Chapter 11

Multi-Criteria Decision-Making in the Implementation of Renewable Energy Sources

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Additional information is available at the end of the chapter

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Abstract

The consideration of renewable energy sources as sources for the production of electricity, demands an approach that would enable an analysis which comprehends various factors and stakeholders. The *P*reference *R*anking *O*rganization *METH*od for *E*nrichment *E*valuations (PROMETHEE), as a mathematical model for multi-criteria decision-making, is one of the ideal methods used when it is necessary to rank scenarios according to specific criteria, depending on whom the ranking is applied. This chapter presents various scenarios whose ranking is done according to defined criteria and weight coefficients for each of the stakeholders. This model recognized and accepted according to the theory of decision-making could be used as a tool for so-called stakeholder value approach.

Keywords: renewable energy sources, PROMETHEE, the production of electricity, stakeholder value, multi-criteria decision-making proces, National Renewable Energy Action Plan (NAPOIE), mini hydros, biomass, wind, solar, geothermal energy

1. Introduction

The basis for this chapter was document which established the goals in usage of renewable energy sources until 2020 (National Renewable Energy Action Plan of the Republic of Serbia further on NAPOIE) [2], as well as the manner in which they are to be achieved. In addition, it has the goal to enhance investments in the field of renewable energy sources.

'According to article 20 of the Treaty Establishing Energy Community (further on: UOEnZ), the Republic of Serbia accepted the obligation to apply European Directives in the field of renewable energy sources (further on: OIE) —Directive 2001/77/EC on the promotion of the use of energy from renewable sources and Directive 2003/30/EC on the promotion of the use of biofuels and other renewable fuels for transport. Those Directives were gradually replaced since 2009, and in January 2012 abolished by the new Directive 2009/28/EC of the European Parliament and the Council of the 23rd of April 2009 on the promotion of the use of energy from renewable sources, amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC CELEX No. 32009L0028'.[1]**

With the adoption of the 'Law of Ratification…',[2] [3] the Republic of Serbia internationally committed to create NAPOIE [2].

Data given in **Tables 1** and **2** were used as input data for this chapter.

Types of renewable energy sources taken in consideration in this chapter are as follows:

- Mini hydros (up to 10 MW).
- Wind energy.
- Solar energy.
- Biomass.
- Geothermal energy.

The National Renewable Energy Action Plan of the Republic of Serbia (NAPOIE) defined target values, that is, the amount of GWh expected to be produced from every renewable energy source and to be delivered in the system. The defined goal is 2252 GWh obtained from following renewable energy sources: mini hydros, biomass, solar, wind and geothermal energy (**Table 3**).

The *goal* is to verify the ranking sequence of renewable energy sources if only one of the listed renewable energy sources would be delivering the total expected amount of GWh into the system and to rank scenarios according to stakeholders[3], on the basis of previously defined criteria and calculated weight coefficients, and also to establish whether the sequence of renewable energy sources is identical for all stakeholders.

On the basis of ranking achieved this way, we may determine which type of renewable energy source is the priority, depending on the stakeholder, and also whether the participation of all listed types is justified.

A multi-criteria analysis will provide a clearly established sequence of renewable energy sources for the stakeholders, and according to clearly established criteria. This sequence is important for the establishing of priorities.

[1]Taken from introduction of document NAPOIE, Ministarstvo energetike, razvoja i zaštite životne sredine, strana 18, Beograd 2013 [2].
[2]Full name "Law on Ratification of the Treaty Establishing Energy Community between the European Community and the Republic of Albania, Republic of Bulgaria, Bosnia and Herzegovina, Republic of Croatia, Former Yugoslav Republic of Macedonia, Republic of Montenegro, Romania, Republic of Serbia and United Nations Interim Administration Mission on Kosovo in compliance with the Resolution 1244 of the UN Security Council" ("Službeni glasnik RS", no. 62/06).
[3]R. Edward Freeman. The stakeholder theory is a theory of organizational management and business ethics that addresses morals and values in managing an organization [1].

Type of renewable energy sources	(MW)	Estimated work hours (h)	(GWh)	(ktoe)	Participation (%)
HE (over 10 MW)	250	4430	1108	95	30.3
MHE (up to 10 MW)	188	3150	592	51	16.2
Wind energy	500	2000	1000	86	27.4
Solar energy	10	1300	13	1	0.4
Biomass: power plants with combined production	100	6400	640	55	17.5
Biogas (manure): power plants with combined production	30	7500	225	19	6.2
Geothermal energy	1	7000	7	1	0.2
Waste	3	6000	18	2	0.5
Landfill gas	10	5000	50	4	1.4
Total planned capacity	1092	–	3653	314	100.0

[1] Full name "Law on Ratification of the Treaty Establishing Energy Community between the European Community and the Republic of Albania, Republic of Bulgaria, Bosnia and Herzegovina, Republic of Croatia, Former Yugoslav Republic of Macedonia, Republic of Montenegro, Romania, Republic of Serbia and United Nations Interim Administration Mission on Kosovo in compliance with the Resolution 1244 of the UN Security Council" („Službeni glasnik RS", no. 62/06 [2].

Table 1. The production of electricity from renewable energy sources from new plants in 2020[1].

Type of renewable energy sources	(MW)	(GWh)	Specific investment costs* (€/kW)	Price according to planned installed capacity until 2020 (millions €)
HE (over 10 MW)	250	1108	1819	454.8
MHE (up to 10 MW)	188	592	2795	525.5
Plants powered by wind energy	500	1000	1417	708.5
Plants powered by solar energy	10	13	2500	25.0
Biomass: power plants with combined production	100	640	4522	452.2
Biogas (manure): power plants with combined production	30	225	4006	120.2
Geothermal energy	1	7	4115	4.1
Waste	3	18	4147	12.4
Landfill gas	10	50	2000	20.0
Total planned capacity	1092	3653	–	2322.6

[1] Full name "Law on Ratification of the Treaty Establishing Energy Community between the European Community and the Republic of Albania, Republic of Bulgaria, Bosnia and Herzegovina, Republic of Croatia, Former Yugoslav Republic of Macedonia, Republic of Montenegro, Romania, Republic of Serbia and United Nations Interim Administration Mission on Kosovo in compliance with the Resolution 1244 of the UN Security Council" („Službeni glasnik RS", no. 62/06 [2].

Table 2. Estimated finances for each of the technologies using renewable energy sources in the production of electricity needed to complete the planned share in energy production from new capacities until 2020 in electric energy sector[1].

Renewable energy type	Mtoe
Hydro	0.80
Solar	0.60
Biomass	2.25
Wind	0.20
Geothermal energy	0.20

Table 3. Available potentials [4].

For solving this type of problems, one of the mathematical models that can be used is the one developed by Jean-Pierre Brans in 1982, for a multi-criteria decision-making in a group of alternatives described with several attributes.

2. Theoretical overview of the PROMETHEE

The *P*reference *R*anking *O*rganization *METH*od for *E*nrichment *E*valuations (PROMETHEE)[4] is part of a group of methods for multi-criteria decision-making within a group of alternatives described with several attributes, used as criteria. This method enables a comprehensive structuring of quality and quantity criteria of different importance into a relation of partial organization in a unique result (PROMETHEE II), on the basis of which alternatives can be ranked in an absolute manner.

We will consider a multi-criteria problem:

$$\text{Max}\left\{\left(k_1(a),\ldots,k_k(a)\right) \mid a \in A\right\}, \tag{1}$$

where A is a finite group of activities and $k_i = 1,\ldots, k$ are *usefulness criteria* which should be maximized or fulfilled according to the principle 'bigger is better' (this supposition enables a more simple presentation of the method—in cases when some of the criteria are *price criteria*, they can be transformed into usefulness criteria, or we can adjust the proceeding to those criteria as well).

The application of the PROMETHEE is characterized by two steps:

(1) constructing a preference relation within a group of alternatives A,

(2) using this relation to find an answer to the problem (1.1).

In the first step, a complex preference relation is formed (in order to stress the fact that this relation is based on the consideration of more criteria, this relation is called *outranking relation*), based on the generalization of the notion of the criteria. A *preference index* is then defined and a complex preference relation is obtained, which is shown in a graph representation. The essence of this step is that the decision maker (stakeholder) must express his preference

[4]Theoretical overview of the PROMEHTEE method is described in brief according to the "*Odlučivanje*", Milutin Čupić, Milija Suknović, Fakultet organizacionih nauka, Beograd 2010. All general theoretical formulas, functions and graphs are taken from Ref. [5].

between two alternatives (action and activity), according to every criterion, on the basis of the difference (differentiation) of criteria values of alternatives which are being compared.

PROMETHEE II can be a tool for 'Management philosophy that regards maximization of the interests of its all stakeholders (customers, employees, shareholders and the community) as its highest objective'.[5]

The preference relation obtained this way is used so that input and output flows are calculated for each alternative, in graphs or tables. On the basis of these flows, the decision maker can apply partial ranking (PROMETHEE I) or absolute ranking (PROMETHEE II) in the group of alternatives.

In this chapter, the absolute ranking method PROMETHEE II was used.

2.1. PROMETHEE preference relation

Let k be a real function used to express one of the attributes used as a criterion for comparing alternatives:

$$k : A \rightarrow \mathbf{R} \tag{2}$$

Let us assume that this is a usefulness criterion, that is, that alternatives (scenarios/models) are compared according to this criterion on the basis of the principle 'bigger is better'.

For every alternative a dA, $k(a)$ a criterion value is calculated according to criterion k. When two alternatives a, b dA are being compared, the result of that comparison is expressed as a preference.

With preference function P

$$P : A \times A \rightarrow [0, 1] \tag{3}$$

the intensity of preference for alternative a in relation to alternative b is expressed, with the following interpretation:

$P(a, b) = 0$ marks indifference between a and b, that is, there is no preference of a over b,

