IDENTIFYING THE MOST SUITABLE SUSTAINABLE ENERGY SYSTEM FOR NEPAL USING ANALYTIC HIERARCHY PROCESS

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ABSTRACT

The issue of climate change and energy crisis can be resolved by the advancement of sustainable energy systems. The process of energy development in developing countries with a poor economy is complicated. One has to consider numerous factors and sub-factors which are important for the system to be acceptable to the multiple stakeholders. Involvement of multiple entities makes the process a real case of Multi Criteria Decision Making (MCDM). This study deals with identification of various stakeholders, factors, sub-factors and alternatives associated with sustainable energy selection in Nepal. The Analytic Hierarchy Process (AHP) has been used as a tool to deal with the MCDM problem in this research. Prioritization of alternatives has been obtained with the application of AHP. Further, the analysis has also been done based on the perception of multiple stakeholder groups. The result shows that politicians are the most important (61%) among the stakeholders for the development of sustainable energy in Nepal. Among the alternatives, the majority of the respondents believe that biogas should be given the highest priority.

Keywords: AHP; MCDM; sustainable; energy systems

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1. Introduction

The increasing demand of energy and the depletion fossil fuel resources have put pressure on researchers to search for alternative energy sources. The current supply of energy is not enough to meet the current demand. The major source of the current supply of energy is from fossil fuel. The use of fossil fuel as a major source of energy comes with two important issues: sustainability and climate change. The first issue is concerned with the long term use of fossil fuels as it is depleting and is non-renewable. For the last few decades, researchers have speculated that if the current trend of fossil fuel use continues it may not last for very long since the deposits of fossil fuels are depleting and will be gone in no time. The other issue is concerned with the changes in environment which results from the increasing trend of emissions that are harmful to the environment. People associated with the development of alternative energy systems are trying to address both of these issues (Sapkota & Kim, 2009).

Energy consumption patterns are always changing both in terms of amount and types of resources used. This pattern depends on several factors which include technological innovation which has the major impact backed up by the resource availability (O'Connor, 2010). Further, the process is gradual requiring efforts and contributions from several sectors. Developed countries are able to meet the increasing demand with increasing energy production. Whereas, developing countries are lagging behind in their ability to meet the increasing demand with adequate supply. There are several reasons associated with this inability to keep up. The main reasons include lack of development policy, an insufficient economy, lack of resources and political instability.

Countries like Nepal with zero petroleum resources are always in search of alternative sources which could reduce their dependency on fossil fuel. In Nepal, the residential sector is the major user of energy, where energy is used for lighting and cooking. The major use of energy is from fossil fuel which is considered responsible for greenhouse gas emissions (GHG), and comes in the form of vehicle fuel, cooking gas and small industries. Out of the total GHG, more than two-thirds of the emissions come from the residential sector (MoSTE, 2014).

Although developing countries seem to be less concerned with climate change, they cannot stay away from adopting necessary measures to mitigate it from their side. Even though they are not major contributors to the climate change, they are among the sufferers of the calamity induced by climate change. Efforts for climate change mitigation from the developing world could be possible with a paradigm shift with regards to energy use, mainly transition from fossil fuel to clean energy (IPCC, 2011; Edenhofer et al., 2012).

Energy development in Nepal has always been slow, and the current energy generation covers only one-third of the total demand. A major portion of the country does not have an access to electricity (NEA, 2014). Although multiple renewable energy resources are available, due to a low economy all types of energy systems cannot be developed together. Further, it also becomes very important to consider several criteria and sub criteria before making any decisions. Furthermore, the failure of past energy projects shows evidence of the impact of stakeholders in the development of energy systems. The government seems to be perplexed in choosing the best among the alternatives, as all alternatives seem to be important and feasible. It becomes very important to prioritize

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these alternatives based on people's need, resource availability, technical capability and environment friendliness. Furthermore, it is also crucial to identify all the influencing actors that have major impacts on the development of energy systems in Nepal.

It is a real case of Multi Criteria Decision Making (MCDM) and the Analytic Hierarchy Process (AHP) has already been proven as an appropriate tool in such situations (Saaty, 2008). This research adopts AHP and identifies and prioritizes major factors, sub-factors, alternatives and actors in sustainable energy development in Nepal.

2. Rationale and objective of the research

For the last decade, Nepal has been facing a huge energy crisis. There is an electric power cut of up to eighteen hours per day in the dry seasons. Further, the supply of petroleum products including cooking gas (LPG) has worsened in recent times. Practically, the country has zero petroleum resources. Although Nepal is considered very rich in natural resources, there is not much interest in exploring those resources. Up to now, the major focus has been on hydropower, and some interest has been given to biogas and solar power. There are several unidentified resources other than hydropower, and several unexplored alternatives. Similarly, the geographical and socio-economic conditions of the country have been ignored. Identifying the best sustainable source of energy in the Nepalese context is the present need of the nation. Nepal should focus on developing alternatives to fossil fuel from among the resources available in the country.

