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Multi-Criteria Analysis on Renewable and Non-Renewable Technologies for Electricity Generation in Myanmar

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လျှပ်စစ်ဓါတ်အား ထုတ်လုပ်ရန်အတွက် အသုံးပြုနိုင်သည့် ပြန်လည်ပြည့်ဖြိုးမြဲစွမ်းအင်နှင့် ပြန်လည်မဖြည့်တင်းနိုင်သည့် စွမ်းအင်များကို ရှုထောင့်ပေါင်းစုံ မှလေ့လာဆန်းစစ်ခြင်း

ခင်မောင်ဇော်၊ လက်ထောက်ညွှန်ကြားရေးမှူး
ပတ်ဝန်းကျင်ထိန်းသိမ်းရေးဦးစီးဌာန၊ ရန်ကုန်

စာတမ်းအကျဉ်း

မြန်မာနိုင်ငံသည် စွမ်းအင်အရင်းအမြစ်များ ပေါကြွယ်ဝသော်လည်း လျှပ်စစ်မီး မကြာခဏပြတ်တောက်ခြင်း ကြုံတွေ့ရလျက်ရှိသည့် လျှပ်စစ်စွမ်းအင် အလွန်အမင်း လိုအပ်နေသော တိုင်းပြည်ဖြစ်ပါသည်။ ၂၀၃၀ ခုနှစ်တွင် တစ်နိုင်ငံလုံး မီးလင်းရေးနှင့် စက်မှုကဏ္ဍ ဖွံ့ဖြိုး တိုးတက်မှုများ၏ အကျိုးဆက်များအနေဖြင့် လျှပ်စစ်စွမ်းအင် ပိုမိုလိုအပ်လာမည် ဖြစ်ပြီး အဆိုပါလိုအပ်ချက်ကို ဖြည့်ဆည်းနိုင်ရန် လျှပ်စစ်ဓာတ်အား ပိုမိုထုတ်လုပ်ရန် အထူး လိုအပ် လျက်ရှိပါသည်။ လျှပ်စစ်စွမ်းအင် အရင်းအမြစ်အသီးသီးသည် စီးပွားရေး၊ လူမှုရေး၊ ပတ်ဝန်းကျင်နှင့် နည်းပညာဆိုင်ရာ စိန်ခေါ်မှုများအမျိုးမျိုးရှိရာ ဆုံးဖြတ်ချက် ချမှတ်သူများ အနေဖြင့် ရှုထောင့်စုံမှသုံးသပ်၍ ဆုံးဖြတ်ချက် ချမှတ်ရန် လိုအပ်လာပါသည်။ ဤသုတေသန စာတမ်းသည် ကျောက်မီးသွေး၊ သဘာဝဓာတ်ငွေ့၊ နေရောင်ခြည်၊ လေစွမ်းအင်နှင့် ရေ အား တို့အား လျှပ်စစ်ဓာတ်အား ထုတ်လုပ်ရာတွင် အသုံးပြုနိုင်ရန် စီးပွားရေး၊ လူမှုရေး၊ ပတ်ဝန်း ကျင်နှင့် နည်းပညာဆိုင်ရာ ရှုထောင့်များမှ လေ့လာသုံးသပ်ထားပါသည်။ သက်ဆိုင်ရာ နယ်ပယ် အသီးသီးမှ ကျွမ်းကျင်သူ (၃၀)ဦးထံ မေးခွန်းလွှာများပေးပို့၍ သုံးသပ်စေခဲ့ပါသည်။ မြန်မာနိုင်ငံအတွက် လျှပ်စစ်ဓာတ်အား ထုတ်လုပ်ရန် သဘာဝဓာတ်ငွေ့၊ ကျောက်မီးသွေး၊ ရေအား၊ နေရောင်ခြည်နှင့် လေစွမ်းအင်တို့အား အသုံးပြုသင့်ကြောင်း လေ့လာတွေ့ရှိရ ပါသည်။ ရှုထောင့် (စံ)ပြောင်းလဲနိုင်ခြေပေါ် မူတည်၍ ရလဒ်ပြောင်းလဲနိုင်စွမ်းရှိမှုကို လေ့လာ ရာတွင်လည်း သဘာဝဓာတ်ငွေ့သည် ထိပ်ဆုံးမှ အသုံးပြုသင့်ကြောင်း လေ့လာ တွေ့ရှိရပါ သည်။