$P(a, b) \approx 0$ marks weak preference of a over b,

$P(a, b) \approx 1$ marks strong preference of a over b,

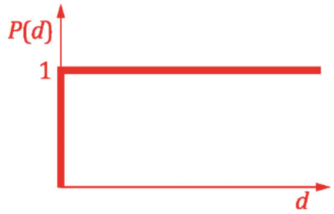
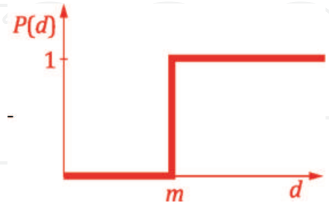
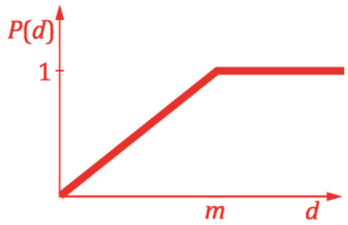
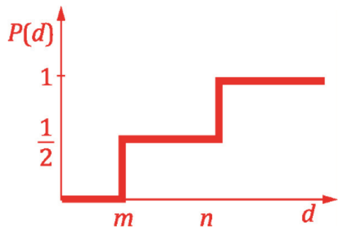
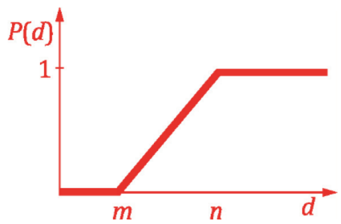
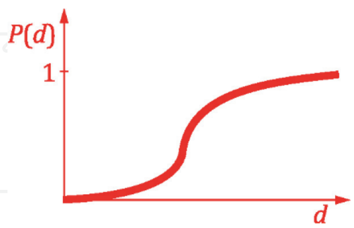
$P(a, b) = 1$ marks strict preference of a over b.

Preference function that is added to a given criterion is the difference function of criteria value of alternatives, and it can be written as

$$P(a, b) = P(k(a) - k(b)) = P(d) \tag{4}$$

$P(d)$ is a non-decreasing function that assumes value zero for negative difference values $d = k(a) - k(b)$, *if the functions should be maximized, that is,* $P(a, b) = P(k(a) - k(b))$, that is, $d = -(k(a) - k(b))$ if the criterion is minimized (**Table 4**).

[5]http://www.businessdictionary.com/definition/stakeholder-value-approach.html.

Criterion	Definition	Graph
Type 1. Common criterion	$P(d)=\begin{cases}0, & d=0\\ 1, & d\neq 0\end{cases}$	
Type 2. Quasi criterion	$P(d)=\begin{cases}0, & d<m\\ 1, & d\geq m\end{cases}$	
Type 3. Criterion with a growing linear preference	$P(d)=\begin{cases}\frac{d}{m}, & d<m\\ 1, & d\geq m\end{cases}$	
Type 4. Linear criterion with an indifference area	$P(d)=\begin{cases}0, & d\leq m\\ \frac{1}{2}, & m<d\leq n\\ 1, & d>n\end{cases}$	
Type 5. Criterion with preference levels	$P(d)=\begin{cases}0, & d\leq m\\ \frac{d-m}{n-m}, & m\leq d\leq n\\ 1, & d>n\end{cases}$	
Type 6. Gauss' criterion	$P(d)=1-\exp\left\{-\frac{d^2}{2\sigma^2}\right\}$	

[1]Taken from Ref. [5].

Table 4. Types of functions in the application of the PROMETHEE[1].

2.2. Multi-criteria preference index

Let us assume that the decision maker sets preference function P_i and weight t_i; for every criterion k_i $(i = 1, \ldots, n)$ of the problem (2.2).

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Weight t_i is the measure of relative importance of the criterion k_i. If all criteria have the same value for the decision maker, all weights are equal.

Multi-criteria preference index IP is defined as the medium of preference functions P_i:

$$IP(a, b) = \frac{\sum_{i=1}^{k} t_i P_i(a, b)}{\sum_{i=1}^{k} t_i}$$

IP (*a*,*b*) represents intensity, that is, the strength of decision maker's preference for activity *a* over activity *b*, when all criteria are compared at the same time. It varies between values 0 and 1.

$P\ (a, b) \approx 0$ marks weak preference of *a* over *b* for all criteria,

$P\ (a, b) \approx 1$ marks strong preference of *a* over *b* for all criteria.

This can also be shown in a graph. Between two nodes (two activities) *a* and *b* there are two arches with values IP(*a, b*) and IP(*b, a*). This relation is shown in **Figure 1**. There is no direct connection between IP(*a, b*) and IP(*b, a*).

Output and input flow:

Input and output flows can be defined for every node (shown in **Figure 2**.)

(a) Output flow is the sum of values of output flows:

$$T^{+}(a) = \sum_{x \in k} IP(a, x)$$

(b) Input flow is the sum of values of input flows (**Figure 3**):

$$T^{-}(a) = \sum_{x \in k} IP(a, x)$$

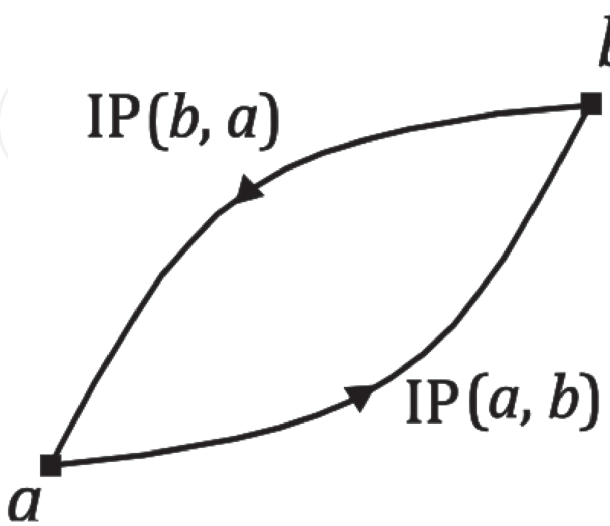

Figure 1. IP relation. Taken from Ref. [5].

