threshold consumption. Scenario REFPLUSHH indicates a policy scenario with change in technology options in order to have 100% electrification with efficient light bulbs such as LED, CFL fluorescent lamps in the households and cooking totally on clean energy with improved cook stoves (ICS) for solid biomass, use of electricity and petroleum products like liquefied petroleum gas (LPG).

In scenario REFPLUSHH, 75% of rural household will be cooking with solid biomass but they will be using improved cook stoves. In the urban areas, cooking will be done 90% on electricity and 10% on LPG by 2030. In this scenario with the focus on policy intervention in the household sector, per capita consumption of modern energy attains 261 kWh in rural household in 2030, which is slightly higher than the IEA's minimum level of access to modern energy (250 kWh/capita). But for the urban households, per capita consumption of modern energy reaches 772 kWh in 2030, which is near the IEA's required level of 800 kWh for developing countries (IEA 2011). It further indicates the share of modern renewable energy in the total final energy at 17% in 2030, which is higher than the share of renewable energy in the total final energy consumptions in scenarios REFO and REFPLUS, respectively. Furthermore, this scenario also reveals that the energy intensity of the economy (GJ/US$1000 GDP) decreases almost 3 times from 2010 to 2030 (Tables 4 and 5). Hence, this scenario shows definitely an energy pathway for Nepal to achieve the objectives of Sustainable Energy for All (SE4ALL) programme of the United Nations (UNDP 2010).

Scenario REFPLUSALL focuses on policy options in energy efficiency and electrification in the commercial, industry, agriculture and the transport sectors in addition to the options taken in the scenario REFPLUSHH. In the commerce sector, cooking on mostly electricity and some portion on LPG, and efficient lighting is expected by 2030. Similarly, substantial electrification and energy efficiency envisaged in the industrial processes and in the agriculture sector by 2030. For the transport sector, mass transport is preferred compared to inefficient private motorcycles

Table 3. Scenario descriptions and assumptions.

Scenarios	Macroeconomic and demographic variables	Technology mix options	Remarks
REFO: Reference case	GDP growth at 5.5% and population growth at 1.4%	Rural cooking Mostly on solid biomass energy–fuelwood, agri-residue and animal waste Rural lighting on kerosene and predominantly on incandescent lamps (for grid and off-grid electricity) Urban cooking on fuelwood, and LPG and Urban lighting on electricity with incandescent, fluorescent and compact fluorescent lamp (CFL) (for grid electricity).	The existing technology mix for the end-use demand services will continue from 2010 to 2030
REFPLUS: Reference case with increased demand in household sector	Same as above	The technology mix is same as in REF0	Same as above
REFPLUSHH: Reference case with increased demand in household sector but with efficiency measures and DSM in lighting and cooking	Same as above	Rural cooking on 100% ICS on biomass energy and biogas Rural lighting on CFL and light emitting diode (LED) lamps (100% electricity access) Urban cooking on electricity and LPG Urban lighting on CFL and LED lamps (100% electricity access)	The technology mix will be proportionately improved to have 100% access to modern energy by 2030 for both the rural and urban populations
REFPLUSALL: REFPLUSHH and energy efficiency and demand-side management measures in all economic sectors	Same as above	Same like in REFPLUSHH but with energy efficiency measures and high electrification in commerce, industry, agriculture and transport sectors, and with establishment of grid connected solar PV plants in the supply	The technology mix will be proportionately improved to have 100% access to modern energy by 2030 for both the rural and urban populations, and solar PV plant capacity to reach to 2000 MW by 2030

Table 4. Comparison of different scenarios.

Scenario	Final energy consumption in 2010, PJ	Final energy consumption in 2030, PJ	Total discounted capital investments, Billion NR	Total discounted systems costs, Billion NR	Total GHG emission in 2030, Mt	Total discounted net fuel imports costs during the time horizon, Billion NR	Discounted net fuel imports cost in 2030, billion NR	Average total capital costs as % of GDP
REF0	408	622	308	4850	11	1451	45	2
REFPLUS	408	733	362	5304	11	1491	47	2
REFPLUSHH	408	434	584	15,176	10	1400	43	4
REFPLUSALL	408	403	410	14,773	7	1207	30	3

Note: US$1.00 = NR 71 in 2005. The costs are in 2005 constant prices.