Nepal, being a developing country with a low economy, cannot develop all the energy systems at the same time. It is very important to prioritize based on the importance these energy sources have in people's lives and their potential to mitigate climate change. This becomes a complex process, as multiple considerations have to be taken into account. One has to consider various criteria (factors), sub-criteria (sub-factors) and potential alternatives before coming to a conclusion of any kind. Further, it becomes very crucial to analyze the influence of actors (stakeholders) during the process, and this adds to the complexity in the process.

This research has been designed to assist policy makers in developing policies for sustainable renewable energy systems development in Nepal. This research provides a framework for renewable energy selection and development. This framework addresses major criteria, sub-criteria and feasible alternatives that need to be considered during the energy selection process, and also highlights the perception of various stakeholders towards energy requirements and environmental consequences. Further, it also identifies the major stakeholders that become active during the process. The research further prioritizes possible alternatives, factors, sub-factors and stakeholders who are most responsible for the development of energy sectors. It follows the AHP approach, as this is clearly a multiple criteria decision-making scenario. The major objective of this research is to develop a decision model for sustainable energy selection in Nepal.

3. Literature review

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The increasing demand for energy is being fulfilled by heavy exploitation of fossil fuel deposition. This has created two major concerns: sustainability and climate change. No analysis suggests that there are enough deposits of fossil fuels to even fulfill the current demand. The shortage of energy will have a major impact on developing countries as their economy and development largely depend on the supply of energy. Climate change is believed to be caused by an increased level of greenhouse gases (GHG) and the use of fossil fuel produces, CO_2, one of the main GHG agents. Development of renewable and sustainable energy sources can address both the issue of sustainability and climate change. At present, the research on renewable and alternative energy sources is at a peak. The proposed source should be sustainable, affordable and adoptable and also produce environmentally benign byproducts (Sapkota & Kim, 2009; Sapkota & Kim, 2010).

3.1 Factors (criteria) associated with energy selection

There has been a series of innovations in the process of energy development and use in the last few centuries. This transition of the energy system has been a gradual process with the involvement of numerous factors. It is very important to identify all the factors which could play a significant role in the development of any energy systems. An IPCC report on renewable energy sources and climate change mitigation emphasized scientific, technological, environmental, economic and social aspects of the contribution of renewable energy sources to the mitigation of climate (IPCC, 2011).

Selection criteria for the renewable energy systems are found to differ from one research to the other. Similarly, factors, sub-factors, actors and the energy system choices are also different according to the geographical location in which the research has been done. A study carried out in Pakistan by Amer & Diam (2011) used multiple factors: technical, economic, social, environmental and political and wind energy, solar photovoltaic, solar thermal and biomass energy options as the alternatives in the decision model. Further, Wang et al. (2009) summarized the criteria of energy supply systems from technical, economic, environmental and social aspects. Similarly, Abbasi et al. (2010) discussed the environmental impacts on biomass energy and Akella et al. (2008) discussed renewable energy system’s impact on social, economic and environmental, and other factors.

3.2 Renewable energy alternatives

Renewable energy technologies (RETs) as well as biofuels have been accelerating rapidly during the past decades, both in technology performance and cost competitiveness (Arent et al., 2011). Globally, biofuel contributes about 12% of the primary energy supply (IPCC, 2001).

Biogas systems can support sustainable communities by reducing methane emissions, improving water quality, producing a local source of renewable heat, electricity and fuel, and strengthening the local economy by reducing energy costs and generating revenue. Countries like Nepal, where biogas production and utilization has been practiced for the last few decades can accelerate the process of biogas production from domestic waste, manure and agriculture waste to reduce the greenhouse gas that causes climate change and produce cheap sustainable energy for the local people. Biogas systems have the potential to capture methane that would escape into the atmosphere and utilize it to create energy. Other byproducts of biogas systems include non-energy products such as nutrient rich soil amendments, pelletized and pumpable fertilizers, and even feedstock for plastics and chemicals (USDA, 2014). Gas-to-liquid (GTL) technology enables conversion of

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biogas into other energy carriers with higher energy density, facilitating fuel distribution (Moghaddama et al., 2015).

Research works carried out in Nepal found several renewable energy technologies in practice consisting of biogas, improved water mill (IWM), stand-alone micro-hydro plants, mini-grid micro-hydro plants, solar PV home systems, mud-Improved Cooking Stoves and metal-Improved Cooking Stoves (AEPC, 2013; Sapkota ,2014).

Another renewable energy source that researchers are considering these days for the replacement of gasoline is biodiesel. For a country like Nepal with zero petroleum resources, development of biodiesel as a substitute to gasoline not only solves the energy crisis but also reduces the greenhouse gas emissions. Converting biomass feedstock to biodiesel or bio-ethanol is an environmentally-friendly process; so is using biofuel for transportation. Because of their compatibility with the natural carbon cycle, biodiesel offers the most beneficial alternative for reducing greenhouse gases from the transportation sector (NREL, 1999).