Multi-Criteria Analysis on Renewable and Non-Renewable Technologies for Electricity Generation in Myanmar

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Abstract

Despite the fact that Myanmar is rich in energy resources, the country is still an electricity-starved country with frequent electricity shortage issues. Myanmar has an urgent need to increase electricity generation so that it can guarantee the adequate supply which has the potential of rise coming from universal access to grid electricity by 2030 and industrial development. In expanding electricity generation, each electricity generation technology brings different degrees of technical, economic, environmental and socio-political challenges to energy decision-making process which calls for a multi-criteria analysis for choosing proper generation technologies. This study analyzes five generation technologies; hydropower, natural gas, coal, solar and wind technologies through the lens of economic, technical, environmental and socio-political criteria Questionnaires were designed by using those criteria, sub-criteria and generation technologies. 30 experts from government organizations, non-government organizations, academic institutions, and private companies participated in this study. According to the results of this study, the best option for electricity generation in Myanmar is natural gas, followed by coal, hydropower, solar and wind technologies. Additional sensitivity analysis was performed to confirm the stability of the ranking of alternatives and the results show that natural gas remains as the best option regardless of changes in the priority weights of the main criteria.

Keywords: Analytical Hierarchy Process, Sensitivity Analysis, Electricity Generation Technologies, Solar, Wind, Natural Gas, Coal, Hydropower

Multi-Criteria Analysis on Renewable and Non-Renewable Technologies for Electricity Generation in Myanmar

1. Introduction

1.1 1.1 Research Background

Despite the fact that Myanmar is rich in energy resources, Myanmar is still an electricity-starved country, with less than 40% of the households having access to grid-based electricity services and an annual per capita electricity consumption of around 300 kWh for the 2016-2017 fiscal year (Kyaw, 2017). Meanwhile, electricity demand is increasing at a rate faster than that of electricity supply (Htwe, 2018). In addition, the country is projected to achieve universal electricity access by 2030. Therefore, Myanmar has an urgent need to increase electricity generation and to make a bold decision on choosing proper generation technologies to be adopted for power expansion.

When it comes to proper choices of generation technologies in Myanmar, it has been common for decision makers to consider technical and economic aspects as important factors. However, nowadays, with the rise of environmental awareness and socio-political issues, generation technology selection calls for environmental and socio-political considerations in energy decision-making. However, multi-dimensional aspects like economic, technical, environmental and socio-political aspects come along with diverse degrees of advantages and disadvantages on the level of power generation in the energy industry. And the choice of technologies necessitates complex trade-offs which suggests a need to analyze renewable and non-renewable technologies in terms of economic, environmental, technical and socio-political aspects.

1.2 1.2 Research Objectives, Questions

The main objective of this study is to prioritize generation technologies to be adopted in the electricity generation sector of Myanmar.

In order to analyze generation technologies from a multi-dimensional point of view, the study aims to answer the following research questions:

1. Which criteria should be used to evaluate electricity generation technologies?
2. Which criteria and sub-criteria should be paid more attention in the decision-making process for choosing proper generation technologies for electricity generation in Myanmar?
3. Which generation technologies are more preferable to be adopted for electricity generation in Myanmar?

2. Literature Review

2.1 2.1 Multi-Criteria Analysis in the Energy Sector

There are many MCDA methods such as the analytical hierarchy process (AHP), Goal Programming, Multi-Attribute Global Inference of Quality (MAGIQ), Simple Multi-Attribute Rating Technique (SMART), etc. However, AHP, developed by Saaty (1980), is one of the most commonly used tools to tackle complex problems with multiple criteria.

2.2 Analytical Hierarchy Process (AHP) for Ranking Generation Technologies

Analytical Hierarchy Process (AHP), one of the most widely-used multi-criteria analysis methods, was introduced by Thomas L. Saaty in 1970. It uses various inputs; not only actual measurements such as price, weight, etc., but also subjective opinions such as feelings or preferences to find solutions for very complicating and conflicting issues. AHP also allows human inconsistency to a certain extent (Golam Baharul, 2016). Due to its flexibility and robustness to support the decision-making process, AHP has been accepted by the international science community as a robust and flexible tool to be applied in finding solutions for complex problems (Elkarmi & Mustafa, 1993).

The AHP method has also been extensively used in the energy sector to formulate energy policy, select suitable power plants, select plant location, allocate energy resource, control greenhouse gas emissions, and to develop energy management systems (Amer & Daim, 2011). Similarly, the AHP method has been widely applied for the selection of the best-suited electricity generation technology to be applied for electricity generation in the energy sector.

3 3. Methodological Framework

Figure 1 summarizes and depicts the methodological framework for this study.

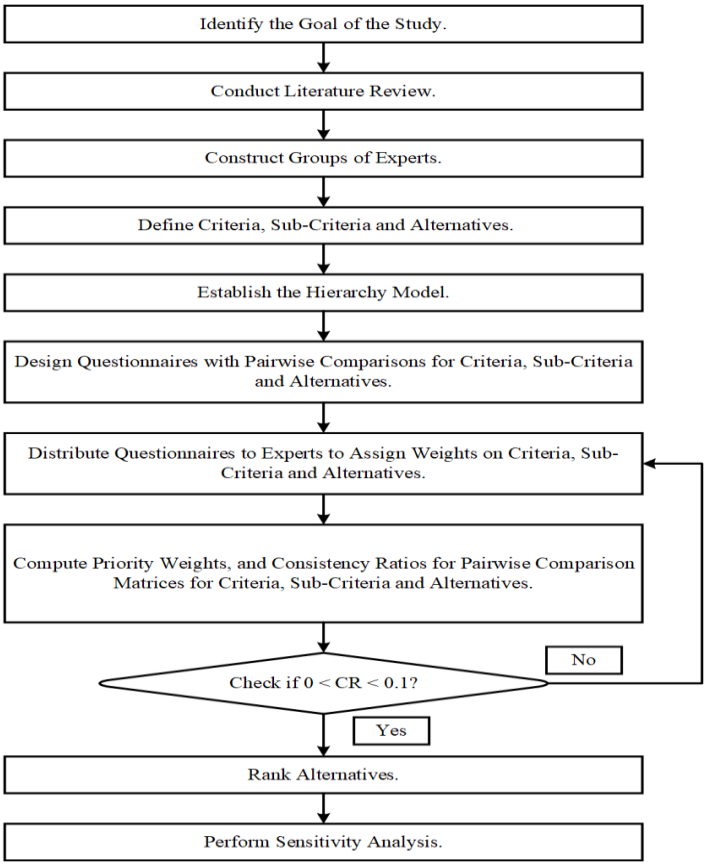


Figure 1. Methodology Framework for Multi-Criteria Analysis on Renewable and Non-Renewable Technologies for Electricity Generation in Myanmar

The resulting overall hierarchy structure for this study is presented in Figure 2.

