Inzinerine Ekonomika-Engineering Economics, 2013, 24(5), 408-414

New Application of SWARA Method in Prioritizing Sustainability Assessment Indicators of Energy System

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crossref http://dx.doi.org/10.5755/j01.ee.24.5.4526

A major topic among the current researches on energy is a sustainable energy development and assessment. An importance of energy system is obvious in our life. There are many important energy applications. There are heating and cooling, power generation, desalination, air conditioning and so on. By the year 2020 world will need 50% more energy than today and the Asia-Pacific region will become world's largest consumer of energy. In 21-st century, world faces with the challenge of converting its fossil fuels energy base to the sustainable energy sources. Regarding the increasing rise of the energy demand and consumption, virtually everyone in the world must implement an integrated resource planning (IRP). It is vitally important to achieve sustainable growth.

Sustainability assessment of energy system is one of the important issues in policy making all around the world. Decision making on energy system is very risky and difficult and therefore cannot be individual. Multi Criteria Decision Making (MCDM) is a renowned methodology in decision making and evaluation. Some of the most famous MCDM tools are as following: AHP, ANP, TOPSIS, ELECTRE, MUSA, AKUTA, VIKOR, PROMETHEE, SAW, MOORA, COPRAS, COPRAS-G, SWARA, FARE.

A Step-wise Weight Assessment Ratio Analysis (SWARA) method is one of the new MCDM methods presented in 2010. SWARA method is applied for some reasons in this paper. Firstly, SWARA's perspective is different from other similar methods like AHP, ANP and FARE. SWARA gives the chance for decision and policy makers to select their priority based on the current situation of environment and economy. In this method, expert has an important role on evaluations and calculating weights. The ability to estimate experts' opinion about importance ratio of the criteria is the main element of this method.

SWARA is developed for identifying importance of criteria and relative weights of each criterion. Current research applies SWARA as a new framework for evaluating and prioritizing sustainability assessment indicators of energy system. General indicator system consists of Resource Indicator, Environment Indicator, Economic Indicator and Social Indicator and their sub-criterions. For instance, complex environmental indicator consists of CO_2, SO_2 and NO_X indicators while complex economic indicator consists of energy costs, investment and efficiency indicators. The research revealed that the most important indicator is Social (0.342). Then, the range of indicators is as following: Environmental (0.284), Economic (0.212) and Resource (0.162).

Finally, the research shows that this methodology can be useful as a framework to operate with sustainability assessment indicators of the energy system. Also, this methodology can be used for decision making in real issues of future researches in different areas. The results of this methodology also can be compared to other methods such as AHP and ANP.

Keywords: *Sustainability assessment, Energy system, Step-wise Weight Assessment Ratio Analysis (SWARA), Multi Criteria Decision Making (MCDM).*

Introduction

Energy as a concerning issue for all people all around the world is as an inevitable component of everyday life (Ates & Durakbasa, 2012). Social and economic development of the societies needs energy (Kahraman & Kaya). Most industrial and commercial wealth generations inevitably require dealing with energy to increase social and economic well-being. Also, in order to relieve poverty increase, human welfare, and improve the living standards, energy as a key factor should be considered (International Atomic Energy Agency, 2005; Dong *et al.*, 2013).

During the last 40 years, energy is placed within the middle of triangle of the nature, society and economy and was converted to an essential element in the world (Bozoglan *et al.*, 2012). Energy demand of wealthy societies' becomes 25 % of the world's energy consuming population and 75 % of the world's energy supply (Dincer, 2000) due to the increase of world's population over 2 %.

There are many important energy applications, some of which are heating and cooling, power generation, desalination, and air conditioning. Much of work is being done to make energy more sustainable: economic, efficient, clean, and secure (Ahmadi *et al.*, 2012; Klevas *et al.*, 2007).

Many discussions and debates within government, non-government and academic circles are about the sustainable development, and it becomes a major focus of the national and international economic, social and environmental agendas (Bilgen *et al.*, 2008; Omer, 2008; Yusel, 2008; Wang *et al.*, 2009).

According to statistics, by the year 2020 world will need 50% more energy than today and the Asia-Pacific region will become world's largest consumer. Here are three major concerns (Tegart, 2009) as follow:

• Energy supply security and sustainability;

• Connection between combustion of fossil fuels and dramatic changes in climate;

• Accessibility of technological innovation in energy conversion, transmission and use.

Sustainability supplies local and national authorities to incorporate environmental considerations into energy planning (Bozoglan *et al.*, 2012).