Table 5. Comparison of energy indicators in different scenarios.

Scenario	% of renewable energy in total final energy in 2010	% of renewable energy in total final energy in 2030	Energy intensity in 2010, |GJ/US$1000 GDP	Energy intensity in 2030, |GJ/US$1000 GDP	Final electricity consumption in 2010, kWh/US$1000 GDP	Final electricity consumption in 2030, kWh/US$1000 GDP
REF0	3	7	49	25	330	437
REFPLUS	3	7	49	30	330	527
REFPLUSHH	3	17	49	18	330	785
REFPLUSALL	3	22	49	16	330	917

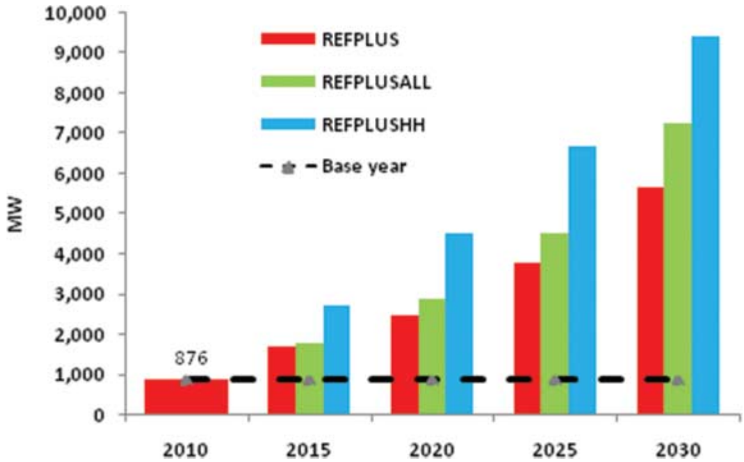

Figure 4. Comparisons of installed power plants in different scenarios.

and cars; electric railways are envisaged starting from 2020 in the southern plains of Nepal for passenger as well as goods transport. This scenario, in addition, also observes the possibility of solar Photovoltaic grid-connected plants of 100, 500 and 2000 MW by 2020, 2025 and 2030, respectively, as Nepal has good solar radiation. With the focus on electrification and energy efficiency in all the economic sectors, the share of modern renewable energy in the total final energy attains 22% by 2030 (Tables 4 and 5).

Figure 4 shows the comparison on power requirements at different scenarios. In 2030, the installed capacity required will be 7200 MW in the scenario REFPLUSALL, whereas it would be 5600 MW in REFPLUS and 9400 MW in the scenario REFPLUSHH. Due to energy efficiency and demand-side management taken in the scenario REFPLUSALL, the power requirement is almost 23% less than the REFPLUSHH scenario, and higher by 68% from scenario REFPLUS as a consequence of high electrification in households and other economic sectors.

Table 4 highlights the overall changes in the energy consumptions, total discounted capital investments, fuel imports costs and the capital investments as share of the GDP in 2030 at different energy development scenarios. Similarly, Table 5 reveals changes of the share of renewable energy, energy and electricity intensities in scenarios from 2010 and 2030.

Figure 5 reflects the marginal carbon abatement cost (MAC) of the scenario REFPLUSALL vis-à-vis scenario REFPLUS. MAC at different periods were calculated as the increase in undiscounted total technology costs in the policy scenario (REFPLUSALL) from those of the scenario at business as usual (REFPLUS) and divided by the GHG reduction in t CO_2 eq. MAC reaches US$120/t CO_2 eq in 2020 as a consequence of major capital investments in demand and supply technologies, such as electric railway trains, energy efficiency and demand-side management in all the sectors, and expansion in hydropower and solar PV plants. It decreases subsequently to US$38/t CO_2 eq by 2030 and the MAC accounts for US$60/t CO2 eq over the study horizon, which is very close to studies conducted in other developing countries (Chen et al. 2007; Shrestha and Pradhan 2010).

The following insights emerge from the analysis:

1. Final energy in 2030 at the REFPLUSALL is almost the same as that in the base year due to energy efficiency and focus on harnessing of indigenous renewable energy resources. The consumption of solid biomass especially fuelwood become sustainable from 2020 onwards in REFPLUSHH and REFPLUSALL due to penetration of improved cook stoves in rural areas and electrification of cooking in urban areas.