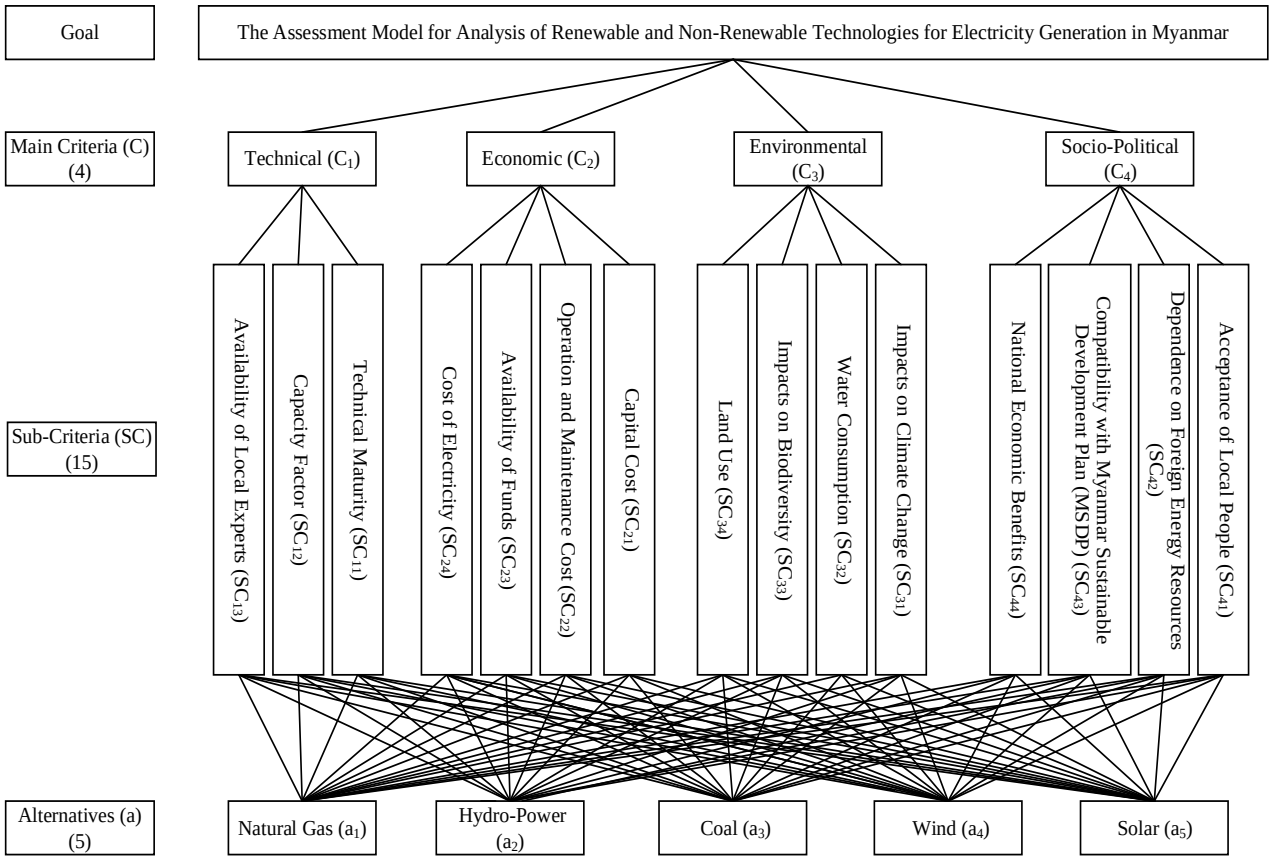


Figure 2. Analytical Hierarchy Structure for this study

4. Results and Discussion

3.1 4.1 Results of Criteria, Sub-Criteria and Alternatives

3.1.1 4.1.1 Questionnaire analysis

3.1.2

Organization: Table 1 shows the various organizations in which the experts are employed. The same number of experts from the Ministry of Natural Resources and Environmental Conservation, Ministry of Electricity and Energy and Non-Governmental Organizations participated in this study; with 23.3% of participants coming from each organization. Meanwhile, 16.7% of the experts were employed in private electricity companies and 13.3% were from academic institutions.

Table 1. Descriptive Statistics by Experts' Organization

Organization	Frequency	Percent
Ministry of Natural Resources and Environmental Conservation	7	23.3
Ministry of Electricity and Energy	7	23.3
Non-Governmental Organizations	7	23.3
Private Company	5	16.7
Academic Institutions	4	13.3
Total	**30**	**100.0**

Experience: Table 2 shows that 46.7% of experts had more than 20 years of experience in their respective professions. Meanwhile, 36.7% of experts had between 10 and 20 years of experience and 16.7% had between 7 and 9 years of experience.

Table 1. Descriptive Statistics by Experts' Experience

Experience of Experts	Frequency	Percent
More than 20 years	14	46.7
10-20 years	11	36.7
7-9 years	5	16.7
Total	**30**	**100.0**

3.1.3

3.1.4 4.1.2 Results of priorities of criteria

3.1.5

The priority weights and rankings of the four main criteria are shown in figure 3.

