Integrated Multi-Attribute Value and Analytic Hierarchy Process Model of Sustainable Energy Development in Central Europe and East Asia

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Abstract. This research presents an overview of different sustainable energy development scenarios in Central Europe and East Asia, and is aimed to evaluate the efficiency and availability for introducing a specific sustainable energy source. Accordingly: wind, hydropower, solar, bioenergy, geothermal, nuclear energy. By conducting analysis through multicriteria decision analysis (MCDA) and analytic hierarchy process (AHP) models, divergences among energy options in Central Europe and East Asia are emphasised due to their preferences in hierarchy. Our evaluation results indicate that Central Europe and East Asia should introduce different sustainable energy technologies on account of their own strengths and drawbacks in energy judgements and criterions

Key words: Renewable Energy; Central Europe; East Asia

JEL classification: R11; Q16; Q42

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1 Introduction

This research presents an overview of different sustainable energy development scenarios in Central Europe and East Asia, and is aimed to evaluate the efficiency and availability for introducing a specific sustainable energy source. Accordingly: wind, hydropower, solar, bioenergy, geothermal, nuclear energy. By conducting analysis though multi criteria decision analysis (MCDA) and analytic hierarchy process (AHP) models, divergences among energy options in Central Europe and East Asia are emphasised due to their preferences in hierarchy. Evaluation results indicating Central Europe and East Asia should introduce different sustainable energy technologies on account of their own strengths and drawbacks in energy judgements and criterions.

2 Literature review

Methods about measuring sustainable energy (SE) and deciding energy structure strategy have been discussed in many researches. Naim H. Afgan et al. (1998) proposed “three pillar” concept S.D. Pohekar and M. Ramachandran (2004) explained that application areas of multi-criteria decision making application (MCDA) often presented in renewable energy planning, energy resource allocation, building energy management, transportation energy management, planning for energy projects, electric utility planning and other miscellaneous areas. Another important book is V. Belton and T. Stewart (2002) that mentioned MCDA along with categories for decision makers to choose optimized energy strategy, including value measurement models, goal, aspiration and reference level models, and outranking models. Similarly, Espen Løken (2007) introduced MCDA method that generally used as sustainable energy choosing strategy, sustainable energy and primary energy allocation strategy.

As for deeper research about how much each variable can impact SE development and decision makers' choice, Ravi P. and Inder K.B. (2009) introduced important calculation formulas for concepts energy pay-back time (EPBT), GHC emissions and cost of electricity generation are feasible specific indicators which can be applied into quantitative and qualitative way.

Additionally, some important case studies like Tzeng G-H et al. (1992) using DSS method in Taiwan, P.D. Lund (2009) exploring the effects and measurements of energy policy. Similarly, Lenschow (2002), Lafferty (2004), Nilsson and Eckerberg (2007) made key contributions here relate to environmental policy integration.

During the sustainable energy evaluation and choose process, complex problems or issues involving value or subjective judgments are suitable applications of the analytic hierarchy process (AHP) approach, put forward by Saaty (1980) and improved by quantity of researches such as R.W. Saaty (1987), T.L. Saaty (1990) and Jiang-Jiang W., et al. (2009). This research is reference to the case study of M.M. Kablan (2004) using AHP model to decide energy promotion policy.

3 Methodology

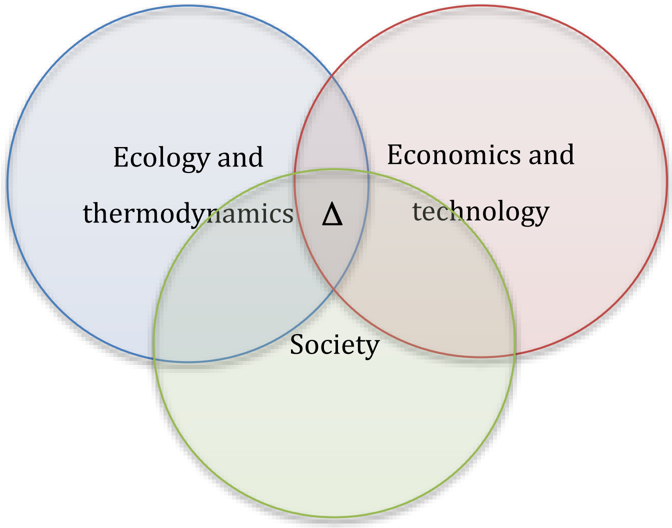
This paper gives a close look at primary energy source and SE deployments diversity, how this impact economic growth, ultimately aim to find optimized energy strategy for CE and EA markets in particular. Above aspects can be analysed with either quantitative or qualitative approaches. But both methodologies provide useful information and have their own advantages and drawbacks. Therefore, they are not being regarded as substitutes. Section 3.1 talks about "Three Pillar" methods application in quantitative and qualitative factors measurement. Followed by STATA computerized programming introduction in Section 3.2 along with several important variables presented. The remaining subsections then reveal how Multi criteria decision analysis (MCDA) method works in this paper through Multi-attribute value theory (MAVT); and the Analytic hierarchy process (AHP) model to outrank: which sustainable energy deployment strategy optimized for decision marking in CE and EA markets respectively.