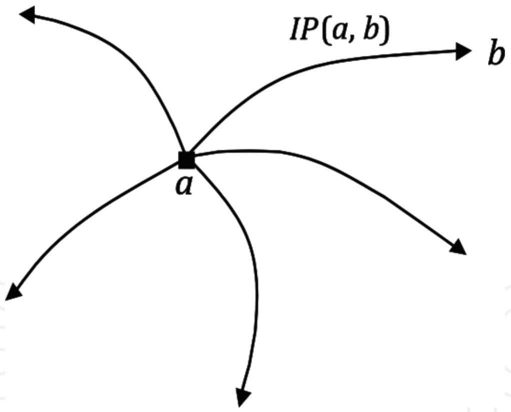

Figure 2. Output flow. Taken from Ref. [5].

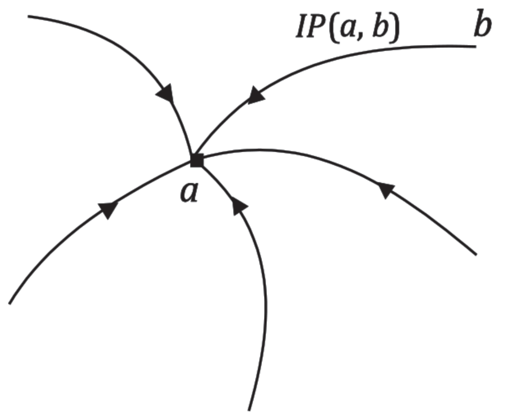

Figure 3. Input flow. Ibid 11, Ref. [5].

3. Absolute ranking: PROMETHEE II

If the decision maker wants an absolute ranking, the clear flow is considered:

Absolute ranking (PII, III) is defined in the following manner:

a PII b (a prefers b) if *T*(a) > T(b).

a III b (a is indifferent to b) if T(a) = T(b).

Elements of scientific research[6] are all the elements that have to be defined so that the aforementioned mathematical model could be applied. Those comprehend:

[6]This research paper gave initial idea for this chapter as well as for stakeholders and used criteria [6, 7].

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- stakeholders
- criteria
- weight coefficients
- preference functions (for every criterion)
- suggested models.

Stakeholders considered in ranking are as follows:

- State (DR)
- Potential investors (PI)
- Local community (LZ).

3.1. Criteria

PRMOTHEE needs criteria to be defined, according to whom the ranking will be done. Criteria used in this study are presented in **Table 5**.

These 10 criteria can be divided into two categories:

(1) Empirical criteria, based on the data taken from NAPOIE (K1, K2, K3, K5, K9 and K10).

(2) Description criteria (K4, K6, K7 and K8).

Weight coefficients are calculated and given in **Table 4**.

Since each of the stakeholders treats each of those 10 criteria in a different manner, it is essential to define weight coefficients so that every criterion has a weight definition in relation to the stakeholder. For each of the stakeholders, the criteria were sorted into three categories:

K1	Maximal usage of available potentials
K2	Price according to planned installed capacity
K3	Incentive purchase price
K4	Technology development
K5	Supply safeness, expected work hours
K6	Possibility of combined production of electric and thermal energy
K7	Contribution to local development and welfare
K8	Social acceptability and sustainability of other influences on the environment
K9	Period of investment return
K10	Installed power

Table 5. Criteria for ranking scenarios.

- Very important,
- Important,
- Of little importance.

An assessment of weight coefficients was made on that basis, with values for K attributed on the scale of 1–10, starting from the categorization of the criteria. A representation of weight coefficients is given in **Table 6**.

Preference functions. A preference function is attributed to every defined criterion. Common functions according the PROMETHEE are presented in **Table 4**. For this chapter, the following allocation was adopted:

- Type 1. A common function is attributed to K6. Type 1 function is used when there are only two expected results, and it provides an obvious preference. Because of that it is attributed to criterion K6, since the combined production of electric and thermal energy is either possible or impossible.
- Type 3. A growing linear preference function is attributed to K2, K3, K5, K9 and K10. Type 3 function is used when the difference can be a constant value. The maximum value of difference is taken as decision threshold ($m = d$max)
- Type 4. A function with preference levels is attributed to K1, K4, K7 and K8. Type 4 function is used for discrete value differences and their outputs are discrete preferences 0, ½, 1 (m and n are decision thresholds). For criterion K1, assumed decision thresholds are m = 10% $d$max, and n = 30% $d$max, while for criteria K4, K7, K8 m = 1 and n = 2.