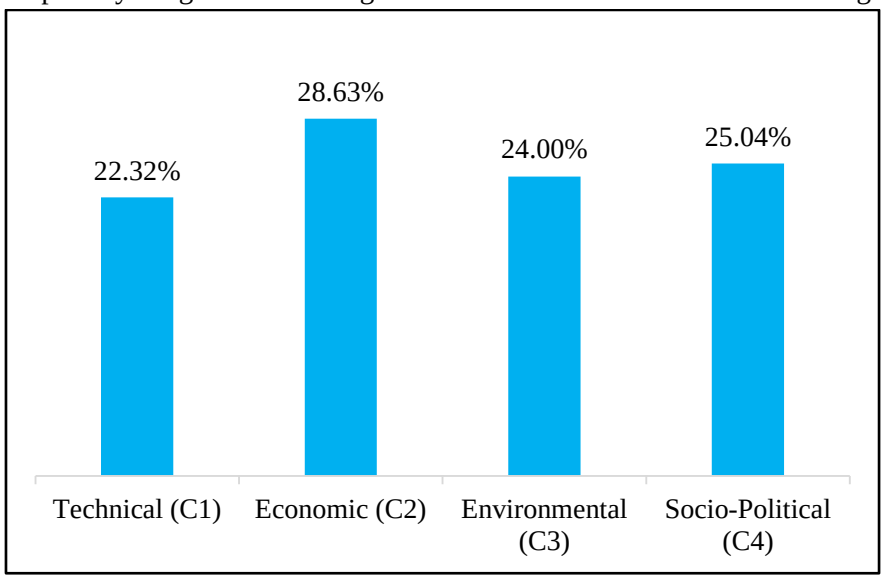


Figure 3. Priorities for Criteria

3.1.6

3.1.7 4.1.3 Results of priorities of sub-criteria

Table 3 presents the global priorities and rankings of all sub-criteria which were considered in this study.

Table 3. Priorities and Rankings for Sub-Criteria

Sub-Criteria (SC)	Priority Weight	Priority Weight (%)	Rank
Cost of Electricity (SC_{24})	0.102	10.23%	1
National Economic Benefits (SC_{44})	0.089	8.85%	2
Acceptance of Local People (SC_{41})	0.083	8.33%	3
Availability of Funds (SC_{23})	0.082	8.25%	4
Availability of Local Experts (SC_{13})	0.081	8.08%	5
Impacts on Climate Change (SC_{31})	0.081	8.07%	6
Land Use (SC_{34})	0.079	7.86%	7
Capacity Factor (SC_{12})	0.073	7.32%	8
Technical Maturity (SC_{11})	0.069	6.93%	9
Operation and Maintenance Cost (SC_{22})	0.060	5.96%	10
Water Consumption (SC_{32})	0.047	4.72%	11
Dependence on Foreign Energy Resources	0.045	4.53%	12

(SC_{42})			
Capital Cost (SC_{21})	0.042	4.20%	13
Impacts on Biodiversity (SC_{33})	0.033	3.35%	14
Compatibility with Myanmar Sustainable Development Plan (MSDP) (SC_{43})	0.033	3.33%	15

3.1.8 4.1.4 Results of priorities of alternatives

Figure 4 show the overall priorities for the five electricity generation technologies.

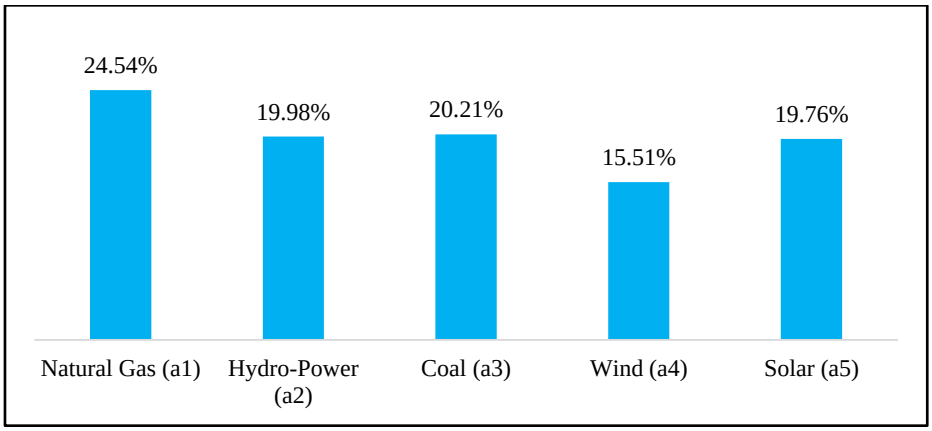
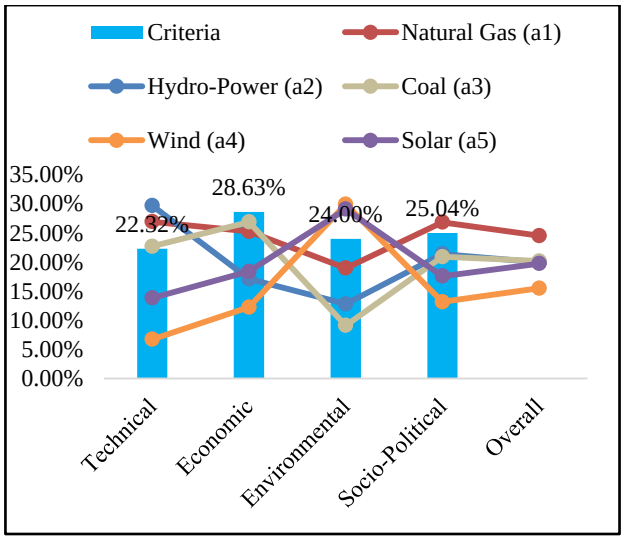


Figure 4. Global Priorities for Alternatives

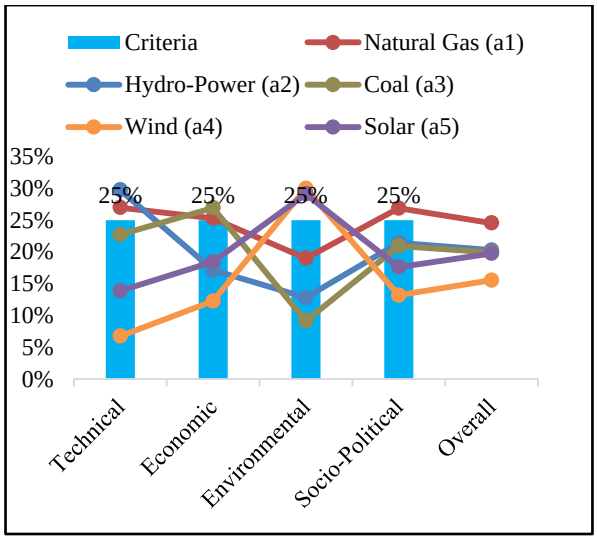
3.2 4.2 Sensitivity Analysis

Sensitivity analysis was performed to evaluate the influence of criteria on the ranking of alternatives. It was conducted by manipulating the priority weights of the main criteria. The following five scenarios were generated to check the stability of the rankings of alternatives.

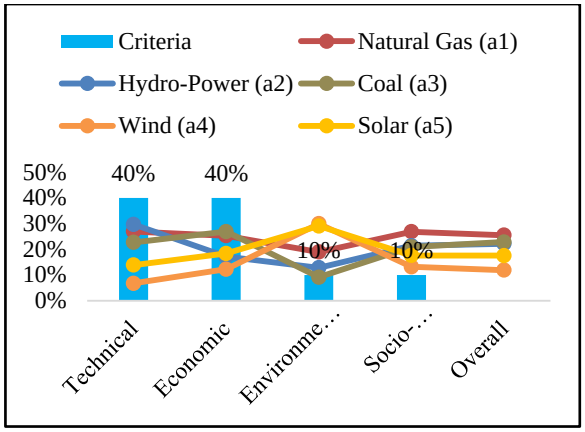
1. Scenario 1: Baseline Scenario
2. Scenario 2: Holistic Scenario
3. Scenario 3: Technical-Economic Scenario
4. Scenario 4: Economic-Environmental Scenario
5. Scenario 5: Environmental-Socio-Political Scenario