In 21-st century, world confronts with the challenge of converting its fossil fuels energy base to the sustainable sources (Allen, 2009, 2010, 2011, 2012). Whole world's major interest is reaching to a sustainable energy balance as soon as possible to avoid both negative effects of global warming and significant economic problems when the oil and gas resources decrease too much and become too expensive to use (Dahlquist *et al.*, 2012).

Regarding the increasing rise of energy demand and consumption, for a sustainable growth, virtually everyone in the world must implement an integrated resource planning (IRP) (Amirnekooei *et al.*, 2012).

A strong influence on human thinking on decision-making in politics and economy is exerted by visions and scenarios of future developments, and it has also effected public debates. Specially, it is true in energy policy field, which is associated with long timescales and high uncertainties (Scrase & MacKerron, 2009; Grunwald, 2011).

Regarding the engineering feasibility and the requirements of such systems in terms of capital investments, and also in order to meet the need of required information on future, as well as being accessible of natural resources, energy policy decisions for the planning of new energy generation capacity have been designed. At the same time, it is expected that future energy systems in many current policy frameworks, will evolve around their gradual decarbonization to decrease anthropogenic interferences with the climate system (Mercure & Salas, 2012). Sustainability assessment of energy system is one of the important issues in policy making all around the world.

To do so, a prioritizing of sustainability assessment indicators should be made at first. That is the focal purpose of this research.

Sustainability Indicators

Schlor *et al.* (2013) selected 15 energy indicators for their analysis of the German energy sector: 1. Energy & raw materials productivity: Energy, Raw materials; 2. Emissions of the six greenhouse gases covered by the Kyoto Protocol; 3. Proportion of energy consumption from renewable energy: Primary energy consumption in %, Electricity consumption in %; 4. Mobility transport intensity: Passenger traffic, Goods traffic; 5. Air quality: Air quality, NO_X, SO_2, CO, Dust, NMVOC, NH_3; 6. Employment: Employment rate in %.

De Castro Camioto *et al.* (2013) used following variables in their sustainability analysis: Sectorial GDP; Personnel expenses; Persons employed; CO_2 emissions from fossil fuels; Energy consumption.

Lior (2012) presented some sustainability effects of the global 2008–2009 (2010) economic downturn using following parameters: Total PE consumption, EJ; Energy consumption/person, GJ/person; Electricity generated, TWh; Electricity generated/person, kWh/person; Electricity generation capacity, GW; Electricity generation capacity, kW/person; Total CO_2 emissions, million ton; CO_2 emissions, ton/person; GDP, PPP/person; Unemployment, %; HDI; Population, Millions.

Indicators used in our research of sustainability assessment of energy system are presented in Table 1. Indicators consist of four criteria. Each criterion includes at least two sub-criteria.

Table 1

Sustainability Indicators

Indicators	
Resource indicator (RI)	$\mathbf{C_1}$
Fuel indicator	$C_{1\text{-}1}$
Carbon steel indicator	$C_{1\text{-}2}$
Stainless steel indicator	$C_{1\text{-}3}$
Copper indicator	$C_{1\text{-}4}$
Aluminum indicator	$C_{1\text{-}5}$
Insulation indicator	$C_{1\text{-}6}$
Environment indicator (EI)	$\mathbf{C_2}$
CO2 indicator	$C_{2\text{-}1}$
SO2 indicator	$C_{2\text{-}2}$
NO_x indicator	$C_{2\text{-}3}$
Economic indicator (EcI)	$\mathbf{C_3}$
Energy costs indicator	$C_{3\text{-}1}$
Investment indicator	$C_{3\text{-}2}$
Efficiency indicator	$C_{3\text{-}3}$
Social indicator (SI)	$\mathbf{C_4}$
Job indicator	$C_{4\text{-}1}$
Diversity indicator	$C_{4\text{-}2}$

Source: Begic & Afgan, 2007

Brief Review on Multiple Criteria Decision Making (MCDM)

Decision making on energy system is very risky and difficult, and can't be individual. Multi-criteria decision making (MCDM) is a renowned methodology in decision making. It is a branch of the general class of operations research models which deal with decision problems under the presence of a number of decision criteria. The major class of models is very often called MCDM (Begic & Afgan, 2007). In this research, one of new MCDM methods applied for decision making. SWARA method is applied for some reasons in this paper. Firstly, SWARA's perspective is different from other similar methods like AHP, ANP and FARE. SWARA gives the chance to decision and policy makers to select their priority based on the current situation of environment and economy.