Various renewable energies such as solar, hydropower, biogas, wind and geothermal energies are already in practice, and some are in the phase of commercialization (Sapkota & Kim, 2009; Sapkota & Kim, 2010). A special report on renewable energy sources and climate change mitigation presented six renewable energy sources to the mitigation of climate change: bioenergy, direct solar energy, geothermal energy, hydropower, ocean energy and wind energy (Edenhofer et al, 2012). Yadoo & Cruickshank (2012) found that renewable energy mini-grids powered by biomass gasifiers or micro-hydro plants appear to be the favored option due to their lower levelized costs. Yuksel (2008) highlighted the development of renewable energy sources like hydropower, biomass, wind and geothermal to mitigate climate change and for the sustainable development of Turkey. Similarly, Cristóbal (2011) used wind power, hydroelectric, solar thermal, solar thermo-electric, photovoltaic, biomass, biogas and biofuels as alternatives in Spain. Bhattarai & Fujiwara (1995) worked on evaluation of appropriate scale of hydropower development for Nepal using AHP with the inclusion of actors (hurdles) that may exist during the process.

3.3 Barriers to renewable energy development

For the development of renewable and sustainable energy technologies, several constraints have to be faced especially in developing countries like Nepal. Luthra et al. (2015) have reported barriers in Indian contexts and categorized these into seven dimensions which include economical & financial; market; awareness & information; technical; ecological and geographical; cultural & behavioral; and political & government issues.

Several reviews have been done on potential technological, economic, social or public barriers to renewable energy investment (Richards et al., 2012). Similarly, Wang et al. (2010) highlighted three barriers of using Clean Development Mechanism (CDM) to promote renewable energy in China as the dilemma of additionality, lower proportional CERs (Certified emission reduction credits) revenues on the investment and lack of incentives for renewable technology transfer.

Wee et al. (2012), found conversion cost, location selection, distribution network and other factors like capital investment, operation and maintenance costs, and capacity factor costs to be the barriers. Whereas, Mirza et al.(2009) broadly classified barriers to renewable energy development as policy and regulatory barriers, institutional barriers, fiscal and financial barriers, market-related barriers, technological barriers and information and social barriers.

3.4 Multi-criteria decision making in renewable energy selection

Even though Nepal is rich in natural resources, it is facing an energy crisis. The current energy scenario of Nepal shows that it should immediately produce more energy to meet the growing energy demands of the country. Choosing the best energy system for a country like Nepal has always been problematic. In order to make a successful choice, selection should consider several perspectives including barriers (hurdles). There is always a need of multi-dimensional analysis. Existence of multiple stakeholders and numerous parameters and too many alternatives creates a multi criteria decision-making (MCDM) problem, and should be commonly formulated by stakeholders in a complex decision-making process.

The multi-criteria decision method (MCDM) has become increasingly popular in decision-making for sustainable energy because of the multi-dimensionality of the sustainability goal and the complexity of socio-economic and biophysical systems (Theodorou et al. 2010; Wang 2009). MCDM techniques are gaining popularity in sustainable energy management. The techniques provide solutions to the problems involving conflicting and multiple objectives. Several methods based on weighted averages, priority setting, outranking, fuzzy principles and their combinations are employed for energy planning decisions (Pohekar et al. 2004). It is observed that the most popular tool for MCDM that has been used globally by researchers is the Analytical Hierarchy Process (AHP) (Pohekar et al. 2004; Ahmad et al. 2014; Amer & Diam, 2011).

AHP uses a pair-wise comparison approach between the two conflicting scenarios, and there is a provision to verify the consistency. AHP is capable of breaking complex problems into smaller parts that can be easily handled by human intelligence (Saaty, 2008).

AHP has been used in selection, evaluation and performance comparison between the different power production options (Kabir et al.2003; Polatidis et al. 2006; Mateo, 2012, Terrados et al., 2010; Daniel et al., 2010). Bhattarai & Fujiwara (1995) worked on an evaluation of the appropriate scale of hydropower development for Nepal using AHP, and Nachtnebel & Singh (2015) used AHP in prioritizing Nepalese hydropower development and identified inexperience, inadequate funding and political stability as development setbacks.   Apart from this there has not been much work done in Nepal regarding energy selection and planning.

All the past works mentioned above were primarily based on the energy selection focusing on technological advancement and availablility of resources. Actors (hurdles) that may exist during the process have not been considered except in the study done by Bhattarai & Fujiwara (1995). This work tries to evaluate all the possible energy sources based on those actors who could influence the energy selection process.

3.5 Probable energy systems for Nepal

Several sustainable energy options are available to meet the increasing Nepalese energy demand. Some of the systems are already in practice whereas others could be feasible in Nepal. Some of the energy options for Nepal are listed below.

Hydropower: Hydropower is the most developed energy system in Nepal. Although Nepal has tremendous potential of hydroelectricity, less than one percent of the total capacity has been generated until now (Nachtnebel & Singh, 2015).

Solar: In recent times, the use of solar energy either in the form of a solar home system or water heating system has increased. Abundantly available sunlight can be tracked to generate this energy. Nepal has already proven to have good potential in energy generation from sun.

Wind: In Nepal, the popularity of wind energy is growing and the government has shown good interest in harnessing energy from the wind. Studies show that Nepal has a good prospect of electricity generation from wind.

Biogas: Energy production from cattle dung is already in practice in Nepal. This has already proven an effective energy source in rural populations. Biogas can be a good substitute to Liquid Petroleum Gas (LPG). Further, it can be generated from municipal organic waste.