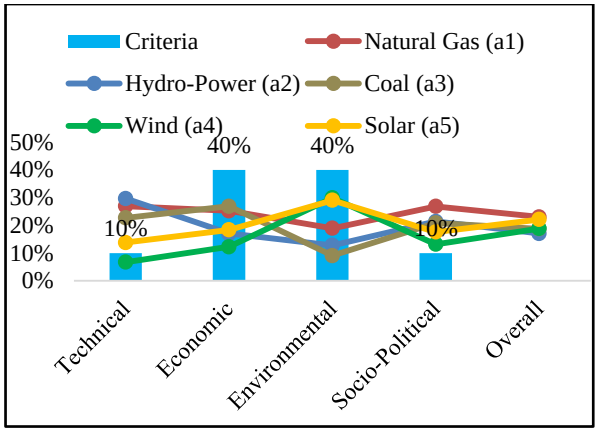
Scenario 1: Baseline Scenario



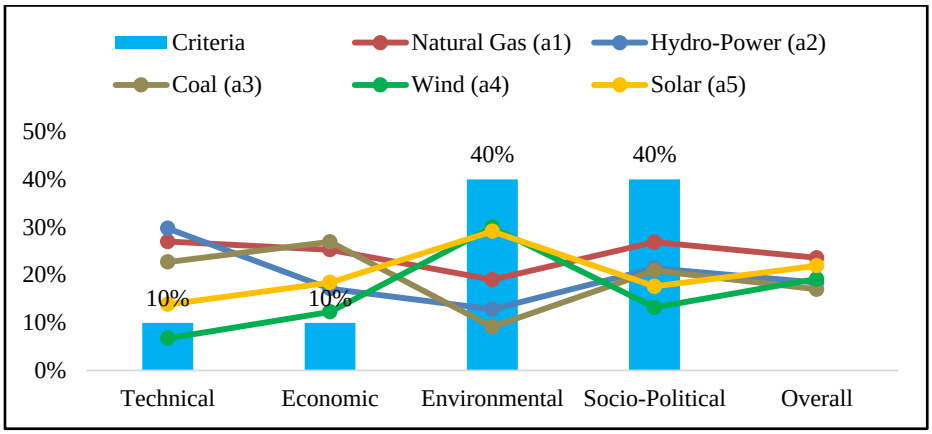
Scenario 2: Holistic Scenario



Scenario 3: Technical-Economic Scenario



Scenario 4: Economic-Environmental Scenario



Scenario 5: Environmental-Socio-Political Scenario

3.3 4.3 Discussion

Regarding the degree of importance of the various criteria, the aggregated results based on experts' opinions show that the most important criterion to be considered in the energy decision making process is the economic criterion. Based on this finding, Myanmar needs to choose the generation technologies which are economically most feasible. This result seems to support the Myanmar Sustainable Development Plan (MSDP) which contains the strategy to provide affordable energy. However, this study found that there is only a slight difference in the priority weights of the economic, socio-political, environmental and technical criteria. This result sheds light on the importance of all criteria to be considered in the energy decision making process.

Regarding the research question about the degree of importance of sub-criteria, the aggregated results based on experts' opinions show that the cost of electricity is the most important sub-criterion to be considered in choosing generation technologies.

Regarding the third research question about preferences of generation technologies, the aggregated results of experts' opinions indicate that the best option is natural gas, followed by coal, hydro-power, solar and wind. It can be observed that there are only slight differences in preferences among coal, hydro-power and solar among the experts.

5. Conclusion and Policy Implications

Based on the results of this study, the following policy implications can be made:

First, energy decision-makers need to consider the economic criterion as the first priority in the decision-making process for the selection of proper generation technologies. While paying special attention to the economic criterion, it is also important to consider socio-political, environmental and technical aspects.

Second, energy decision-makers need to pay more attention to the following six sub-criteria: cost of electricity, national economic benefits, acceptance of local people, availability of funds, availability of local experts and impacts on climate change.

Third, energy decision-makers need to understand that natural gas is the best option in all considered generation scenarios. For the remaining positions of rank order, coal and hydro-power are preferable in the baseline, holistic and technical-economic scenarios while solar and wind are preferable in economic-environmental and environmental-socio-political scenarios.

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