Secondly, the role of the experts is very important in this method. Experts have a key role in process of decision making on very important projects. At the end it should be added that SWARA has the advantage of more logical calculation of weights and relative importance of criteria.

In this research, application of SWARA is shown with a numerical example.

Operation research/Management science has many sub-disciplines with MADM one of them. Also, MADM is one of the two main categories of multi criteria decision making (MCDM). The other category of MCDM is multi objective decision making (MODM). In many decision-making problems, decision maker (DM) should deal with selecting an alternative among existing alternatives. Also, for making a decision by DM, alternatives should be compared and evaluated (Zavadskas *et al.,* 2009).

Some of the most famous MADM tools are as following: analytic hierarchy process (AHP) (Saaty, 1980), analytic network process (ANP) (Saaty & Vargas, 2001), technique for order preference by similarity to ideal solution (TOPSIS) (Hwang & Yoon, 1981), Elimination and Choice Translating Reality (ELECTRE) (Roy, 1968; Roy, 1991), MUSA (Grigoroudis & Siskos, 2002), AKUTA (Bous *et al.,* 2010), VIsekriterijumska optimizacijai KOmpromisno Resenje (VIKOR) (Opricovic, 1998), Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE) (Brans *et al.,* 1984; Brans & Vincke, 1985), Simple Additive Weighting (SAW) (Churchman & Ackoff, 1954), Multi-Objective Optimization on basis of Ratio Analysis (MOORA) (Brauers & Zavadskas, 2006; Brauers *et al.,* 2008), Complex Proportional ASsessment (COPRAS) (Zavadskas & Kaklauskas, 1996; Zavadskas *et al.,* 2007), Complex Proportional ASsessment with Grey relations (COPRAS-G) (Zavadskas *et al.,* 2009; Hashemkhani Zolfani *et al.,* 2011), Step-wise Weight Assessment Ratio Analysis (SWARA) (Kersuliene *et al.,* 2010; Zavadskas & Turskis, 2011; Balezentis *et al.,* 2012), Factor Relationship (FARE) (Ginevicius, 2011).

Step-wise weight assessment ratio analysis (SWARA) method

Weight assessment is an important issue in many MADM problems. Some famous weight assessment approaches in the literature include analytic hierarchy process (AHP) (Saaty, 1980), analytic network process (ANP) (Saaty & Vargas, 2001), Entropy (Shannon, 1948; Susinskas *et al.,* 2011, Kersuliene & Turskis, 2011), FARE (Ginevicius, 2011), SWARA (Kersuliene *et al.,* 2010), etc. Among these methods, SWARA method is one of the brand-new ones.

In this method, expert has an important role on evaluations and calculating weights. Also, each expert has chosen the importance of each criterion. Next, each expert ranks all the criteria from the first to the last one. An expert uses his or her own implicit knowledge, information and experiences. Based on this method, the most significant criterion is given rank 1, and the least significant criterion is given rank last. The overall ranks to the group of experts are determined according to the mediocre value of ranks (Kersuliene & Turskis, 2011).

The ability to estimate experts' opinion about importance ratio of the criteria in the process of their weights determination is the main element of this method (Kersuliene *et al.,* 2010). Moreover, this method is helpful for coordinating and gathering data from experts. Furthermore, SWARA method is uncomplicated and experts can easily work together. The main advantage of this method in decision making is that in some problems priorities are defined based on policies of companies or countries and there aren't any needs for evaluation to rank criteria.

In other methods like AHP or ANP, our model is created based on criteria and experts' evaluations that will affect priorities and ranks. So, SWARA can be useful for some issues that priorities are known former according to situations and finally SWARA was proposed for applying in certain environment of decision making. All developments of decision making models based on SWARA method up to now are listed below:

(Kersuliene *et al.,* 2010) in selection of rational dispute resolution method.

(Kersuliene & Turskis, 2011) for architect selection.

Hashemkhani Zolfani *et al.,* (2013a) in design of products.

Hashemkhani Zolfani *et al.,* (2013b) in selection optimal alternative of mechanical longitudinal ventilation of tunnel pollutants.

(Aghadaie *et al.,* 2013) in machine tool selection.

The procedure to the criteria weights determination is presented in Figure 1.