	Weight coefficient t_i	**$\sum t_i$**	
State			
k1; k5; k10	(8 + 9 + 10)/3 = 9	0.1636	Very important: 16.36%
k2; k3; k6; k7; k8	(3 + 4 + 5 + 6 + 7)/5 = 5	0.0909	Important: 9.09%
k4; k9	(1 + 2)/2 = 1.5	0.02727	Of little importance: 2.72%
Investors			
k2; k3; k4; k9	(7 + 8 + 9 + 10)/4 = 8.5	0.154545	Very important: 15.45%
k5; k6; k10	(4 + 5 + 6)/3 = 5	0.0909	Important: 9.09%
k1; k7; k8	(1 + 2 + 3)/3 = 2	0.03636	Of little importance: 3.63%
Local community			
k6; k7; k8	(8 + 9 + 10)/3 = 9	0.1636	Very important: 16.36%
k1; k5	(6 + 7)/2 = 6.5	0.11818	Important: 11.818%
k2; k3; k4; K9; K10	(1 + 2 + 3 + 4 + 5)/5 = 3	0.0545	Of little importance: 5.45%

Table 6. Calculation of weight coefficients.

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3.2. Suggested models

The following models (scenarios) were defined (**Table 6**):

- The first model (A1) represents allocation A1. This allocation fits the goals planned until 2020 according to NAPOIE.
- The second model (A2) represents allocation A2, in which the needed energy from renewable energy sources would be produced in mini hydros.
- The third model (A3) represents allocation A3, in which the needed energy from renewable energy sources would be produced from biomass.
- The fourth model (A4) represents allocation A4, in which the needed energy from renewable energy sources would be produced by the Sun.
- The fifth model (A5) represents allocation A5, in which the needed energy from renewable energy sources would be produced by the wind.
- The sixth model (A6) represents allocation A6, in which the needed energy from renewable energy sources would be produced from geothermal potentials.

N.B.: It is VERY important to point out here that, according to available potentials, as shown in **Table 7** (data taken from the document 'Politika Republike Srbije u oblasti OIE'), each of the renewable energy sources listed (mini hydros, biomass, solar, wind and geothermal energy) can deliver 2252 GWh of energy independently (**Table 8** presents coneversion of available resources presented in **Table 7** from Mtoe to GWh), which represents the remainder from the total of 3360 GWh, diminished by the amount delivered by hydro potentials >10 MW. The first model A1 of this chapter was given illustratively as the goal which was set to be reached and will be used in further researches as a continuation of this chapter.

Scenaria are treated according to the defined criteria. Values of criteria for each scenaria are calculated and presetned in **Table 9**.

	A1	**A2**	**A3**	**A4**	**A5**	**A6**
	GWh	**GWh**	**GWh**	**GWh**	**GWh**	**GWh**
Hydro potential						
>10 MW	**1108**	**1108**	**1108**	**1108**	**1108**	**1108**
<10 MW	592	2252	0	0	0	0
Biomass	640	0	2252	0	0	0
Solar	13	0	0	2252	0	0
Wind	1000	0	0	0	2252	0
Geothermal	7	0	0	0	0	2252
Total	3360					

Table 7. Scenarios A1–A6.

Type of renewable energy sources	Mtoe	GWh
Hydro	0.8	9304
Biomass	2.25	26,167
Solar	0.6	6978
Wind	0.2	2326
Geothermal energy	0.2	2326

Table 8. Available potentials of renewable energy sources.

		K1 (%)	K2 (€)	K3	K4	K5	K6	K7	K8	K9	K10
A1	PLAN	43.00	1,356,627,968	9.87	4	3564	1	3	4	6.1	799
A2	Hydro potential <10 MW	24.20	1,998,203,175	9.89	5	3150	0	2	4	9.0	715
A3	Biomass	8.61	1,591,178,750	10.74	4	6400	1	4	4	6.6	352
A4	Solar	32.27	4,330,769,231	18.45	3	1300	0	1	3	10.4	1732
A5	Wind	96.82	1,595,542,000	9.20	4	2000	0	1	3	7.7	1126
A6	Geothermal	96.82	1,323,854,286	8.30	4	7000	1	2	5	7.1	322

Table 9. Scenarios according to K criteria values.

4. Mathematical model

Criterion K4: Technology development	
Technologies in laboratory and research phases (laboratory)	1
Technologies in pilot programs (pilot)	2
Technologies demanding further improvements to enhance their efficiency (further improvement)	3
Commercially ready technologies with a reliable place in the overall local market (com_loc)	4
Commercially ready technologies with a reliable place in the supranational and European market (com_EU)	5

Criterion K7: Contribution to local development	
Without any influence on local economy (none)	1
Weak influence on local economy(weak)	2
Moderate influence on local economy (only a small number of permanent workplaces) (moderate)	3
Moderate to large influence on local economy (opening new workplaces and chains of companies in energy production sector)	4
Very large influence on local economy (strong incentive to local growth, creation of small industrial regions on wider areas)	5

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Criterion K8: social acceptability and sustainability of other influences on the environment	
Most inhabitants are against any installations, regardless of their surroundings (no)	1
Inhabitants' opinion is split (split)	2
Most inhabitants accept installations, since they are far from inhabited areas and have no visible damaging effects (vis-res)	3
Most inhabitants accept installations, since they are far from inhabited areas, regardless of whether there is a visual contact (res)	4
Most inhabitants are pro installations (OK)	5

Mathematical model representation for the state as a stakeholder

	State	**Min**	**Min**	**Min**	**Max**	**Max**	**Max**	**Max**	**Max**	**Min**	**Max**
		K1%	**K2 €**	**K3**	**K4**	**K5**	**K6**	**K7**	**K8**	**K9**	**K10**
A2	Hydro potential <10 MW	0.2420	1,998,203,175	9.89	5	3150	0	2	4	9.0	715
A3	Biomass	0.0861	1,591,178,750	10.74	4	6400	1	4	4	6.6	352
A4	Solar	0.3227	4,330,769,231	18.45	3	1300	0	1	3	10.4	1732
A5	Wind	0.9682	1,595,542,000	9.20	4	2000	0	1	3	7.7	1126
A6	Geothermal	0.9682	1,323,854,286	8.30	4	7000	1	2	5	7.1	322

***d*(*a*2,*ai*)**	**Hydro potential <10 MW**	**Differentiation *d:* difference between scenario *a*2 and other suggested scenarios**									
		0.0000	**0**	**0.00**	**0**	**0**	**0**	**0**	**0**	**0.0**	**0**
	Biomass	−0.1559	−407,024,425	0.85	1	−3250	−1	−2	0	−2.4	363
	Solar	0.0807	233,266,056	8.56	2	1850	0	1	1	1.4	−1017
	Wind	0.7262	−402,661,175	−0.69	1	1150	0	1	1	−1.3	−411
	Geothermal	0.7262	−674,348,889	−1.60	1	−3850	−1	0	−1	−1.9	393

***P*(*a*2,*ai*)**	**Hydro potential <10 MW**	**Preference function *P:* scenario *a*2 versus other suggested scenarios**									
		0	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
*a*3	Biomass	0	0	0.099299	0.5	0	0	0	0	0	0.923
*a*4	Solar	0	1	1	1	1	0	0.5	0.5	1	0
*a*5	Wind	1	0	0	0.5	0.62	0	0.5	0.5	0	0
*a*6	Geothermal	1	0	0	0.5	0	0	0	0	0	1
	Ti	0.1636	0.0909	0.0909	0.02727	0.1636	0.0909	0.0909	0.0909	0.02727	0.1636

***d*(*a*3,*ai*)**	**Hydro potential <10 MW**	**Differentiation *d:* difference between scenario *a*3 and other suggested scenarios**									
		0.1559	**407,024,425**	**−0.85**	**−1**	**3250**	**1**	**2**	**0**	**2.4**	**−363**
	Biomass	0.0000	0	0.00	0	0	0	0	0	0.0	0
	Solar	0.2366	2,739,590,481	7.71	1	5100	1	3	1	3.8	−1380

d(*a*3,*ai*)	Hydro potential <10 MW	Differentiation *d:* difference between scenario *a*3 and other suggested scenarios									
		0.1559	**407,024,425**	**−0.85**	**−1**	**3250**	**1**	**2**	**0**	**2.4**	**−363**
	Wind	0.8821	4,363,250	−1.54	0	4400	1	3	1	1.1	−774
	Geothermal	0.8821	−267,324,464	−2.45	0	−600	0	2	−1	0.5	30

P(*a*3,*ai*)	Hydro potential <10 MW	Preference function *P*: scenario *a*3 versus other suggested scenarios									
		0.5	**0.148**	**0**	**0**	**0.637**	**1**	**1**	**0**	**0.63**	**0**
*a*3	Biomass	0	0	0	0	0	0	0	0	0	0
*a*4	Solar	0.5	1	1	0.5	1	1	1	0.5	1	0
*a*5	Wind	1	0.0016	0	0	0.862	1	1	0.5	0.289	0
*a*6	Geothermal	1	0	0	0	0	0	1	0	0.131	1
	ti	0.1636	0.0909	0.0909	0.02727	0.1636	0.0909	0.0909	0.0909	0.02727	0.1636

d(*a*4,*ai*)	Hydro potential<10 MW	Differentiation *d*: difference between scenario *a*4 and other suggested scenarios									
		−0.0807	**−2,332,566,056**	**−8.56**	**−2**	**−1850**	**0**	**−1**	**−1**	**−1.4**	**1017**
	Biomass	−0.2366	−2,739,590,481	−7.71	−1	−5100	−1	−3	−1	−3.8	1380
	Solar	0.0000	0	0.00	0	0	0	0	0	0.0	0
	Wind	0.6455	−2,735,227,231	−9.25	−1	−700	0	0	0	−2.7	606
	Geothermal	0.6455	−3,006,914,945	−10.16	−1	−5700	−1	−1	−2	−3.3	1410

P(*a*4,*ai*)	Hydro potential <10 MW	Preference function *P*: scenario *a*4 versus other suggested scenarios									
		0	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0.721**
*a*3	Biomass	0	0	0	0	0	0	0	0	0	0.978
*a*4	Solar	0	0	0	0	0	0	0	0	0	0
*a*5	Wind	1	0	0	0	0	0	0	0	0	0.43
*a*6	Geothermal	1t	0	0	0	0	0	0	0	0	1
	ti	0.1636	0.0909	0.0909	0.02727	0.1636	0.0909	0.0909	0.0909	0.02727	0.1636

d(*a*5,*ai*)	Hydro potential <10 MW	Differentiation *d*: difference between scenario *a*5 and other suggested scenarios									
		−0.7262	**402,661,175**	**0.69**	**−1**	**−1150**	**0**	**−1**	**−1**	**1.3**	**411**
	Biomass	−0.8821	−4,363,250	1.54	0	−4400	−1	−3	−1	−1.1	774
	Solar	−0.6455	2,735,227,231	9.25	1	700	0	0	0	2.7	−606
	Wind	0.0000	0	0.00	0	0	0	0	0	0.0	0
	Geothermal	0.0000	−271,687,714	−0.90	0	−5000	−1	−1	−2	−0.6	804