3.1 "Three pillar" of addressing sustainability

The "Three pillar" of SE diagram imply that differing professional disciplines and insights are required in order to address each dimension (Ibon G., M. Gonzˆlez-Eguino, Anil M., 2011)

Figure 3.1

Venn diagram representations of "three pillars" of sustainability



Δ: area of sustainability

- The environmental pillar: this can be tackled in quantitative terms via energy and environmental performance appraisal (Hammond and Winnett, 2006), typically on an environmental cost-benefit analysis (CBA) assessment of individual sustainable energy technologies. This can be undertaken by using the techniques of GHG emissions (greenhouse gas emissions) estimation according to the full operational life cycle of each SE resource "from birth to grave" ─ from plant manufacturing to fully into operation process, outlined in more detail below by Eq. (1):

$$GHG\ emissions = \frac{Total\ atmospheric\ emissions\ throughout\ its\ life\ cycle\ \left(gGHG_{eq}\right)}{Annual\ power\ generation\ (kWh_e/year) \times lifetime\ (year)} \quad (1)$$

- The economic pillar: this one more a pillar that can be addressed in quantitative terms via methods such as by measuring average cost of production of electricity over the full life cycle of each generation sustainable energy technology accounting for construction, installation, operation, maintenance, decommissioning, recycling or disposal. For purpose of calculations, the estimation of cost of electricity generation is shown by Eq. (2).

$$Cost\ of\ electricity\ generation = \frac{Annualised\ expenses\ of\ the\ SE\ system\ (cent/year)}{Annual\ electricity\ generation\ by\ the\ SE\ system\ (kWh_e/year)} \quad (2)$$

- The social pillar: this pillar can be applied are mainly qualitative but some can be transferred into relative quantitative calculation such as analytic hierarchy process (AHP) model, typically represents as public acceptance and legal system. To understand the benefits of each sustainable energy source towards society, there is a need for the estimation of each sustainable energy payback time and influence level to society to show its capability.

  In this paper, qualitative factors about social pillar or other aspects can be addressed by generating dummy variables in STATA[1] computerized programming system and comparing different results via multicriteria decision analysis (MCDA) methods.

3.2 STATA analyse energy production and efficiency

Accordingly, this paper will focus on a panel sample of 12 countries and looks for statistical robustness across all the countries at the period 2004-2013 (a 10-years period). Therefore, in this paper, both panel data and time series are tested jointly, given that in recent years there have been well-known common guidelines concerning sustainable energy policies. Performing econometric analysis using the Stata 12.1, including

[1] STATA is a programming for statistics and data, its capabilities includes data management, statistical analysis, graphics, simulations, regression, and custom programming. http://www.stata.com

correlation and covariance analysis, ordinary logistic regression, and mix-effects linear regression:

$$\boldsymbol{\eta}_i = \boldsymbol{X}_{ij}\boldsymbol{\beta} + \boldsymbol{Z}_y \qquad E.q\ (3)$$

$\boldsymbol{\eta}_i$: The conditional expectations on i_{th} variable original scale, in our case, electricity net generation of i_{th} sustainable energy.

$\boldsymbol{X}_{ij}$: Particular predictor of interest, say in column j, to a constant.

$\boldsymbol{Z}_y$: Other predictors may affect conditional expectations, say in column y.

Table3.1

Summary of introduced important variables tested in STATA analysis

Selected Variables	
PRODUCTION	EFFICIENCY $\left(\frac{\text{SE net production / net electricity production}}{\text{SE consumption}}\right)$
EXGM (Exports share of global markets)	GDP (GDP per capita)
LIFE (Life cycle (years))	RAW (Raw materials/feedstock reserves)
EPBT (SE pay-back time)	COST (Cost & tariff of electricity generation)
INVEST (financial investment in SE)	INV (Innovation system reform)
CEIC (cumulative installed electricity)	AEIC (added installed electricity)
LAW (energy policy changes & legislation system)	SIZE (Home market size)

BS (Business consolidation)	CLR (international & domestic collaborations)
TVALUE (Total Value)	RANK (Outranking of each country)

3.3 Value measurement model: Multi-attribute value theory (MAVT)

Eq. (4) explained how MAVT model addressing each sustainable energy's contributions to its own Value:

$$V(a) = \sum_{i=1}^{m} w_i v_i(a) \qquad E.q\ (4)$$

V: total value

a: estimating alternatives

w_i: weight of i_{th} alternative

v_i: value of i_{th} alternative

Alternative replaced by different sustainable energy each time during V calculation, weight *w* represented by contribution or proportion of sustainable energy, data are collected from public reports, initiative value.

The most used value measurement method is MAVT which is an addictive value function to calculate numerical score (or value) V is assigned to each sustainable energy source.

These scores produce a preference order for the sustainable energy choosing such that sustainable energy a is preferred to another sustainable energy b $(a > b)$ only if and only if $V(a) > V(b)$.

When using this approach, various of criteria are given weights w that represent each sustainable energy contribution to total energy structure as overall score, based on how important this criteria is for the CE and EA markets. Ideally, the weights should indicate how much each country is willing to accept in the tradeoff between two criteria, such as between primary energy and sustainable energy, or nuclear energy and solar energy.

3.4 Analytic hierarchy process (AHP) model

AHP method builds on the pair-wise comparison model for determining the weights for every unique criterion. This model was proposed primarily by Saaty in 1980, it assumed different and independent alternatives in n quantity $(A_1, A_2, \dots, A_n)$ with its weights $(w_1, w_2, \dots, w_n)$ respectively, therefore, decision makers will be provided by $n \times n$ matrix on pairs of alternatives. The matrix of pair-wise comparisons when there are n criteria at a given level can be formed as E.q (5):

$$D=\begin{pmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{pmatrix} = \begin{pmatrix} w_1/w_1 & w_1/w_2 & \dots & w_1/w_n \\ w_2/w_1 & w_2/w_2 & \dots & w_2/w_n \\ \vdots & \vdots & \ddots & \vdots \\ w_n/w_1 & w_n/w_2 & \dots & w_n/w_n \end{pmatrix} \quad \text{E.q (5)}$$

Where w is a weight vector in column and multiplies the matrix of pair-wise ratios with w into nw, that is: $Aw = nw$. In the method of Saaty, w were computed as the principal right eigenvector of the matrix A, that is: $Aw = \lambda_{max} w$, and if matrix A is a positive reciprocal one then $\lambda_{max} \geq n$ (T.L. Saaty, 1980)

The eigenvector method yields a natural measure of consistency. Saaty defined the consistency index (CI) as:

$$CI = (\lambda_{max} - n)/(n - 1) \qquad E.q\ (6)$$

For each size of matrix n; random matrices were generated and their mean CI value, called the random index (RI), was computed and tabulated as shown in Table 3.2.

