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Evaluating Climate Change Mitigation Options in the Philippines with Analytic Hierarchy Process (AHP)

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The environmental problem of climate change is an issue that needs to be addressed worldwide. As the electricity-generating power sector is the largest contributor of CO_2 in the country, low-carbon technologies or sustainable energy systems are being considered as viable alternatives to reduce the CO_2 emissions from this sector. These are fossil-based power plants with carbon capture and storage (F-CCS) technology, nuclear energy (NE) and renewable energy (RE) technologies, particularly solar energy (SE), wind energy (WE), hydroelectricity (HE), geothermal energy (GE) and biomass (BE). However, successful implementation of any of these CCMOs depends not only on the technical and economic aspect but also the socio-political aspect of the project. This study therefore proposes an analytical decision modeling framework to evaluate these options by incorporating the subjective judgment of stakeholders. The Analytic Hierarchy Process (AHP) was used to structure the problem and quantify the relative preference of each option with respect to four criteria namely environmental effectiveness (EE), economic viability (EV), technical implementability (TI), and social acceptability (SA).Results from the decision model indicate that the most important criterion is environmental effectiveness, and the least important is social acceptability. With respect to environmental effectiveness, their most preferred CCMO was solar energy whereas their least preferred is nuclear energy mainly because of the risk posed by the generated nuclear wastes. With respect to economic viability, their most preferred CCMO was geothermal energy, and the least preferred was nuclear energy. With respect to technical implementability, the respondents gave the highest preference weight on geothermal energy and the least preferred is nuclear energy. With respect to social acceptability, the most preferred was wind energy and again, the least preferred was nuclear energy.

Keywords: Climate Change, AHP, Renewable Energy, Carbon Capture and Storage, Nuclear Energy

INTRODUCTION

Climate change is a global environmental issue that needs to be addressed not only by developed nations but also by emerging nations like the Philippines. According to the 2009 World Energy Outlook (WEO) report, abatement protocols call for three main climate change mitigation options (CCMOs) namely, Carbon and Capture Storage (CCS) technology, Nuclear Energy (NE) and Renewable Energy (RE)resources to achieve the 450 ppm concentration of CO_2 in the atmosphere (IEA,2009). As the electricity-generating power sector is the largest contributor of CO_2 in the country (DOE, 2009), low-carbon technologies or sustainable energy systems are being considered as viable alternatives to reduce the CO_2 emissions from this sector. These are fossil-based power plants with carbon capture and storage (CCS) technology, nuclear energy (NE) and renewable energy (RE) technologies, particularly solar energy (SE), wind energy (WE), hydroelectricity (HE), geothermal energy (GE) and biomass energy (BE). However, the public perception would play a crucial role in implementing such kind of technology in the Philippines. Public opinion can be crucial as it drives or constrains the socio-political and economic action in addressing certain risks (Leiserowitz, 2007). Not only the technological and economic factors but also the social aspects surrounding these technologies must therefore be considered in the conceptualization, design and implementation of such project. Accordingly, this study proposes a decision modeling framework based on Analytic Hierarchy Process (AHP) to evaluate these CCMOs by incorporating the opinion and subjective judgment of stakeholders.

BACKGROUND OF METHODOLOGY

AHP is one of the popular multi-criteria decision analysis (MCDA) methods that can be used to facilitate the decision-making process that incorporates the value judgment of the decision maker, and prioritize the set of alternatives according to multiple and conflicting criteria. Because of its flexibility and intuitive in nature, AHP and its generalized form, the Analytic Network Process have been used in wide spectrum of applications (Promentilla, 2012; Promentilla *et al.*, 2006; Vaidya and Kumar, 2006). The AHP decision modeling framework is based on these three principles namely: (1) structuring complexity, (2) measuring priority on a ratio scale, and (3) synthesizing by hierarchic composition (Saaty, 1980). The complexity of the decision problem is handled by decomposing it to a hierarchical structure with the identified alternatives (solutions) at the bottom, the various criteria and sub-criteria at the middle, and the main problem or the goal at the top of the hierarchy. Moreover, both tangible and intangible factors are taken into account in the decision structure. The ratio-scale priority weights are obtained from the pairwise comparison matrices where each entry reflects the importance or preference of one element over another with respect to a controlling parent element (or higher-level element). These local priorities are computed from the principal eigenvector (**w**) of the said pairwise comparison matrix

A as shown in the following equation (Saaty, 1980):

$$Aw = \lambda_{max}\mathrm{w} \quad (1)$$

The overall composite weight or priority of an alternative is then computed from the additive weighting of these local priorities.