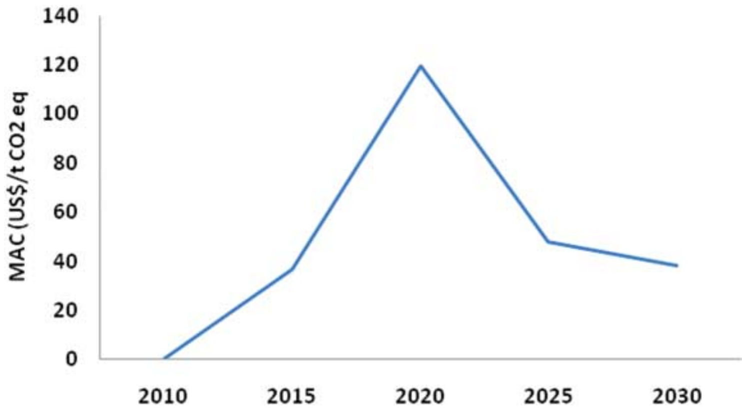

Figure 5. MAC in different periods in the policy case.

2. Clean cooking and electricity access to households can be realised by 2030, achieving the main objectives of SE4ALL. The access to modern energy in rural households crosses the minimum threshold level of 250 kWh/capita but in urban areas it reaches near the required level of 800 kWh/capita by 2030 (IEA 2011).
3. GHG emission in CO_2 equivalent in the REFPLUSALL is reduced by 35% from the reference case REFPLUS and the average MAC during the planning horizon remains at US$60/t CO_2 equivalent, which is commensurate with the carbon abatement costs in other developing countries.
4. Though the total energy systems costs are three times higher in REFPLUSALL than in REFPLUS, the total incremental technology costs are substantially less than savings from decline in imports of fuels which are six times lower than the total discounted fuel cost savings in the whole planning horizon. Furthermore, the average total capital cost for end-use demand and supply technologies required for the REFPLUSALL is within 3% of the GDP. The capital investment only for supply technologies accounts for 1.8% of GDP, which is within the normal range for developing countries (IIASA 2012).
5. The share of modern renewable energy in the scenario REFPLUSALL is increased to 22% in 2030 from 3% in the base year. The energy intensity in REFPLUSALL in 2030 is reduced by three times from its values in the base year and is half the value of REFPLUS. But, on the other hand, electricity intensity in REFPLUSALL increases threefolds from the base year and is almost double the value of REFPLUS. REFPLUSALL scenario indicates a pathway that can provide energy security with a reduced dependence on imported fossil fuels and can also enable Nepal to move to a sustainable future.

Conclusion/Summary

Though several studies had been conducted with LEAP and MARKAL modelling frameworks for Nepal, this paper is the first attempt to integrate the MAED energy demand model with the MARKAL supply model for assessing and analysing energy systems and their implications in Nepal. This modelling framework can be useful for researchers and policy-makers especially in developing countries.

Sound policy and change in technology options can make Nepal achieve the goal of universal access to modern energy by 2030. But it demands three times increases in the total systems costs in comparison with the reference case. With efficient deployment of improved cook stoves in rural households, the consumption of fuelwood becomes sustainable in later periods of study horizon. The increased supply costs, especially from the proper harnessing and utilisation of indigenously available renewable resources, can be balanced by reduction in imported fossil fuels by 20%, and curtailing GHG emission by more than 35% by 2030. Furthermore, there are co-benefits that can be obtained from carbon trading due to reduction in the GHG emission. One vital aspect of importance is that modern renewable energy will attain a share of 22% in the final energy consumption of the country in 2030. This analysis further highlights that Nepal, if it focuses on policy options for harnessing of indigenous renewable energy resources, energy efficiency and demand-side management measures in all the economic sectors, can be on a pathway for sustainable energy development and energy security on a long run.

There are limitation and uncertainty of the modelling framework as energy consumption, commodity prices and the technology development and its future prices are difficult to be predicted ex-ante. Despite this limitation and uncertainty, the integrated modelling framework provides a tool for analysing several pathways for energy development in future.

Notes

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