Accordingly, Saaty also defined the consistency ratio (CR) as:

$$CR = CI/RI \qquad E.q\ (7)$$

Table 3.2

Average random index (RI) for corresponding matrix size (Saaty, 1980)

Matrix size (n)	1	2	3	4	5	6	7	8	9	10
Random index (RI)	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

The consistency ratio measures how a given matrix A compares to a random matrix in terms of each correspond consistency indices. If the consistency ratio $CR \leq 10\%$, imply that energy policy is considered acceptable; otherwise, larger values of CR require the decision makers to revise his judgements.

In this research, AHP model is consists of three steps:

a) Identifying energy goal in regions, each criteria and level, state key judgements in sub-criteria then modeling key judgements variables into hierarchy;

b) Doing pair-wise comparisons of all elements to get normalized priorities, and compute consistency ratio at the same time to ensure consistent judgements.

c) Conducting synthesize analysis of judgements to get overall priority for each alternative.

The relative importance can be scaled in the tree graph Table 3.3 below. Based on the matrix, criteria weights can be calculated in some methods, such as arithmetic mean method, characteristic root method, and least square method (Xu J.P., 2006). Since individual judgments will never agree perfectly, the necessary measurements of consistency ratio needed in the pair-wise comparisons in which indicating whether the comparison made is sound.

Table 3.3

The AHP pair-wise comparison scale（Saaty, 1980）

Intensity of weight	**Definition**	**Explanation**
1	Equal importance	Two criteria contribute equally to objectives
3	Weak/moderate importance of on over another	Experience and judgment slightly favored one criteria over another
5	Essential or strong importance	Experience and judgment strongly favor one criteria over another
7	Very strong or demonstrated importance	A criteria is favored very strongly over another; its dominance demonstrated in practice
9	Absolute importance	The evidence favoring one criteria over another is of the highest possible order of affirmation

2,4,6,8	Intermediate values between the two adjacent scale values	Used to represent compromise between the priorities listed above
Reciprocals of above non-zero number		If criteria *i* has one of the above non-zero numbers assigned to it when compared to criteria *j*, then *j* has the reciprocal value when compared with criteria I

Accordingly, AHP approach has 3 levels includes design objectives, criteria and alternative (or sub-criterion), it has been used for many energy planning study cases as goal programming by comparing multi-dimension criterions. In order to achieve "Design objectives" in energy structure, decision makers have to consider environmental, social, economic and technical criteria, along with its sub-criterions.

The most commonly used AHP method in energy planning problems seems to be the method of displaced ideals. In this paper, the AHP method has been used for, e.g. sustainable energy supplies optimization (Oliveira C., Antunes C.H., 2004) and for choosing a sustainable energy resource portfolio (Hobbs B.F., Meier P.M. 1994).

AHP approach is less subjective, much simpler for decision maker and especially suitable for multi-dimensional comparison when complex criterions exist with another alternatives, e.g. choice between coal burning, wind power and nuclear energy deployment. However, AHP model limits that each criterion needs to be associated with an attribute defined on a measurable scale, which means that the methods are generally able to handle quantitative and non-quantitative criteria. In addition, other complementary techniques will be combined with when other factors are going to be included.

In a nutshell, several related calculation equations for multi-dimensional factors used in the very beginning, such as GHG emissions and cost of electricity generation, then computing correlation and importance level among generation and variables by MCDA approaches and STATA programming method, which covered through whole study process. MCDA methods in this paper including two parts: 1) MAVT method, which usually used in which sustainable energy production volume and emission calculation; 2) AHP model as an approach to help choose energy policy based primarily on quantitative and qualitative pair-wise comparisons among variables in different hierarchy.

4 Database

Along with Global Wind Energy Council and Greenpeace International statistics, OECD publishing statistics[2] to map investments in sustainable energy, and the Bureau of Energy, Ministry of Economic Affairs (BOE) also provide with abundant statistics and information, especially giving detailed insights on Taiwan market, additional reports and detailed documents can be found on respective websites. In this research, most of statistics used in sustainable status analysis are collected from the databases of U.S. Energy International Agency (U.S. EIA) provides majority of data used in this paper, some form World Bank and the data of Chinese Taiwan were collected from its own database: Bureau of Energy, Ministry of Economic Affairs (BOE).

2 OECD publishing, *Green Finance and Investment: Mapping Channels to Mobilize Institutional Investment in Sustainable Energy*, 2015

5 Results

5.1 Modelling major problems as a hierarchy into AHP analysis

The six categories of available sustainable energy options for CE and EA decision makers to promote clean energy environment are identified in the very beginning.

Prioritization of energy policy options for decision makers in CE and EA markets depends upon a variety of variables. According to the results from scenarios tree graph Figure 5.1 downwards proposes energy judgements in four different aspects in level 2 and its sub-criteria in level 3 correspondingly, which have impact on carried out under the AHP mechanism:

The variables that influence the decision of sustainable energy options in CE and EA markets are identified in this paper as:

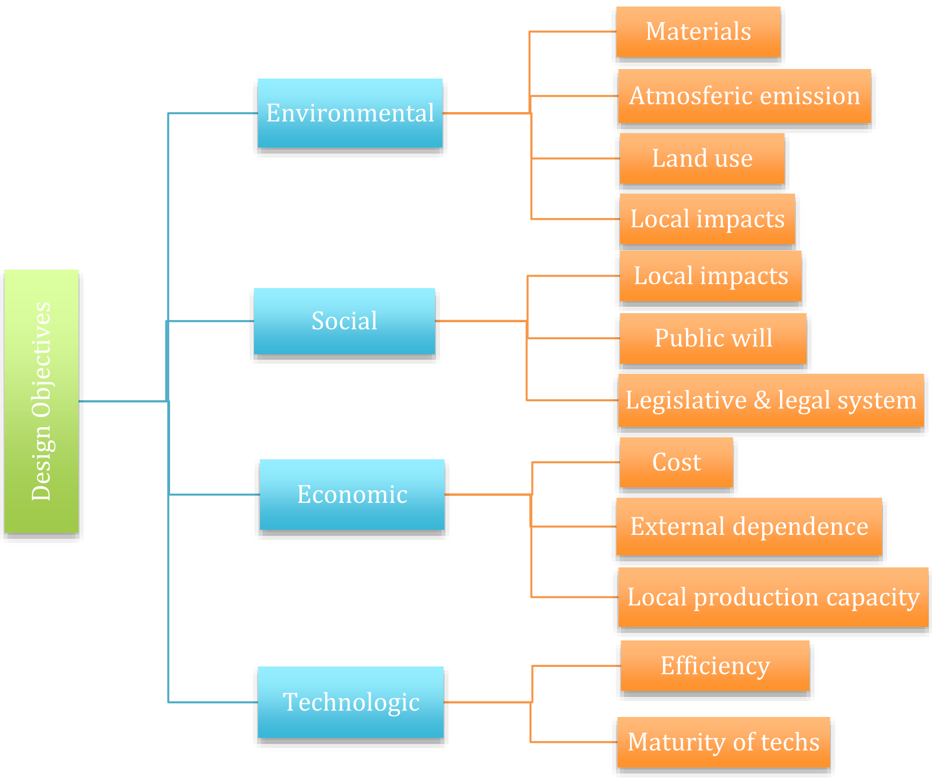
- *Environmental:* this implies that a sustainable energy should be satisfied with long-term society requirements, necessary environmental factors play a crucial role during decision-making process; besides, basic requirements for environmental friendly should not be violated, emissions and waste needed to be limited.
- *Social:* public will and acceptance towards a specific sustainable energy can be decisive in a region. For example, Poland and Austria are non-nuclear countries which phase-out the possible of introducing this sustainable energy. More ecological balanced sources are appealing to CE markets.
- *Economic:* the costs and feed-in tariffs of a sustainable energy should not be excessive too high than fossil fuels energy so that industries continue to produce and operate economically. Nuclear energy takes up a remarkable status in EA countries

such as South Korea and China thanks to its competitive price and lower costs.

- *Technologic:* technology conditions in CE and EA markets are not in perfect even for each sustainable energy. EA markets possess mature technology in wind energy and hydropower, in which CE markets prefer solar and wind energy. Maturity and efficiency of sustainable energy technology in a market tell the availability of introducing and expanding this sustainable energy.

Figure 5.1

Tree graph of key criterions, variables and evaluation level



5.2 Pair-comparisons analysis

Basically, AHP has three underlying concepts: (i) Structuring the complex decision problem as a hierarchy of goal, criteria; (ii) and alternatives, pair-wise comparison of elements at each level of the hierarchy with respect to each criterion on the preceding level; (iii) and finally vertically synthesizing the judgements over the different levels of the hierarchy (Saaty, 1980; Tiwari and Banerjee, 2001). Accordingly, based on equation and tables in *Section 2. Methodology,* the pair-wise comparisons and results are as follow:

Firstly, the matrices of judgements corresponding to the pairwise comparison of elements at each level of the hierarchy in Figure 5.1 are generated after the former scenarios analysis in this research; these judgements are only based on statistics in CE and EA during specific period.

Table 5.1

Pair-wise comparison of criteria with respect to the energy goal

CE pair-wise judgements

	Environmental	Social	Economic	Technical
Environmental	1	1/3	4	2
Social	3	1	5	3
Economic	1/4	1/5	1	1/3
Technical	1/2	1/3	3	1

EA pair-wise judgements

	Environmental	Social	Economic	Technical

Environmental	1	1/4	3	2
Social	4	1	4	3
Economic	1/3	1/4	1	1/5
Technical	1/2	1/3	5	1

Table 5.1 displays the matrix of pair-wise comparisons between the influence level of different criteria in level 2 of the hierarchy above with respect to the energy goal that decision makers want to achieve in CE and EA. Data below the diagonal are the reciprocal of those entries above; the diagonal elements of the matrix always equal to 1 because when criterion is compared with itself. Obviously, there are uneven acceptances in different criteria for CE and EA markets.

By normalizing the vector in each column of the matrix (dividing each entry of the column by the column total) and then averaging over the rows of the resulting matrix as shown in Table 6.3 (Saaty, 1980). The resulting local priority vector can be given as: (0.253, 0.506, 0.072, 0.168) for CE markets and (0.215, 0.506, 0.076, 0.203) for EA markets (see Appendix 13).