Numerical Example

Experts are core elements of SWARA method. Firstly, it's important to identify our expert/experts. As mentioned before about process of SWARA solving, at the first step, the experts selected the priority of criteria. In major decisions, it is so important to experts to consider all important aspects of the subject. Sustainability in major issues is effective in social and economical matters. Energy is a critical issue in various aspects of life and effects on all dimensions of people's life, and sustainability about energy is inevitable. Usually, government and experts are decision makers of energy topics. SWARA can be useful for the top level of decision making in each society. Thus, SWARA can be worked as a framework in energy and sustainability and all major issues in top level of decision making. In this part a numerical example based on our research model is presented in Table 1. The results in Table 2 show that social indicator is the most important indicator in this research. Weights of each indicator show the importance of each indicator. Another advantage of SWARA method is that the researches have the chance to remove criteria and indicators that are not so effective because experts should compare criteria together, and if distance between criteria becomes too much, they can argue that one of criteria has no important role in the model of the research.

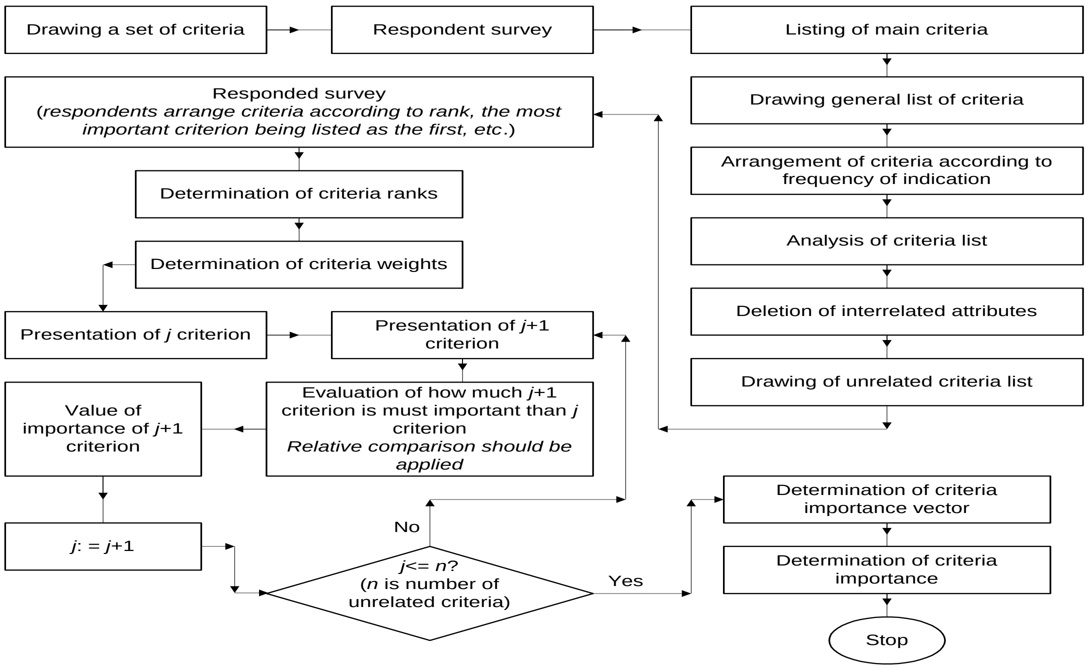

Figure 1. Determining of the criteria weights based on SWARA
Source: Kersuliene & Turskis, 2011

Table 2

Final results of SWARA method in weighting assessment indicators

Criterion	Comparative importance of average value s_j	Coefficient $k_j = s_j + 1$	Recalculated weight $w_j = \frac{x_{j-1}}{k_j}$	Weight $q_j = \frac{w_j}{\sum w_j}$
X_4		1	1	0.342
X_2	0.20	1.20	0.833	0.284
X_3	0.35	1.35	0.617	0.212
X_1	0.30	1.30	0.474	0.162

Source: created by the authors

Weights and relative values of each resource indicator are calculated in Table 3.

Table 3

Final results of SWARA method in weighting of resource indicators

Criterion	Comparative importance of average value S_j	Coefficient $k_j = s_j + 1$	Recalculated weight $w_j = \frac{x_{j-1}}{k_j}$	Weight $q_j = \frac{w_j}{\sum w_j}$
X_{1-1}		1	1	0.264
X_{1-2}	0.25	1.25	0.8	0.210
X_{1-4}	0.20	1.20	0.666	0.176
X_{1-3}	0.30	1.30	0.512	0.134
X_{1-6}	0.15	1.15	0.445	0.118
X_{1-5}	0.20	1.20	0.370	0.098

Source: created by the authors

Weights and relative importance of each indicator of environment indicators are calculated in Table 4.

Weights and relative importance of each indicator of economic indicators are calculated in Table 5.