Biodiesel: This can be a good alternative to fossil petroleum products. Nepal has not developed any such product yet, but slowly non edible oil sources like *Jatropa* which are easily available in Nepal have become a concern of research for energy specialists. This technology could be the most important energy system for countries like Nepal with zero petroleum resources.

Fuel cell: In developed countries, the research and development of fuel cells is at a peak. Because of its wide range of applicability, fuel cell could be the future energy source of the world. Fuel cell cars are already in practice in developed countries. Countries like Nepal with huge water potential can convert water to useful hydrogen energy for fuel cell.

Nuclear: This has already been the major source of energy generation in developed countries. If Nepal wishes to meet the ever increasing energy demand of the country, it should move towards nuclear energy at some point. Although nuclear energy has some consequences, this can be one of the best solutions to the acute power shortage of the country.

The current energy scenario of Nepal shows that Nepal should immediately develop more energy production to meet the growing energy demand of the country. Nepal should not just focus on the development of electricity but also address the production of liquid petroleum products for vehicles and means that can provide alternatives to the cooking gas (LPG).

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4. Methodology

4.1 Research design

This study has adopted four tools in addition to literature review which include a questionnaire, Delphi method, one on one interviews and model development using AHP. The steps followed during the research work are shown in the research framework in Figure 1.

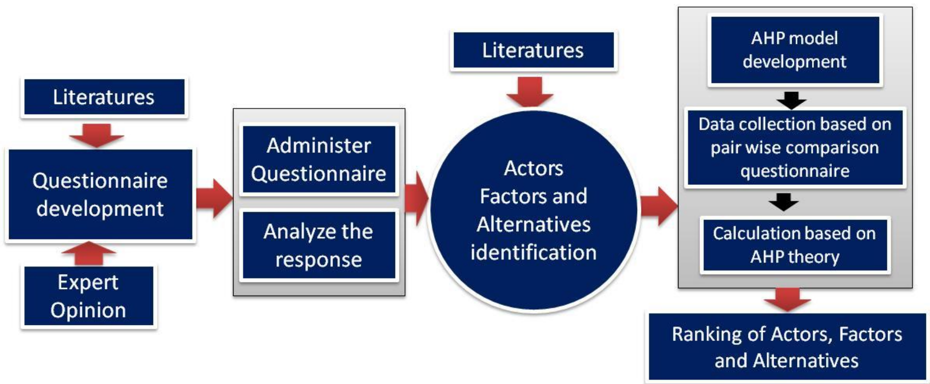

Figure 1. Research framework

A group of experts from four different areas has been formed. The group consists of energy experts (2); an energy project manager (1); with social science/political background (1); and an electrical engineer (1). All the group members have Master's degrees and two years of work experience in the field of their expertise. The initial questionnaire to identify actors, factors, sub-factor and alternatives has been developed based on the opinion of these experts and the literature. The developed questionnaire was administered among educated Nepalese people. Thirty-five valid responses were collected during this process. The responses were analyzed and further literature consulted. Based on the result of the preliminary survey and literature review, factors, sub-factors, alternatives and actors were identified and a hierarchy model based on AHP theory was developed. The hierarchy model developed is shown in Figure 2. The weight that has been given to the actors by the respondents has been further used during sensitivity analysis of the actors.

A pair-wise comparison questionnaire was developed based on the hierarchy model. This questionnaire was administered in the form of an interview among groups of all the identified actors.

4.2 Model development

A hierarchy model based on AHP theory was developed during the course of the research as shown in Figure 2. Here, the goal "sustainable energy system for Nepal" is at the top at level 1. The second level (level 2) has five actors; these are the people (or agencies) that have a direct or indirect relationship to the energy system development in Nepal. The selection of these actors was done based on the expert's opinion, literature review and the view of people whose responses were collected during the first stage of data collection. The actors identified for the achievement of the goal are donor agencies, politician/political parties, end users (general people), energy experts and business people

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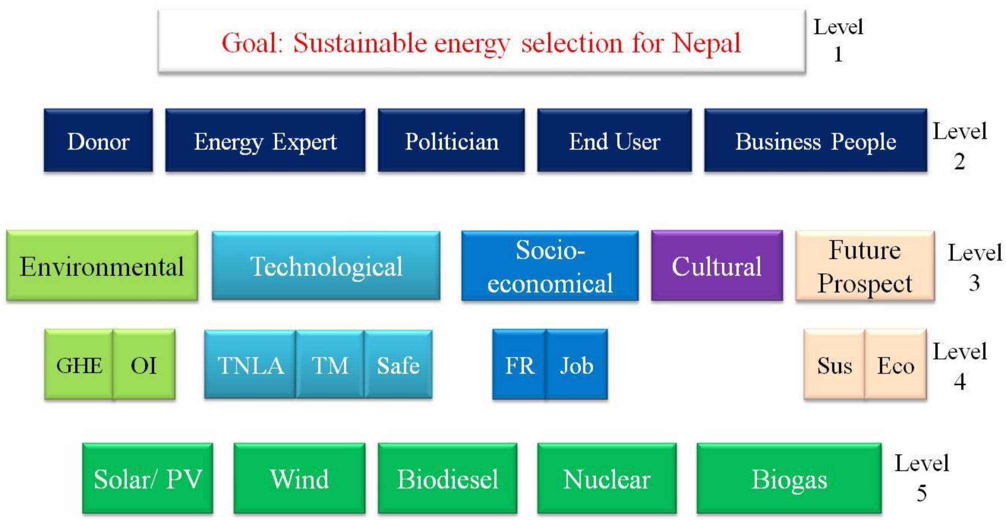
(people associated with the energy business). All of these actors are found to have influence in the past during the time of energy project development and implementation in Nepal.

The third level of the hierarchy has five factors that are important in classifying an energy system as a sustainable system. These are environmental factors, technological factors, socio-economic factors, cultural factors and future prospects. All the factors have sub-factors which are kept at level 4. Table 1 shows the list of factors and sub-factors that have been identified during the course of the research. The identification of these factors and sub-factors has also been done based on expert opinion, literature review and responses received from the respondents during the first stage of the questionnaire.



GHE: Greenhouse gas emission, OI: Other impacts, FR: Financial requirements, JB: Job opportunity, TM: Technology maturity, TNL: Technology known to local actors , Eco: Economy, Sus: Sustainability, FR: Financial requirements

Figure 2. Hierarchy model

Alternatives identification was done based on the expert opinions and literature review. The majority of the identified alternatives are in practice in Nepal. A few of the alternatives like solar and biogas are at a high level of development and use whereas, other sources like wind and biodiesel are in the developing stages. There has been never been any nuclear energy system in Nepal. Hydropower has not been included as one of the alternatives. There is still a dilemma regarding the consideration of larger hydropower operations as renewable and sustainable because of their impact on ecology, displacement of large number of human inhabitants, and in light of global warming, the potential of hydropower may be unpredictable due to change in rainfall patterns and melting of Himalayan glaciers. Micro hydro can be a potential alternative, but there is still a problem regarding grid integration and connection.

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Table1
Identified factors and sub-factors

Factors	Sub-factors	Explanation of factors/ sub-factors
Environmental	GHE	Greenhouse gases emission: carbon dioxide, methane etc emission.
	OI	Other impacts: noise, health hazards, negative ecological impact etc.
Technological	TNLA	Technology known to the local actors: how easy the system and technology is to operate at local level, whether the technology is well known by the locals.
	TM	Technology maturity: how mature is the technology, what about the scaling up, economies of scale etc?
	Safe	Safety in operation: How safe is the system to operate, What sorts of risks are possible?
Socio-economic	FR	Financial requirements: How much is the initial investment and operation & maintenance cost.
	Job	Job prospect: What about the employment opportunity with the development of the desired system? Can it provide job to local people?
Future prospect	Eco	Economic: What about the economic benefit to the people, How much will be their saving and other benefits?
	Sus	Sustainability: How sustainable is the system? How long can the system be operated economically? What about the resources needed?
Culture		Is the system compatible with local custom, culture, tradition and even policies?

4.3 Tools and technique

The analysis of this research was done based on the theory of the Analytical Hierarchy Process (AHP). All the calculations were done using Excel 2007. A geometric mean of the responses obtained from the pair-wise comparison questionnaire was calculated. This mean value was further used to calculate consistency ratio, priority vector, row average and finally the prioritization of actors, factors, sub-factors and alternatives.

An inconsistency ratio has been calculated for all the data obtained. The data with an inconsistency ratio less than 10% was used for further calculations.

4.4 Data collection

The total number of samples collected for the first stage of data collection was 35. The number of valid samples obtained during the second stage of data collection was 25, five from each group of actors.

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5. Calculations and results

The calculations were done for two different conditions separately. The first one was with inclusion of actors and the second one was without actors.

5.1 Inclusion of actors

The geometric mean of the group data was calculated, individually among the group of actors and collectively. The mean value obtained was arranged in a matrix form and further calculations were done. A sample of the matrix developed during the process is shown in the Table 2.

Table 2
Sample matrix developed

	Actor 1	Actor 2	Actor 3	Actor 4
Actor 1	1	1.491	0.677	0.318
Actor 2	0.670	1	0.454	0.213
Actor 3	1.478	2.202	1	0.47
Actor 4	3.143	4.685	2.127	1

The consistency of the developed model was checked and the overall inconsistency calculated is 4%.

A calculation to identity the most important actors involved in keeping the goal of sustainable energy system development for Nepal was done. A matrix developed for this work is shown in Table 2. Here, there are four actors so the size of the matrix is 4X4. Further calculations were done using the value of the matrix and the obtained result is shown in the Figure 3.

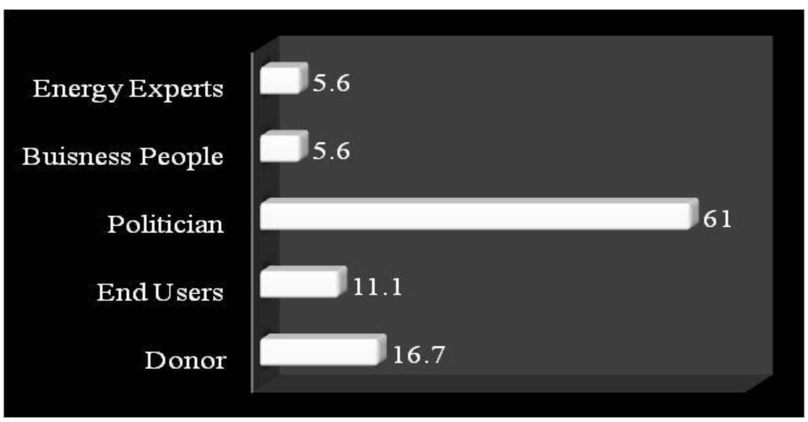


Figure 3. Result of prioritization of actors

The majority of the respondents believe that politicians (61%) are mainly responsible for the sustainable energy development in Nepal followed by donors (16.7%), end users (11.1%) and the other two actors, business people and energy experts are believed to be equally responsible at 5.6% each.

Similar calculations were done for level 3 factors, level 4 sub-factors and level 5 alternatives. In the case of alternatives, the matrix becomes 5X5. The result obtained for the prioritization of alternatives is shown in Figure 4.

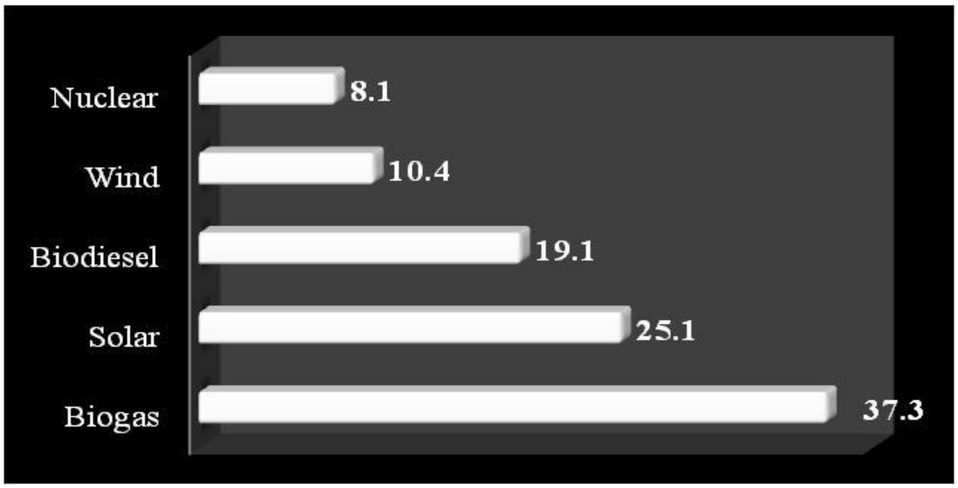


Figure 4. Result of prioritization of alternatives

The results show that the majority of the respondents believe that biogas should be developed as a sustainable energy system for Nepal (37.3%) followed by solar/ PV (25.1%), biodiesel (19.1%), wind (10.4) and finally nuclear (8.1%).

5.2 Results with exclusion of actors

A second case with exclusion of actors was developed and analyzed. Figure 5 shows a model without actors.

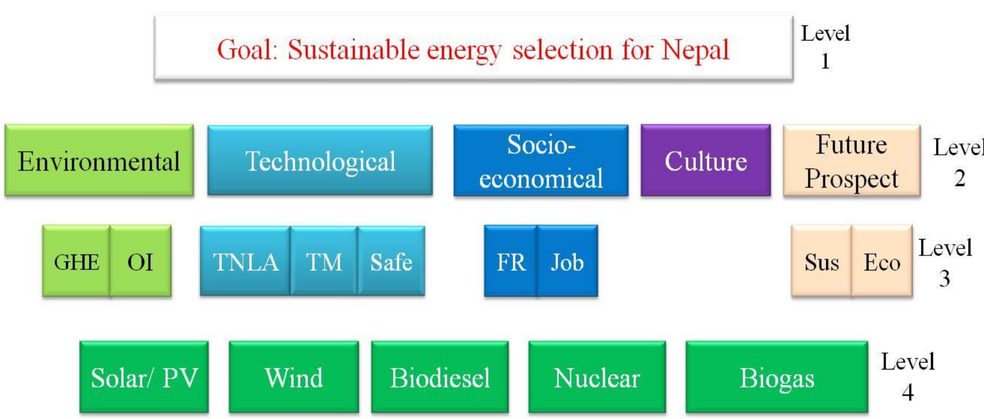
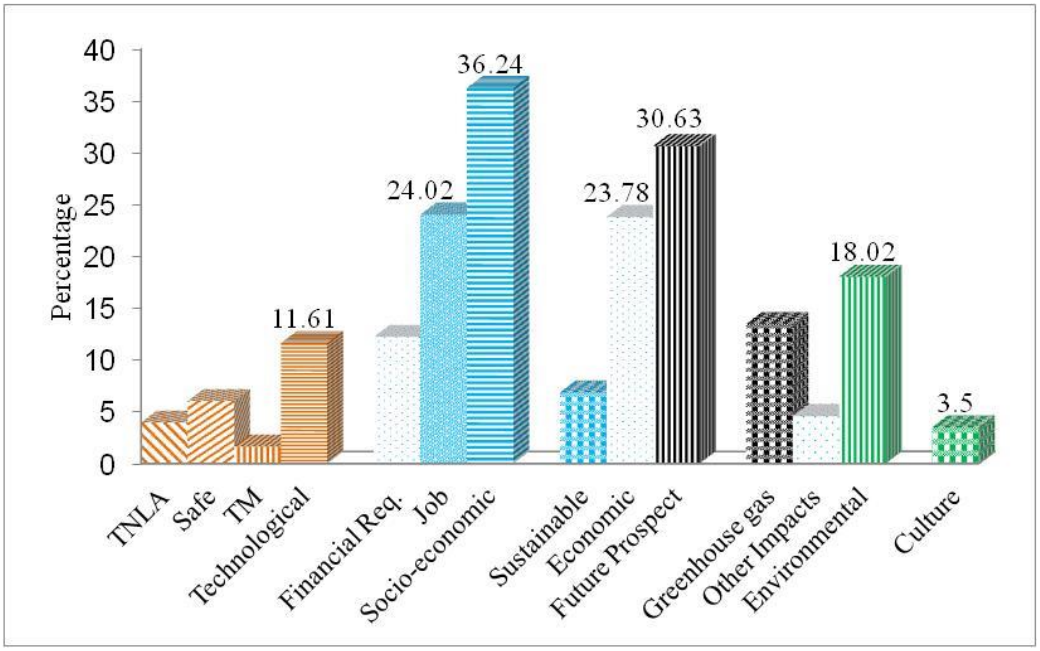


Figure 5. Hierarchy with exclusion of actors

The result with exclusion of actors shows that the most important factors to be considered while selecting sustainable energy for Nepal are socio-economic (36.24%) followed by future prospect (30.63%), environmental (18.02%), technological (11.61%) and culture (3.5%). Furthermore, respondents believe that job creation (24.02%) should be the prime focus followed by economic wellbeing (23.78). The detailed results of the case are shown in Figure 6.



TM: Technology maturity, TNL: Technology known to local, Financial Req: Financial requirement

Figure 6. Factors and sub-factors identification excluding actors

There was only a slight change among alternatives even after the exclusion of actors. The preference of biogas (30%) is still at the highest priority followed by solar (22.9%) and biodiesel (22.8%). The results for alternatives preferences are shown in Figure 7.

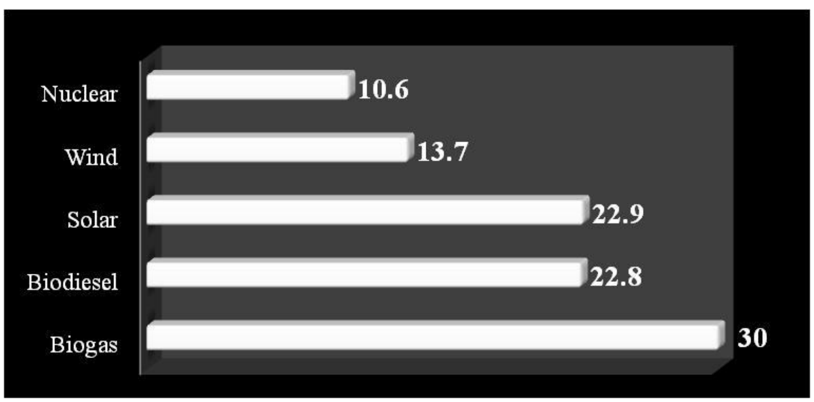


Figure 7. Alternatives preference with exclusion of actors

5.3 Discussion and sensitivity analysis

The results that were obtained were unexpected for most of the respondents. They were expecting solar/PV to be the first priority among all the alternatives instead of biogas. Further analysis showed that the results diverted towards the view of politicians as they have been given the highest priority among the actors (61%). In the view of politicians, biogas should be the sustainable energy option for Nepal. Because of this, the decision will be focused predominantly on the view of the politicians.

Further, analysis showed that politicians put socio-economic factors as the top priority, in this case 48.5 %. Among socio-economic factors, the highest priority was found to be given to job opportunity. Politicians believe that development of biogas can give an energy solution to the country in a sustainable manner. The analysis from the perspective of political people is shown in Figure 8.

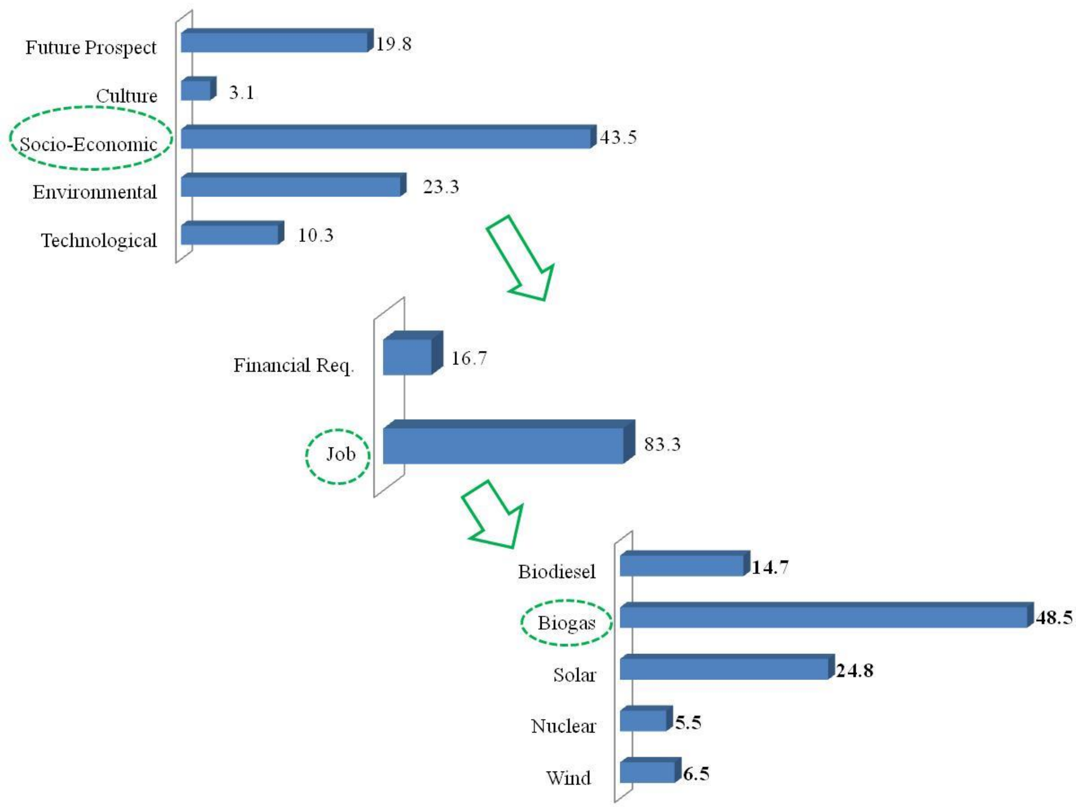


Figure 8. Factor, sub-factor and alternative preference from the actor: politician

The effects of other actors and factors were analyzed. Apart from energy experts, there was no significant change in the outcome when other actors were changed. When energy expert were given a major priority of 81%, biodiesel becomes the first choice followed by biogas. This scenario is shown in the Figure 9.

Figure 9. Preference of alternative from the view of actor: energy expert

Furthermore, when environmental factors were given the highest priority (80%), solar energy becomes the first priority followed by biogas and biodiesel. This situation is shown in Figure 10.

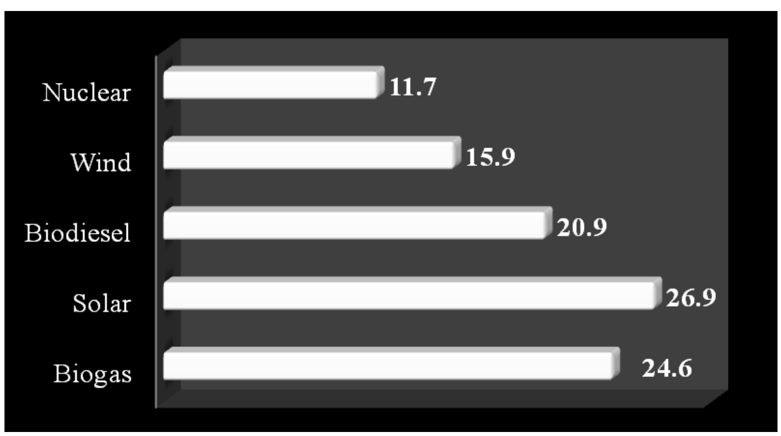


Figure 10. Analysis with 80% priority on environmental factor

The result represents the need of Nepalese people from all the sectors. The current need of the people is energy for cooking and lightning. Furthermore, people reckon that the socio-economic factor should be of highest priority among factors while selecting sustainable energy systems for Nepal. Among sub-factors, job creation was rated as the most important. People have not given much concern to environmental factors as environment consequences are of less concern in developing countries like Nepal.

6. Conclusions

The main objective of this research is to develop a framework for sustainable energy selection for Nepal that could be useful for policy makers and researchers in designing and implementing sustainable energy systems. Energy policy development is a difficult process, as multiple considerations have to be made. The process becomes more complex when there are constraints in resources and multiple alternatives exist. Furthermore, in the case of developing countries like Nepal the complexity of the selection process becomes more rigorous with the involvement of multiple actors who become active at various stages of project development. Lessons learnt from the failure of past projects have already proven the strength of hurdles these actors may create in the projects.

Among the five most important actors identified, the majority of the respondents believe that politicians are most responsible for the development of energy systems in Nepal. Similarly, among the five important factors identified for the sustainability of energy systems, the respondents have rated socio-economic as the most important. Furthermore, the majority of the respondents believe that biogas should be given priority as a sustainable energy system for Nepal followed by biodiesel and solar, wind and nuclear.

Although, the finding of this research is based on the subjective judgment of a selected few people, the developed model will be useful and applicable in most cases. Furthermore, this model will be very useful in conducting stakeholders and risk analysis during project development and implementation.

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