Table 5.2

Computing priority vector from judgements in Table 5.1 above

CE pair-wise

	Environmental	Social	Economic	Technical	Priority vector
Environmental	0.211	0.179	0.308	0.316	0.253

Social	0.632	0.536	0.385	0.474	0.506
Economic	0.053	0.107	0.077	0.053	0.072
Technical	0.105	0.179	0.231	0.158	0.168

EA pair-wise

	Environmental	Social	Economic	Technical	Priority vector
Environmental	0.171	0.136	0.231	0.323	0.215
Social	0.686	0.545	0.308	0.484	0.506
Economic	0.057	0.136	0.077	0.032	0.076
Technical	0.086	0.182	0.385	0.161	0.203

Hence, the average value of λ_{max} and correspond CI and CR value are as following:

a) CE markets: $\begin{pmatrix} 1 & 1/3 & 4 & 2 \\ 3 & 1 & 5 & 3 \\ 1/4 & 1/5 & 1 & 1/3 \\ 1/2 & 1/3 & 3 & 1 \end{pmatrix}\begin{pmatrix} 0.253 \\ 0.506 \\ 0.072 \\ 0.168 \end{pmatrix} = \begin{pmatrix} 1.048 \\ 2.132 \\ 0.293 \\ 0.680 \end{pmatrix} = \lambda_{max}\begin{pmatrix} 0.253 \\ 0.506 \\ 0.072 \\ 0.168 \end{pmatrix}$

$(\lambda_{max})average$

$$= \frac{(1.048/0.253) + (2.132/0.506) + (0.293/0.072) + (0.680/0.618)}{4}$$

$= 4.111$

$CI = (\lambda_{max} - n)/(n-1) = 0.037$

$CR = CI/RI = 0.041$

b) EA markets: $\begin{pmatrix} 1 & 1/4 & 3 & 2 \\ 4 & 1 & 4 & 3 \\ 1/3 & 1/4 & 1 & 1/5 \\ 1/2 & 1/3 & 5 & 1 \end{pmatrix}\begin{pmatrix} 0.215 \\ 0.506 \\ 0.076 \\ 0.203 \end{pmatrix} = \begin{pmatrix} 0.975 \\ 2.280 \\ 0.315 \\ 0.858 \end{pmatrix} = \lambda_{max}\begin{pmatrix} 0.215 \\ 0.506 \\ 0.076 \\ 0.203 \end{pmatrix}$

$(\square_{max})average$

$$= \frac{(0.975/0.215) + (2.280/0.506) + (0.315/0.076) + (0.858/0.203)}{4}$$

$$= 4.354$$

$CI = (\lambda_{max} - n)/(n - 1) = 0.118$

$CR = CI/RI = 0.131$

Correspondingly, the pair-wise comparison matrices of four alternatives (environmental, social, economic and technical) in the second level of the hierarchy with respect to each criterion in the proceeding level are displayed in Tables 6.4–6.7 in the next section respectively, with each local priority vector and the consistency ratio computed and showed on each corresponding table.

5.3 Synthesizing judgements

The composite priorities of the sustainable energy alternatives are then determined by aggregating its importance weights throughout the hierarchy (see Appendix). The judgements in sub-criterions are computed by multiplying market priorities of alternative sustainable energy with its matrix, and the results of sustainable energy priorities in CE and EA entities with its criteria are as following:

Table 5.3

Pair-wise comparison of sustainable energy options with respect to the criteria environmental

a) CE markets pair-wise: *CI=0.780, RI=1.24, CR=0.629*

	Wind	Hydro	Solar	Bioenergy	Geothermal	Nuclear	Priority vector
Wind	1	1/7	1/4	1/3	5	2	0.130
Hydro	7	1	2	1/4	2	1/3	0.161
Solar	4	5	1	1/4	5	3	0.243
Bioenergy	3	4	4	1	3	4	0.339
Geothermal	5	1/2	1/5	1/3	1	2	0.121
Nuclear	1/2	3	1/3	1/4	1/2	1	0.089

b) EA markets pair-wise: *CI=0.413, RI=1.24, CR=0.333*

	Wind	Hydro	Solar	Bioenergy	Geothermal	Nuclear	Priority vector
Wind	1	3	1/3	1/2	1	3	0.164
Hydro	1/3	1	1/4	1/2	2	2	0.133
Solar	3	4	1	1/3	1/2	2	0.203
Bioenergy	2	2	3	1	1/4	1/3	0.176
Geothermal	1	1/2	2	4	1	2	0.212
Nuclear	1/3	1/2	1/2	3	1/2	1	0.112

Table 5.4

Pair-wise comparison of sustainable energy options with respect to the criteria social

a) CE markets pair-wise: *CI=0.695, RI=1.24, CR=0.560*

	Wind	Hydro	Solar	Bioenergy	Geothermal	Nuclear	Priority vector
Wind	1	1/3	2	1/3	1/2	5	0.133
Hydro	3	1	4	3	1/2	1/3	0.206
Solar	1/2	1/4	1	1/2	3	7	0.200
Bioenergy	3	3	2	1	1/3	1/4	0.185
Geothermal	2	2	1/3	3	1	2	0.181
Nuclear	1/5	1/3	1/7	4	1/2	1	0.095

b) EA markets pair-wise: *CI=0.141, RI=1.24, CR=0.114*

	Wind	Hydro	Solar	Bioenergy	Geothermal	Nuclear	Priority vector
Wind	1	1/2	2	3	3	1/3	0.179
Hydro	2	1	2	4	1/2	1/3	0.169
Solar	1/2	1/2	1	1/3	1/2	1/4	0.066
Bioenergy	1/3	1/4	3	1	1/2	1/5	0.084
Geothermal	1/3	2	2	2	1	1/2	0.153
Nuclear	3	3	4	5	2	1	0.349