***P*(*a*3,*ai*)**		**Hydro potential <10 MW**	**Preference function *P* – scenario *a*5 versus other suggested scenarios**									
		0	0.147	0.075	0	0	0	0	0	0.481	0.51	*a*3
Biomass	0	0	0.166	0	0	0	0	0	0	0.962	*a*4	Solar
0	1	1	0.5	1	0	0	0	1	0	*a*5	Wind	0
0	0	0	0	0	0	0	0	0	*a*6	Geothermal	0	0
0	0	0	0	0	0	0	1		*ti*	0.1636	0.0909	0.0909
0.02727	0.1636	0.0909	0.0909	0.0909	0.02727	0.1636						

***d*(*a*6,*ai*)**	**Hydro potential <10 MW**	**Differentiation *d* – difference between scenario *a*6 and other suggested scenarios**									
		−0.7262	674,348,889	1.60	−1	3850	1	0	1	1.9	−393
	Biomass	−0.8821	267,324,464	2.45	0	600	0	−2	1	−0.5	−30
	Solar	−0.6455	3,006,914,945	10.16	1	5700	1	1	2	3.3	−1410
	Wind	0.0000	271,687,714	0.90	0	5000	1	1	2	0.6	−804
	Geothermal	0.0000	0	0.00	0	0	0	0	0	0.0	0

***P*(*a*6,*ai*)**	**Hydro potential <10 MW**	**Preference function *P* – scenario *a*6 versus other suggested scenarios**									
		0	0.224	0.157	0	0.675	1	0	0.5	0.576	0
*a*3	Biomass	0	0.089	0.241	0	0.105	0	0	0.5	0	0
*a*4	Solar	0	1	1	0.5	1	1	0.5	1	1	0
*a*5	Wind	0	0.09	0.088	0	0.877	1	0.5	1	0.182	0
*a*6	Geothermal	0	0	0	0	0	0	0	0	0	0
	ti	0.1636	0.0909	0.0909	0.02727	0.1636	0.0909	0.0909	0.0909	0.02727	0.1636

IP(*a*2,*a*3)	**IP(*a*2,*a*4)**	**IP(*a*2,*a*5)**	**IP(*a*2,*a*6)**
0.1736	0.49084	0.369567	0.340835
IP(*a*3,*a*2)	IP(*a*3,*a*4)	IP(*a*3,*a*5)	IP(*a*3,*a*6)
0.398447	0.695355	0.5399	0.421672
IP(*a*4,*a*2)	IP(*a*4,*a*3)	IP(*a*4,*a*5)	IP(*a*4,*a*6)
0.117956	0.160001	0.233948	0.3272
IP(*a*5, *a*2)	IP(*a*5,*a*3)	IP(*a*5,*a*4)	IP(*a*5,*a*6)
0.116733	0.172473	0.386305	0.1636
IP(*a*6,*a*2)	IP(*a*6,*a*3)	IP(*a*6,*a*4)	IP(*a*6,*a*5)
0.29712	0.92625	0.613555	0.391871

N.B.: IP = (*ai*,*as*), *i*,*s* = 2,3,4,5,6; IP = ∑*tjPj*(*ai*,*as*).

	*a*2	*a*3	*a*4	*a*5	*a*6	T+	T
*a*2	0	0.1736	0.49084	0.369567	0.340835	0.343711	0.111147
*a*3	0.398447	0	0.695355	0.5399	0.421672	0.513844	0.364169
*a*4	0.117956	0.160001	0	0.233948	0.3272	0.209776	−0.33674
*a*5	0.116733	0.172473	0.386305	0	0.1636	0.209778	−0.17404
*a*6	0.29712	0.092625	0.613555	0.391871	0	0.348793	0.035466
T−	0.232564	0.149675	0.546514	0.383822	0.313327		

The results for State are shown in **Figure 4**.

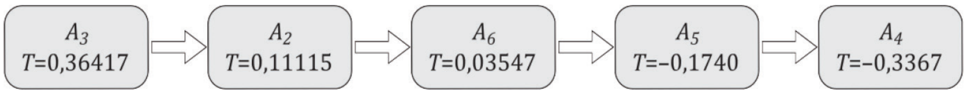

Figure 4. Chart representation of ranking results for the state as a stakeholder.

The same approach could be usd for detailed calculation for the investors and local community as stakeholders.

For the investors as stakeholders:

Determination of preference index			
IP(*a*2,*a*3)	IP(*a*2,*a*4)	IP(*a*2,*a*5)	IP(*a*2,*a*6)
0.1611	0.590895	0.272998	0.359078
IP(*a*3,*a*2)	IP(*a*3,*a*4)	IP(*a*3,*a*5)	IP(*a*3,a6)
0.377197	0.640883	0.402209	0.33841
IP(*a*4,*a*2)	IP(*a*4,*a*3)	IP(*a*4,*a*5)	IP(*a*4,*a*6)
0.195746	0.206178	0.21615	0.281805
IP(*a*5,*a*2)	IP(*a*5,*a*3)	IP(*a*5,*a*4)	IP(*a*5,*a*6)
0.143413	0.087446	0.477263	0.245445
IP(*a*6,*a*2)	IP(*a*6,*a*3)	IP(*a*6,*a*4)	IP(*a*6,*a*5)
0.294074	0.041479	0.622703	0.267196

N.B.: IP = (*ai*, *as*), *i*, *s* = 2,3,4,5,6; IP= $\sum tjPj(ai,as)$.