In this study, the following decision structure was used as shown in Figure 1 for illustration purpose**.** The main criteria are environmental effectiveness (EE), technical implementability (TI), economic viability (EV) and social acceptability (SA). Environmental effectiveness pertains to the environmental impact of the CCMO in terms of mitigating climate change and the effects of the by-products that it may produce. Technical implementability considers the technological factors like efficiency, reliability, maturity of technology and the availability of experts. On the other hand, economic viability pertains to financial affordability and its effect on the economy whereas social acceptability considers the perception of the general public and local community.

For the value judgment elicitation, nine key stakeholders were identified that would represent the different societal sector from the industry or private organizations, government agencies, non-government organizations and the academe. These respondents were considered knowledgeable on the different CCMOs presented due to their current and previous work experience, and therefore could provide a well-informed judgment on the decision structure presented.

RESULTS AND DISCUSSION

Table 1 summarizes the respondents' aggregated weights to describe the relative importance of the criteria in evaluating the different climate change mitigation options. Indications suggest that the majority of the stakeholders were rooting towards environmental effectiveness as

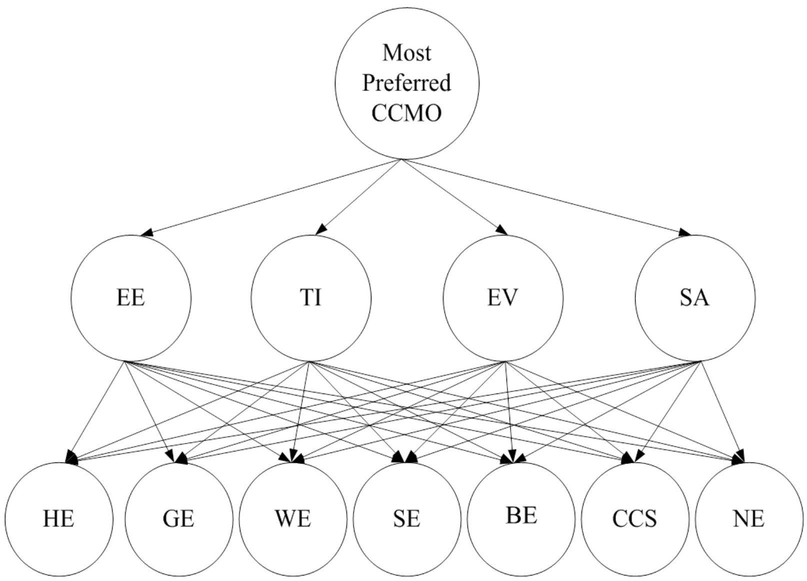


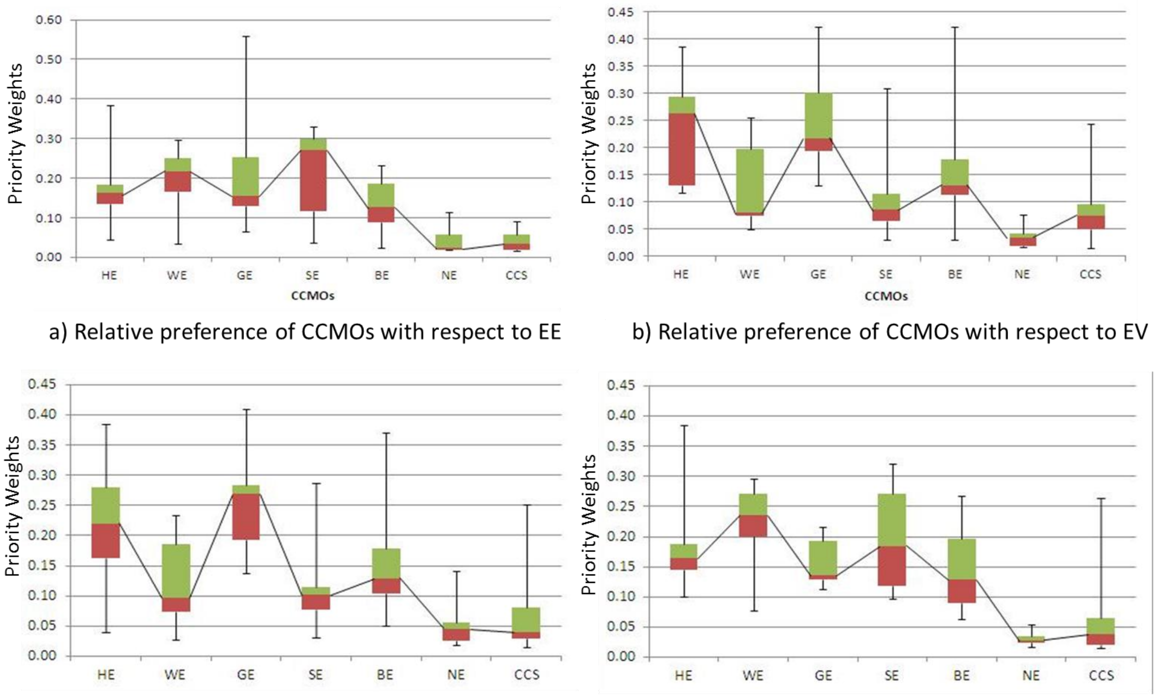
Fig.1: The decision structure used in this study

Table 1. Antioxidant capability of SFE extracts

Criteria	Aggregated Weights
Environmental Effectiveness (EE)	0.337
Economic Viability (EV)	0.262
Technical Implementability (TI)	0.205
Social Acceptability (SA)	0.196

well as economic viability whereas the technical implementability and social acceptability were not given the top priority.

Figure 2 describes the variation of weights among respondents as regard to relative preference of CCMOs with respect to each criterion. Although all respondents accepted the fact that RE, CCS, and NE can lessen CO_2 emission, some of the respondents still did not want to consider NE and CCS as a way to mitigate climate change in the country. Indications also suggest that the stakeholders are leaning towards RE sources. Moreover, solar energy (SE) and wind energy (WE) are the most preferred CCMO with respect to environmental effectiveness (EE) as the resources are perceived to be clean and inexhaustible whereas nuclear energy is their least preferred mainly because of the risk posed by the generated nuclear wastes. On the other hand, the most preferred CCMOs in terms of economic viability (EV) and technical implementabiity are geothermal energy (GE) and hydroelectric energy resource (HE), while the least preferred are still associated with nuclear power plants (NE) and fossil-based power plants with CCS. The latter according to the



a) Relative preference of CCMOs with respect to EE

b) Relative preference of CCMOs with respect to EV

c) Relative preference of CCMOs with respect to TI

d) Relative preference of CCMOs with respect to SA

Fig. 2: The relative preference of CCMOs with respect to each criterion

Table 2. Overall priority weights of the CCMOs

CCMOs	Aggregated priorities (Rank)
Hydroelectric Energy (HE)	0.205 (2)
Wind Energy (WE)	0.180 (3)
Geothermal Energy (GE)	0.214 (1)
Solar Energy (SE)	0.157 (4)
Biomass Energy (BE)	0.150 (5)
Nuclear Energy (NE)	0.040 (7)
Fossil-based with Carbon Capture and Storage (CCS)	0.054 (6)

respondents still requires the maturity in technology and availability of experts in the Philippines before it can be fully implemented. In terms of social acceptability, most of the respondents perceived that WE will be the energy resource which the public will embrace with ease. In contrast, NE is the least socially-acceptable CCMO particularly because of the recent Fukushima Daiichi nuclear accident. Table 2 summarizes the aggregated overall priority weights of CCMOs. Results from this AHP model suggest that the most preferred alternatives are geothermal energy and hydroelectric energy whereas the least preferred alternatives are nuclear energy and fossil-based power plants with CCS.

CONCLUSION

The AHP-based decision modeling framework allows us to prioritize the different climate change mitigation options by incorporating the value judgment of stakeholders. This method facilitates the decision making process in a transparent and documented manner. This current study indicates the inclination of the stakeholders in the Philippines to prefer renewable energy resources (RE) more than that of nuclear (NE) and fossil-based power plants with CCS.

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