Table 5.5

Pair-wise comparison of sustainable energy options with respect to the criteria economic

a) CE markets pair-wise: *CI=0.448, RI=1.24, CR=0.361*

	Wind	Hydro	Solar	Bioenergy	Geothermal	Nuclear	Priority vector
Wind	1	2	2	3	1/2	2	0.239
Hydro	1/2	1	1/3	1	4	1/2	0.141
Solar	1/2	3	1	1/2	5	3	0.280
Bioenergy	1/3	1	2	1	1/3	1/3	0.121
Geothermal	2	1/4	1/5	4	1	2	0.207
Nuclear	1/2	2	1/3	3	1/2	1	0.141

b) EA markets pair-wise: *CI=0.624, RI=1.24, CR=0.504*

	Wind	Hydro	Solar	Bioenergy	Geothermal	Nuclear	Priority vector
Wind	1	2	3	3	1/3	2	0.201
Hydro	1/2	1	4	3	1/2	1/2	0.154
Solar	1/3	1/4	1	2	3	1/2	0.120
Bioenergy	1/4	1/3	1/2	1	4	1/3	0.114
Geothermal	3	2	1/3	1/4	1	3	0.194
Nuclear	4	2	2	3	1/3	1	0.218

Table 5.6

Pair-wise comparison of sustainable energy options with respect to the criteria technical

a) CE markets pair-wise: *CI=0.360, RI=1.24, CR=0.290*

	Wind	Hydro	Solar	Bioenergy	Geothermal	Nuclear	Priority vector
Wind	1	2	1/2	3	1/4	1/2	0.152
Hydro	1/2	1	1/4	2	1/2	1/3	0.105
Solar	2	4	1	1/3	1/3	2	0.239
Bioenergy	1/3	1/2	3	1	3	1/2	0.249
Geothermal	2	2	2	1/3	1	2	0.262
Nuclear	2	3	1/2	2	1/2	1	0.203

b) EA markets pair-wise: *CI=0.370, RI=1.24, CR=0.298*

	Wind	Hydro	Solar	Bioenergy	Geothermal	Nuclear	Priority vector
Wind	1	1/2	1	3	1/3	2	0.137
Hydro	2	1	1/3	3	1/2	5	0.198
Solar	1	3	1	2	3	1/3	0.239
Bioenergy	1/3	1/3	1/2	1	1/3	2	0.079
Geothermal	3	2	1/3	3	1	2	0.217
Nuclear	1/2	1/5	3	1/2	1/2	1	0.131

The judgements in sub-criterions are computed by multiplying market priorities of alternative sustainable energy with its matrix, and the results of priorities with its criteria are as following:

a) CE markets:

$$\begin{pmatrix} 0.130 & 0.133 & 0.239 & 0.152 \\ 0.161 & 0.206 & 0.141 & 0.105 \\ 0.243 & 0.200 & 0.280 & 0.239 \\ 0.339 & 0.185 & 0.121 & 0.249 \\ 0.121 & 0.181 & 0.207 & 0.262 \\ 0.089 & 0.095 & 0.141 & 0.203 \end{pmatrix} \begin{pmatrix} 0.253 \\ 0.506 \\ 0.072 \\ 0.168 \end{pmatrix} = \begin{pmatrix} 0.143 \\ 0.173 \\ 0.223 \\ 0.057 \\ 0.181 \\ 0.115 \end{pmatrix}$$

b) EA markets:

$$\begin{pmatrix} 0.164 & 0.179 & 0.201 & 0.137 \\ 0.133 & 0.169 & 0.154 & 0.198 \\ 0.203 & 0.066 & 0.120 & 0.239 \\ 0.176 & 0.084 & 0.114 & 0.079 \\ 0.212 & 0.153 & 0.194 & 0.217 \\ 0.112 & 0.349 & 0.218 & 0.131 \end{pmatrix} \begin{pmatrix} 0.215 \\ 0.506 \\ 0.076 \\ 0.203 \end{pmatrix} = \begin{pmatrix} 0.169 \\ 0.166 \\ 0.135 \\ 0.105 \\ 0.182 \\ 0.244 \end{pmatrix}$$

Results above indicates that the composite weights in overall criteria for energy policy instruments for introducing sustainable energy deployments in CE and EA markets are as the Table 5.7 following:

Table 5.7

Composite weights for the policy instruments for promoting sustainable energy in CE and EA markets, respectively

	CE markets	EA markets
Wind	0.143	0.169
Hydro	0.173	0.166

Solar	0.223	0.135
Bioenergy	0.057	0.105
Geothermal	0.181	0.182
Nuclear	0.115	0.244

In this paper, the integrated MCDA-AHP model has been developed for tackling problems involving both quantitative and qualitative criteria when conducting the energy options evaluation.

In combination with the results and findings in former section of this paper, a data interpretation with its reasons to corresponding countries is downwards.

6 Data interpretation

Firstly, larger priority vectors in criteria social (50.6% for both CE and EA markets) and criteria environmental (25.3% for CE markets, 21.5% for EA markets), indicating judgements in this hierarchy plays decisive role in outcomes under different sustainable energy policy. Decision makers in EA markets also influenced by technology development degree (20.3%) to some extent. In the contrary, economic judgements seems like less decisive when compared with other judgements.

The results of the prioritization process indicate that the most promising sustainable energy source in CE markets is solar energy (22.3%), followed by geothermal energy (18.1%), hydropower (17.3%), wind power (14.3%), nuclear energy (11.5%) and bioenergy (5.7%). The rank of solar energy was the first in the order of priority (22.3%), most probably because it is conceived that no geographic limitation for promoting solar energy in CE markets, the mature technology and high public acceptance towards solar energy have reduced its costs and obstacles. Although for practical reasons, solar PV power can be extracted only during daytime, but with flourish of technologies for storing and utilizing passive solar thermal energy in CE area. Moreover, solar energy impacts on these two areas almost in same degree.

The second in the order of priority because it is expected that technical and social benefits incentives will encourage many entities to implement geothermal energy production projects. The shortages of a few specialty materials is loom as the greatest obstacles, see wind power condition in CE market.

Mixing supply of energy will stimulate the development processes of other sustainable energies, for example, CE countries are not regarded as geothermal recourse-rich area in the world, in spite of it rank second place in the pair-wise evaluation. Thus, an energy policy giving solar and geothermal energy development priority might promote new geothermal technologies so that make up for lacking of abundant geothermal sources, and on the other side, large selective energy base makes energies can be used as complementary energy to each other.

Despite of the limitation of hydropower sources, compare to EA markets, in CE countries, hydropower score was also not that low (17.3%) indicates many enterprises might implement the hydro programs particularly small-hydro plants to generate electricity, but they might not make use of it if not simulated by law or motivated by some financial incentives, it can replaced by a more competitive sustainable source. Nuclear energy had a relative low score (11.5%) although with advanced nuclear technology and experts in CE area, in which also lower costs and high yield ratio. Most probably because of the rather low public acceptance to nuclear energy and even been phased-out in some countries, even if the nuclear usage still remains significant proportion in some countries currently. Overall, the availability of each sustainable energy sources in CE markets varies across countries and categories, which actually provides external collaborating opportunities.

Thirdly, the difference is nuclear energy (24.4%) is expected to provide more efficiency in EA markets, especially when decision makers considering a more economical and cost-effective sustainable source. Access to clean, affordable and reliable energy has been a cornerstone of the emerging markets' increasing prosperity and economic growth since China, South Korea and Taiwan are recognized as emerging entities. The ranks of other sustainable sources are geothermal (18.2%), followed by wind power (16.9%) and hydropower (16.6%). Solar energy ranked fifth place (13.5%) and bioenergy (10.5%) in the end. Bioenergy score was not that high (18.0%) because a large proportion is taken up by wind and hydropower in EA markets, might narrowed potential spaces for bioenergy companies to rationalize their use of energy but it might be expanded in the future considering the sufficient development of biofuels plants and ethanol gasoline projects in this area, for example, see China and Taiwan.

Thanks to rapidly falling prices and gains in efficiency, the usage of solar energy has surged at about 20 percent a year over the past 15 years in EA countries, but it has not been widely used in some areas in EA markets due to the technology restriction. Japan and Germany are major markets for solar cells. With tax incentives and promotion for expertise in solar techs, solar electricity can often pay for itself in short periods. In the interim, however, certain forms of more advanced sustainable energy will be significantly more costly than fossil power especially in developing countries in CE area. Some combination of sustainable energy subsidies and carbon taxes would thus be needed for a time. However, the availability of each sustainable energy sources in EA markets is rather even, which gives this region high potential to create a more sustainable society.

7 Conclusions

A series of multi-dimensional variables that may affect the introducing of specific sustainable energy technology was identified. Those variables can be addressed into four hierarchies that are environmental, social, economic and technical aspects.

Sustainable power for electricity generation will continue expanding if only the increasing in efficiency and decreasing in price, and is being employed in many niche applications, but being times more expensive now than primary fossil fuels generation methods, and also limited by the extent and quality of the electricity distribution grid, and even by accessibility of more advanced technology, it may not reach absolute parity until more competitive characteristics developed. Significant weakness in one instrument that affects sustainable energy deployment can be decisive to decision-making process, no matter quantitative or qualitative factors. For example, low public acceptance for nuclear energy in some CE countries and Japan makes it unlikely to expand this energy greatly in those markets, same trends showed in the lowest priority in AHP evaluation outcomes of nuclear energy in CE markets (11.5%). Even though some sources of sustainable energy such as wind and solar continue to be expanded fast in EA markets, the price seems not attractive as the primary energy. The full economic benefit of these variable sources of energy will not be realized until the more cost-effective forms of generation and operation are integrated with sustainable sources into transmission and distribution, load response and storage of electricity.

Region characteristics in introducing a sustainable energy (or mix) deserve much more attention. Improvements and technological advances in the distribution and storage of electric power will continue and should be advanced much faster. The investments in energy R&D appear to be relative low considering booming consumption requirements; demographic factors sometimes can be decisive for decision makers.

The introduction of AHP model to support energy option management in the prioritization process of policy instruments for promoting energy conservation is illustrated in this research using the case study of 12 markets in CE and EA regions, the outcomes of prioritization process analysis among the different judgements criterions for sustainable energy which gives findings: The most promising sustainable energy sources for promoting energy deployments in CE markets are solar energy (22.3%), followed by geothermal (18.1%), hydropower (17.3%), and wind power (14.3%); for EA markets, nuclear energy rank the first (24.4%), followed by geothermal (18.2%), wind power (16.5%), and hydropower (16.6%) similarly.

In addition, according to the AHP evaluation of energy policy in CE and EA markets, it is highly advisable, and likely, that despite with some limitations or advantages, a specific sustainable energy technology is still likely to be resourced when complementary judgements gain competitiveness; conversion and consumption continue to be developed, see geothermal energy capability in CE markets. Therefore, mixing sustainable energy supply could be a possible new path to the sustainable future.

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Appendix:

Appendix 1: Computing priority vector from judgements

EA pair-wise					
	Environmental	Social	Economic	Technologic	Priority vector
Environmental	0.211	0.179	0.308	0.316	0.253
Social	0.632	0.536	0.385	0.474	0.506
Economic	0.053	0.107	0.077	0.053	0.072
Technologic	0.105	0.179	0.231	0.158	0.168
CE pair-wise					
	Environmental	Social	Economic	Technologic	Priority vector
Environmental	0.171	0.136	0.231	0.323	0.215
Social	0.686	0.545	0.308	0.484	0.506
Economic	0.057	0.136	0.077	0.032	0.076
Technologic	0.086	0.182	0.385	0.161	0.203

Appendix 2: Pair-wise comparison of sustainable energy options with respect to the criteria environmental

CE pair-wise							
	Wind	Hydro	Solar	Biomass	Geothermal	Nuclear	Priority vector
Wind	0.049	0.010	0.034	0.138	0.333	0.214	0.130
Hydro	0.341	0.073	0.276	0.103	0.133	0.036	0.161

Solar	0.195	0.366	0.138	0.103	0.333	0.321	0.243
Biomass	0.146	0.293	0.552	0.414	0.200	0.429	0.339
Geothermal	0.244	0.037	0.028	0.138	0.067	0.214	0.121
Nuclear	0.024	0.220	0.046	0.103	0.033	0.107	0.089

EA pair-wise

	Wind	Hydro	Solar	Biomass	Geothermal	Nuclear	Priority vector
Wind	0.130	0.273	0.047	0.054	0.190	0.290	0.164
Hydro	0.043	0.091	0.035	0.054	0.381	0.194	0.133
Solar	0.391	0.364	0.141	0.036	0.095	0.194	0.203
Biomass	0.261	0.182	0.424	0.107	0.048	0.032	0.176
Geothermal	0.130	0.045	0.282	0.429	0.190	0.194	0.212
Nuclear	0.043	0.045	0.071	0.321	0.095	0.097	0.112

Appendix 3: Pair-wise comparison of sustainable energy options with respect to the criteria social

CE pair-wise

	Wind	Hydro	Solar	Biomass	Geothermal	Nuclear	Priority vector
Wind	0.103	0.048	0.211	0.028	0.086	0.321	0.133
Hydro	0.309	0.145	0.422	0.254	0.086	0.021	0.206
Solar	0.052	0.036	0.106	0.042	0.514	0.449	0.200
Biomass	0.309	0.434	0.211	0.085	0.057	0.016	0.185
Geothermal	0.206	0.289	0.035	0.254	0.171	0.128	0.181
Nuclear	0.021	0.048	0.015	0.338	0.086	0.064	0.095

EA pair-wise

	Wind	Hydro	Solar	Biomass	Geothermal	Nuclear	Priority vector
Wind	0.140	0.069	0.143	0.196	0.400	0.127	0.179
Hydro	0.279	0.138	0.143	0.261	0.067	0.127	0.169
Solar	0.070	0.069	0.071	0.022	0.067	0.096	0.066

Biomass	0.047	0.034	0.214	0.065	0.067	0.076	0.084
Geothermal	0.047	0.276	0.143	0.130	0.133	0.191	0.153
Nuclear	0.419	0.414	0.286	0.326	0.267	0.382	0.349

Appendix 4: Pair-wise comparison of sustainable energy options with respect to the criteria economic

EA pair-wise							
	Wind	Hydro	Solar	Biomass	Geothermal	Nuclear	Priority vector
Wind	0.207	0.216	0.375	0.240	0.051	0.343	0.239
Hydro	0.103	0.108	0.063	0.080	0.407	0.086	0.141
Solar	0.103	0.324	0.188	0.040	0.508	0.514	0.280
Biomass	0.069	0.108	0.375	0.080	0.034	0.057	0.121
Geothermal	0.414	0.027	0.038	0.320	0.102	0.343	0.207
Nuclear	0.103	0.216	0.063	0.240	0.051	0.171	0.141
CE pair-wise							
	Wind	Hydro	Solar	Biomass	Geothermal	Nuclear	Priority vector
Wind	0.110	0.264	0.277	0.245	0.036	0.273	0.201
Hydro	0.055	0.132	0.369	0.245	0.055	0.068	0.154
Solar	0.037	0.033	0.092	0.163	0.327	0.068	0.120
Biomass	0.028	0.044	0.046	0.082	0.436	0.045	0.114
Geothermal	0.330	0.264	0.031	0.020	0.109	0.409	0.194
Nuclear	0.440	0.264	0.185	0.245	0.036	0.136	0.218

Appendix 5: Pair-wise comparison of sustainable energy options with respect to the criteria technical

EA pair-wise

	Wind	Hydro	Solar	Biomass	Geothermal	Nuclear	Priority vector
Wind	0.128	0.160	0.069	0.346	0.061	0.150	0.152
Hydro	0.064	0.080	0.034	0.231	0.122	0.100	0.105
Solar	0.255	0.320	0.138	0.038	0.082	0.600	0.239
Biomass	0.043	0.040	0.414	0.115	0.735	0.150	0.249
Geothermal	0.255	0.160	0.276	0.038	0.245	0.600	0.262
Nuclear	0.255	0.240	0.069	0.231	0.122	0.300	0.203

CE pair-wise

	Wind	Hydro	Solar	Biomass	Geothermal	Nuclear	Priority vector
Wind	0.128	0.071	0.162	0.240	0.059	0.162	0.137
Hydro	0.255	0.142	0.054	0.240	0.088	0.405	0.198
Solar	0.128	0.427	0.162	0.160	0.529	0.027	0.239
Biomass	0.043	0.047	0.081	0.080	0.059	0.162	0.079
Geothermal	0.383	0.284	0.054	0.240	0.176	0.162	0.217
Nuclear	0.064	0.028	0.486	0.040	0.088	0.081	0.131