	*a*2	*a*3	*a*4	*a*5	*a*6	T+	T
*a*2	0	0.1611	0.590895	0.272998	0.359078	0.346018	0.09341
*a*3	0.377197	0	0.640883	0.402209	0.33841	0.439675	0.315624
*a*4	0.195746	0.206178	0	0.21615	0.281805	0.22497	−0.35797
*a*5	0.143413	0.087446	0.477263	0	0.245445	0.238392	−0.05125

http://dx.doi.org/10.5772/67734

	*a*2	*a*3	*a*4	*a*5	*a*6	T+	T
*a*6	0.294074	0.041479	0.622703	0.267196	0	0.306363	0.000179
T-	0.2526075	0.124051	0.582936	0.289638	0.306185		

The reuslts for investors are shown in **Figure 5**.

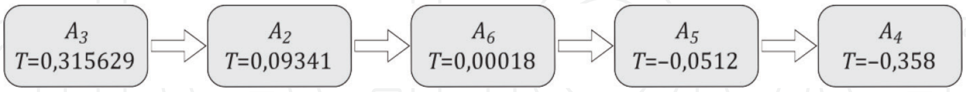

Figure 5. Chart representation of ranking results for the investors as stakeholders.

For the local community as a stakeholder:

Determination of preference index			
IP(*a*2,*a*3)	IP(*a*2,*a*4)	IP(*a*2,*a*5)	IP(*a*2,*a*6)
0.082911	0.393418	0.316357	0.19993
IP(*a*3,*a*2)	IP(*a*3,*a*4)	IP(*a*3,*a*5)	IP(*a*3,*a*6)
0.436219	0.670658	0.553205	0.34342
IP(*a*4,*a*2)	IP(*a*4,*a*3)	IP(*a*4,*a*5)	IP(*a*4,*a*6)
0.039295	0.053301	0.141615	0.17268
IP(*a*5,*a*2)	IP(*a*5,*a*3)	IP(*a*5,*a*4)	IP(*a*5,*a*6)
0.066109	0.061476	0.202568	0.0545
IP(*a*6,*a*2)	IP(*a*6,*a*3)	IP(*a*6,*a*4)	IP(*a*6,*a*5)
0.305534	0.10103	0.611568	0.438984

IP = (*ai, as*), *i,s* = 2,3,4,5,6; IP= $\sum tjPj(ai, as)$.

	*a*2	*a*3	*a*4	*a*5	*a*6	T+	T
*a*2	0	0.082911	0.393418	0.316357	0.19993	0.248154	0.036365
*a*3	0.436219	0	0.670658	0.553205	0.34342	0.500876	0.426196
*a*4	0.039295	0.053301	0	0.141615	0.17268	0.101723	−0.36783
*a*5	0.066109	0.061476	0.202568	0	0.0545	0.096163	−0.26638
*a*6	0.305534	0.10103	0.611568	0.438984	0	0.364279	0.171647
T−	0.211789	0.0746795	0.469553	0.36254	0.192633		

The results for community are shown in **Figure 6**.

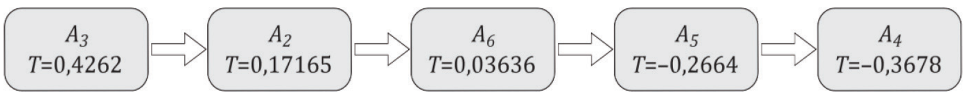

Figure 6. Chart representation of ranking results for the local community as a stakeholder.

5. Chart representation of results

After applying the PROMETHEE, as a tool for stakeholder value approach, and after the ranking, we can reach following conclusions on the basis of results obtained:

The results obtained and shown in the charts indicate, in fact, that, according to defined criteria and weight coefficients, the sequence of types of renewable energy sources is absolutely identical regardless of the stakeholder. The sequence of priorities in the application of renewable energy sources for the production of electricity goes as follows:

(1) Biomass

(2) Mini hydros

(3) Geothermal

(4) Wind energy

(5) Solar energy

Further activities of all stakeholders should be given to mini hydros and biomass, since they have the best relation toward the aforementioned criteria.

According to presented model, potentials of all the mentioned types of renewable energy sources are capable for achieving its goals, with the limitation that wind and geothermal energy would have, according to such a premise, a 96.82% usage, which is not a convenient circumstance, while biomass would have an 8.61% usage and mini hydros 24.20%.

The general conclusion is that the state as a stakeholder should focus its activities regarding the production of electricity from renewable energy sources on biomass and mini hydros, since, according to listed hypotheses, defined criteria and the application of the mathematical model, they proved to be the best solution. The same goes for investors and local community as stakeholders.

Methodology use in this chapter is taken into account the criteria and stakeholders which where possible to use according to the official available data. The final number of stakolders and criteria are endless and just make calculation model more comprehensive.

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