Table 4

Final results of SWARA method in weighting of environment indicators

Criterion	Comparative importance of average value s_j	Coefficient $k_j = s_j + 1$	Recalculated weight $w_j = \frac{x_{j-1}}{k_j}$	Weight $q_j = \frac{w_j}{\sum w_j}$
X_{2-2}		1	1	0.400
X_{2-3}	0.25	1.25	0.8	0.320
X_{2-1}	0.15	1.15	0.695	0.280

Source: created by the authors

Table 5

Final results of SWARA method in weighting of economic criteria

Criterion	Comparative importance of average value s_j	Coefficient $k_j = s_j + 1$	Recalculate d weight $w_j = \frac{x_{j-1}}{k_j}$	Weight $q_j = \frac{w_j}{\sum w_j}$
X_{3-1}		1	1	0.390
X_{3-3}	0.15	1.15	0.869	0.338
X_{3-2}	0.25	1.25	0.695	0.272

Source: created by the authors

Weights and relative importance of each indicator of social indicators are calculated in Table 6.

Table 6

Final results of SWARA method in weighting of social sub-criteria

Criterion	Comparative importance of average value s_j	Coefficient $k_j = s_j + 1$	Recalculated weight $w_j = \frac{x_{j-1}}{k_j}$	Weight $q_j = \frac{w_j}{\sum w_j}$
X_{4-2}		1	1	0.565
X_{4-1}	0.30	1.30	0.769	0.435

Source: created by the authors

Conclusions

One of the most important concerns of society is a decision making especially on sustainability development issues. Energy is one of the most basic needs of each society and has a key role in economies and industries of the countries. It is expected that the role of energy in economies and industries will increase in forthcoming years. Topic of sustainability development is substantially connected to energy, so top level decision and policy makers should consider that point in their programs.

This research followed two important ideas and goals. Decision making on major issues is the first goal of this research and the next one is decision making on sustainable development of energy. In this research the authors propose a new methodology to solve the major issues.

As mentioned before, SWARA has some advantages in decision making that are suitable for decision making in high level. SWARA can play a key role in future decisions.

In this research by a numerical example we show the application of this method in decision making. The authors believe that this contribution can be useful as a framework for future researches in different areas.

This methodology can be used for decision making in real issues of future researches. The results of this methodology also can be compared to other methods such as AHP and ANP.

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***SWARA* metodo taikymas nustatant energetikos sistemos darnos prioritetinius rodiklius**

Santrauka

Kiekvieno pasaulio gyventojo neatsiejama gyvenimo dalis yra energijos vartojimas ir su juo susijusios problemos. Be to, energijos reikia socialinei ir ekonominei žmonijos plėtrai. Tiek išsivysčiusios industrinės, tiek besivystančios šalys naudoja energiją savo socialinei ir ekonominei gerovei kelti bei gyvenimo standartams didinti. Per pastaruosius keturiasdešimt metų, energija tapo svarbiausiu jungiančiuoju socialinės, ekonominės ir aplinkos darnios plėtros elementu. Svarbiausias dabartinių mokslinių tyrimų tikslas energetikos srityje, yra jos darni plėtra ir vertinimas. Energetikos svarba mūsų gyvenime yra akivaizdi. Energija naudojama šildymui, vėdinimui, oro kondicionavimui, elektros genaravimui, vandens gėlinimui ir t. t. Pasaulyje atliekama daug mokslinių tyrimų siekiant energetiką paversti darnia, ekonomiška, efektyvia, švaria ir saugia. Šios problemos yra aptariamos pasaulio vyriausybių, nevyriausybinių organizacijų, taip pat akademinės visuomenės.

