Renewable Energy 85 (2016) 148–156

Contents lists available at ScienceDirect

Renewable Energy

journal homepage: www.elsevier.com/locate/renene

# Multi-criteria analysis of electricity generation technologies in Lithuania

Dalia Štreimikienė [a, *], Jūratė Šliogerienė [b], Zenonas Turskis [b]

[a] Lithuanian Energy Institute, Breslaujos 3, LT-44403 Kaunas, Lithuania
[b] Vilnius Gediminas Technical University, Saulėtekio al. 11, LT-2040 Vilnius, Lithuania

ARTICLE INFO

*Article history:*
Received 1 September 2013
Received in revised form
21 October 2014
Accepted 14 June 2015
Available online xxx

*Keywords:*
Electricity generation technologies
Scenarios
Multiple criteria analysis
AHP (Analytic Hierarchy Process)
ARAS (Additive Ratio Assessment)
Lithuanian case study

ABSTRACT

The paper presents the process of choice of electricity generation technologies, which has been solved using a case of Lithuania's power sector and such multiple criteria mathematical methods as AHP (Analytic Hierarchy Process) and ARAS (Additive Ratio Assessment method). Having considered the impact of environment, a set of evaluation criteria was compiled for electricity generation technologies. Analysis of qualitative and quantitative criteria helped to rate the electricity generation technologies considering their economic, technological, environmental social and political aspects and rank them in order of priority. The derived results show that in case of Lithuania it is viable to consider further development of the nuclear power generation capacity. Among the electricity generation technologies related to renewable energy sources a clear priority is assigned to biomass technologies. Sensitivity analysis performed by applying multi criteria method ARAS, has confirmed this result.


## 1. Introduction

Today Lithuanian government and society must make a decision: to continue relying on ever-pricier resources, to choose and develop nuclear energy production technologies received controversially by the public, or to bet their future on constantly improving renewable energy technologies. This issue is now paramount in attempts to determine the future of the state energy system. When it comes to decisions on the choice of energy generation technologies, the spotlight usually falls on economic and technological questions.

Higher regard for the environment and the quality of life demands for solutions that would focus more on public attitudes and accepted values, public favour or hostility towards technologies, and the role of community's self-determination in the process of important decision-making. Any energy infrastructure must be developed and long-term decisions made looking for ways to link economic benefits, public attitudes, and technological solutions. A promising approach is the analysis of energy-sector development based on the choice of technologies that are the most acceptable to people rather than the most efficient.

The objective of the paper is to apply multi-criteria decision support methods in order to assess the best electricity generation technologies in Lithuania taking into account quantitative and qualitative economic, environmental, social, political and technological criteria. The main tasks to achieve the stated objective: to analyse literature in the field of multi-criteria decision making in energy sector, including selection of criteria for assessment, analysis of multi-criteria tools and case studies; to describe methods of assessment; to conduct case study for electricity generation technologies assessment in Lithuania based on the expert inquiry and provide conclusions regarding the most suitable electricity generation technologies in view of the Lithuanian situation.

### 1.1. Review of literature

In the course of the year most countries have evaluated the importance of environmental issues, negative impact of fuel on the environment and reconsidered their priorities within energy sector, in order to minimize the dependence on imported energy sources and raw products [1,2]. Particular countries such as Germany, Japan, Italy, and Switzerland that are influenced by clearly stated public opinion have assessed the potential of innovative

* Corresponding author.
*E-mail addresses:* dalia@mail.lei.lt (D. Štreimikienė), jurate.sliogeriene@vgtu.lt (J. Šliogerienė), zenonas.turskis@vgtu.lt (Z. Turskis).

http://dx.doi.org/10.1016/j.renene.2015.06.032

technology development and abandoned nuclear technologies in order to bet their future on renewable, environment-friendly energy production technologies [3].

In order to perform reasoned assessment of various alternatives and offer appropriate solutions, the multiplicity of data regarding alternative economic variables, environmental impact, social eligibility, technological innovativeness shall be analysed. Furthermore, criteria (criteria groups) which have a potentially decisive effect on solution making phase shall be properly chosen and analysed [4].

Sets of criteria intended for the assessment of sustainability and development level of the energy sector in accordance with the state priorities [5–8] and actual development aspects are prepared and applied in Lithuania [9–12], Turkey [13], India [14] and other countries. Many of proposed sets of criteria are analogous and introduce the assessment of varying economic, political, environmental, social, and technological dimensions of energy sector.