2020 metais pasauliui reikės 50 proc. daugiau energijos negu šiandien, o Azijos-Ramiojo vandenyno regionas bus didžiausias jos vartotojas. Tai iškels tris pagrindinius iššūkius: 1) energijos tiekimo saugumo ir darnos; 2) iškastinio kuro deginimo ir staigios klimato kaitos; 3) energijos transformacijos, perdavimo ir naudojimo technologinių inovacijų prieinamumo. XXI amžiuje pasaulis susiduria su iššūkiu iškastinį kurą pakeisti atsinaujinančiais energijos šaltiniais. Tai būtina, norint pristabdyti globalinį klimato atšilimą ir energijos brangimą, kai išseks naftos ir dujų ištekliai. Dėl didėjančio energijos poreikio, visame pasaulyje teks įdiegti integruotą išteklių valdymą. Tuo pat metu tikimasi, jog ateityje energetikos sistemos tobulės ir mažės jų poveikis pasaulinei klimato sistemai. Sprendimų priėmimas energetikoje yra sudėtingas ir rizikingas procesas, todėl negali būti vienasmenis. Daugiakriteris sprendimų priėmimas yra žinoma metodika, priimant ir vertinant sprendimų alternatyvas. Ši metodika įgyvendinama naudojant daugiakriterius metodus. Žinomiausi daugiakriterės sprendimų paramos metodai yra šie: analitinis hierarchijos procesas: *AHP*, *ANP*; atstumo iki idealaus taško: *TOPSIS, ELECTRE, MUSA, AKUTA, VIKOR, PROMETHEE*; paprastas svertinis sumavimas: *SAW*, *MOORA*; kompleksinis proporcingumo įvertinimas: *COPRAS, COPRAS-G, SWARA, FARE.* Šiame straipsnyje taikytas palaipsnis *reikšmingumų* nustatymo metodas (*SWARA*) - vienas naujausių daugiakriterės sprendimų paramos metodų. Šis metodas pasirinktas dėl kelių priežasčių. Pirma, *SWARA* vertinimas yra kitoks nei *AHP*, *ANP* ar *FARE*, t. y. metodas leidžia sprendimo priėmėjui nusistatyti prioritetus, atsižvelgiant į esamą ekonomikos ir aplinkos būklę. Antra, skaičiuojant *SWARA* metodu svarbus ekspertų vaidmuo. Ekspertų nuomonė yra esminė vertinant labai svarbius projektus. Palaipsnis *reikšmingumų* nustatymo metodas yra vienas daugiakriterės sprendimų paramos metodų, sukurtų 2010 metais. Naudojant *SWARA* galima nustatyti rodiklių reikšmingumus.

Šiame straipsnyje *SWARA* metodas taikomas energetikos darnos rodikliams vertinti ir prioritetams nustatyti. Rodiklių sistema sudaryta iš keturių kompleksinių rodiklių: išteklių (I), aplinkos (A), ekonominio (E) ir socialinio (S). Kiekvienas kompleksinis rodiklis turi savąją, bent iš dviejų rodiklių sudarytą sistemą. Kompleksinį išteklių rodiklį sudaro šie, žemesnio lygio rodikliai: kuras, anglinis plienas, nerūdijantis plienas, varis, aliuminis, izoliacinės medžiagos. Kompleksinis aplinkos rodiklis sudarytas iš CO_2, SO_2 ir NO_x rodiklių, o kompleksinis ekonominis rodiklis iš energijos sąnaudų, investicijų ir efektyvumo rodiklių. Galiausiai, sudėtinis socialinis rodiklis skaidomas į du tikslesnius rodiklius: darbo ir įvairovės.

Galutiniai skaičiavimų rezultatai parodė, jog svarbiausias rodiklis – socialinis (0,342), antroje vietoje yra aplinkos (0,284), trečioje – ekonominis (0,212), ketvirtoje – išteklių (0,162). Atlikus modeliavimą su išteklių. „žemesnio“ lygio rodikliais, gauti tokie reikšmingumai: kuras (0,264), anglinis plienas (0,210), nerūdijantis plienas (0,134), varis (0,176), aliuminis (0,098), izoliacinės medžiagos (0,118). Po skaičiavimų su „aplinkos“ rodikliais, jų reikšmingumai pasiskirstė taip: CO_2 (0,280), SO_2 (0,400) ir NO_x (0,320). Sumodeliavus „ekonomikos“ rodiklių grupę, kiekvieno rodiklio reikšmingumas lygus: energijos sąnaudos (0,390), investicijos (0,272) ir efektyvumas (0,338). Ir pagaliau, įvertinus „socialinių“ rodiklių grupę, gauti tokie rezultatai: darbas (0,435) ir įvairovė (0,565). Siūloma metodologija yra naudinga modeliuojant energetikos sistemas pagal darnos vertinimo rodiklius. Be to, *SWARA* metodas gali būti naudojamas kaip sprendimų paramos sistema atliekant tyrimus ateityje. Rezultatai, gauti skaičiuojant siūlomu metodu, gali būti lyginami su gautaisiais, skaičiuojant pagal *AHP* ir *ANP*.

Raktažodžiai: *darnos vertinimas, energetikos sistema, palaipsnis reikšmingumų nustatymo metodas (SWARA), daugiakriteris sprendimų priėmimas.*

The article has been reviewed.

Received in June, 2013; accepted in December, 2013.