Distinctive feature of the energy sector is multidimensionality, uncertainty, prevailing multiplicity of provisions and technologies, considered technologies can be distinguished for qualitative and quantitative parameters. In order to perform analysis and assessment of alternatives, particular multi-criteria methods that are broadly used as additional means for development of double standard solutions shall be applied.

A variety of multi-criteria methods exists in the literature. The decision maker usually decides which method to be used by taking the nature of the problem into consideration. In method selection, the suitability, validity and user-friendliness of the methods are the important factors to be considered [12,13]. Table 1 includes common mathematical methods selected on the basis of scientific literature analysis that are applied for problem solving within energy sector.

Multi-criteria methods can be applied in order to solve intricate problem. These methods ensure deeper comprehension of the multidimensionality of problems and promote the involvement of participants into the decision making process, simplify group decisions and compromise decisions, enable modelling of different scenarios and projection of consequences. Multi-criteria methods provide the possibility to prove objectiveness and rationality of made decisions.

## 2. Methodology

Two multiple criteria methods, namely AHP (Analytic Hierarchy Process) and ARAS (Additive Ratio Assessment), have been selected for solution of the task aimed at analysis of the energy generation technologies applied in Lithuania and provision of conclusions regarding the most suitable technologies in view of the Lithuanian situation. These methods have been selected in respect to the possibility to assess external factors influencing selection of technologies from the quantitative and qualitative point of view. These methods are quite simple and easy to apply, both includes quantitative and qualitative factors necessary for multi-criteria analysis of electricity generation technologies.

**Table 1**
List of some multi-criteria decision making methods.

| Methods | References |
|---|---|
| AHP, Fuzzy AHP, | [1,10,13,14,17–20] |
| ARAS | [21,22] |
| COPRAS | [9,19] |
| Delphi | [20] |
| ELECTRE, ELECTRE III | [4,14,23–27] |
| MAUT | [14] |
| PROMETHEE | [14] |
| SAW | [28] |
| VIKOR | [18,29] |
| TOPSIS, Fuzzy TOPSIS | [10,30–33] |

The research is based on the expert assessment of alternatives. The research is organised as the two-level structure: the external factors encompassing institutional – political, technological, economical, environmental protection and social criteria are evaluated in the first level. The analysed alternatives are assessed during the second level. The research structure, based on the AHP method, is shown in Fig. 1.

The AHP pairwise comparison method was applied for determination of values of the external factors, as well as values and weights of importance of the criteria characterising these external factors. The analysis of evaluated technologies by determining their value, efficiency, order of priority was performed by applying the multiple criteria method ARAS. The optimal criteria values of evaluated technologies were as well determined by means of this method.

### 2.1. AHP (Analytic Hierarchy Process) method

AHP is developed by T. Saaty [15,16]. AHP uses the hierarchy based structure of the task that enables to decompose the considered problem into several smaller sub-problems, each of which can be analysed independently, thus leading to a more easy solution of the overall problem. The pairwise comparison is applied for derivation of needed data. The pairwise comparison is used for deriving weights of importance of the criteria and relative rankings of alternatives for each criterion. If estimations of comparisons are not compatible, logical, then the method proposes means for magnifying the compatibility ratio. Ratio scale and the use of verbal comparisons are used for weighting of quantifiable and non-quantifiable elements. The method computes and aggregates their eigenvectors until the composite final vector of weight coefficients for alternatives is obtained. AHP (Analytic Hierarchy Process) method is widely analysed, including a considerable number and variety of articles written by different authors on application of this method, its advantages and disadvantages [1,10,13–20].

### 2.2. The determination of priority and importance of considered alternatives by ARAS method

According to the ARAS method, a utility function value determining the complex relative efficiency of a feasible alternative is directly proportional to the relative effect of values and weights of the main criteria considered in a project [21,22].

The first stage is decision-making matrix (DMM) forming. In the MCDM of the discrete optimization problem any problem to be solved is represented by the following DMM of preferences for $m$ feasible alternatives (rows) rated on $n$ signfull criteria (columns):

$$X = \begin{bmatrix} x_{01} & \cdots & x_{0j} & \cdots & x_{0n} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ x_{i1} & \cdots & x_{ij} & \cdots & x_{in} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mj} & \cdots & x_{mn} \end{bmatrix}; \quad i = \overline{0, m}; \quad j = \overline{1, n}, \tag{1}$$

where $m$ – number of alternatives, $n$ – number of criteria describing each alternative, $x_{ij}$ – value representing the performance value of the $i$ alternative in terms of the $j$ criterion, $x_{0j}$ – optimal value of $j$ criterion.

If optimal value of $j$ criterion is unknown, then: