Ranking of Baltic States on progress towards the main energy security goals of European energy union strategy

Dalia Streimikiene
Mykolas Romeris University,
Vilnius, Lithuania,
Dalia.Streimikiene@lei.lt
ORCID 0000-0002-3247-9912

Abstract. The article is aimed to assess Baltic States in terms of achieved progress towards the goals of European energy union strategy. MCDM tools were applied for ranking Baltic States by applying the most important criteria formed on the basis of the goals of European energy union strategy. The discussion of policies to achieve these goals was performed for Baltic States based on energy policy analysis and National Energy and Climate plans (NAECP) submitted by countries to European Commission. Policy recommendations were developed based on analysis and assessments provided for Baltic States.

Keywords: Energy union strategy, energy security, MCDM, Baltic States.

JEL Classification: Q42, Q48, P46

1. INTRODUCTION

Energy services are related to the three main dimensions of sustainable development: environmental, economic and social (Fang et al, 2018). Energy sector plays very important role in economic and social development of the countries. The main issue to be addressed in the energy sector development is ensuring sustainable energy supply and maintaining of natural energy resources. As energy supply is the main driving force of modern civilization it is also responsible for the increasing quality of life including living standards for current and future generations (Heffron et al., 2015, Bilan at al, 2019). Therefore, energy supply is essential for human well-being, as can contribute significantly to strengthening social stability and is the main driver of development and prosperity of all sectors of modern economy. Though the energy intensity of GDP in modern economies is declining with the implementation of new technologies and technological progress, the huge amounts of energy will still be necessary for the improvement of living conditions in the developing nations (Kozubikova, Kotaskova, 2019; Bartiaux et al., 2019). Overall energy sector itself captures an important posture in the world economy by promoting growth of employment, income, and increase in international trade flows. The concept of sustainable energy development is the key in developing energy policies (European Commission, 2011).

EU has set ambitious targets to ensure sustainable energy development in EU. The main aim is to ensure just low carbon energy transition by 2050 (European Commission, 2018). Low carbon transition

means transition to renewable energy sources based energy supply and energy efficiency improvement (Turton, Barreto, 2006). These two ways of sustainable development provides for implementation of climate change mitigation targets. "Just" means satisfying energy equality by reducing energy vulnerability and energy poverty (Goldthau, Sovacool, 2012; Heffron, McCauley, 2018). The EU has developed European energy strategy in 2015 following various energy and climate frameworks establishing targets by 2020, 2030 and 2050 for renewables, energy efficiency and GHG emission reduction (European Commission, 2014; 2015; 2019).

The main objective of Energy union strategy adopted in 2015 is to provide energy consumers (households and businesses) in EU Member States (MS) with secure, affordable and clean energy (European Commission, 2015). The Energy union strategy covers five thoroughly interlinked and commonly reinforcing sustainable energy development magnitudes: security, solidarity and trust of European citizens; a completely-integrated internal energy markets; energy saving and increase in energy efficiency; decarbonization of energy and economy; research and development, innovation and competitiveness (Le Coq, Paltseva, 2009; Shindina et al., 2018).

In order to measure the progress made by EU MS in each of these magnitudes the key indicators were developed by European Commission (European Commission, 2015). The progress made in the five dimensions of the EU MS and the whole EU can be assessed by applying the following 5 thematic area indicators:

- Energy supply security, affordability, solidarity and trust of consumers;
- Development of fully integrated internal EU energy markets;
- Energy efficiency and demand side management;
- Decarbonisation of the economy and energy sector;
- Investments in R&D, innovation and competitiveness.

These broad thematic areas encompass amounts of greenhouse gas (GHG) emissions, primary and final energy consumption data, the shares of renewable energy sources in final energy consumption, electricity, heating and cooling, transport; energy intensities of GDP and branches of economy, energy import dependency indicators, energy retail and wholesale prices, annual switching rates for energy suppliers, investments in research and development and issued and registered patents. These indicators allow to ensure consistent assessment of progress achieved by countries in implementing targets set by energy and climate packages (Gracceva, Zeniewski, 2014). However, there are clear trade -offs between these thematic areas and indicators monitoring specific issues, therefore it is necessary to assess the overall progress achieved by countries in meeting all goals (Augutis et al., 2020). For this purpose the MCDM tools can be applied for monitoring progress achieved by EU Member States in implementation energy security goals which are first of all linked to energy supply security, solidarity and trust and developed of fully integrated internal energy markets areas and to provide ranking countries (Zeng et al., 2017).

As energy security is one of the most important issues in ensuring just low carbon energy transition as moving to 100% renewables rises very important energy security issues due to high intermittency of these energy generation sources (Badea et al., 2011; Kumar, 2016; Huchang et al., 2019), however then main research in this field is attributed to meeting climate change mitigation targets and moving to 100% renewables scenario (Newiadomsky, Seeliger, 2016; Ren at al., 2015; Jewel et al., 2014; Sovacool, 2013), the paper aims to overcome this gap and provides case study on MCDM assessment and ranking of Baltic States in terms of progress achieved in approaching energy security goals linked to EU energy union strategy. The rest of the article is organised as follows. Section 2 presents literature review; Section 3 introduces data and methods; Section 4 presents the results and discusses avenues for further research; section 5 concludes.

2. LITERATURE REVIEW

The concept "sustainable development" and "sustainability" as well as their derivatives such as "sustainable agriculture", "sustainable energy", "and sustainable economic development" called the most modern words of ninth century. As it was mentioned above sustainable energy is energy generated and applied in modes that provide for long -term human development in all its social, economic, and environmental dimensions (Lee et al, 2016). Or sustainable energy can be defined as energy generation and use of energy resources in modes that encourage long-term human well-being as well as ecological balance (Van Benthem, Romani, 2009). While it seems that there is no physical limits to the world's energy supply for the forthcoming 50 years, the development of energy systems encounter many challenges now linked to energy vulnerability, equity, poverty and resilience as well to various environmental issues including climate change and cause many geopolitical problems that will for sure have important consequences in the future (Radovanovic et al, 2017). The main issues of unsustainable energy development which are necessary to address are the following: low accessibility and affordability of energy; an inequity in energy distribution and consumption that provides moral, political, and practical implications at global level (Wang, Zhou, 2017; Wang, Liu, 2015, Bilan at al, 2019). In addition, it is necessary to stress that current energy system is not adequately secure, reliable and accesible to support common economic growth of world countries and it still has significant negative environmental impact on local, regional, and global level (Kruyt et al., 2009; Loschel et al., 2010; Hillerbrand, 2018).

Energy markets having the proper price signals, and policy frameworks including regulatory regimes, can provide for implementation of the main economic development goals for world countries but energy markets alone can't ensure that the energy needs of the most vulnerable people will be met as well as can't ensure environmental protection due to well-known market failures (Markandya, Pemberton, 2010). Therefore, though energy consumption in all its forms provides many assistances to sustainable development of the countries, however, it is also linked with several important environmental and social problems like negative health effects of air, water and land pollution. The negative environmental effects of energy supply are called as external energy generation costs, because they are not integrated in the costs of energy and do not provide needed price signals to reduce consumption of polluting energy resources. The policies and actions are necessary for quantifying damages associated with energy generation to provide for rational decisions on external costs integration via taxes on polluting fuels or/and subsidies to clean energy carriers. Therefore, energy market failures can be corrected by internalisation of the external energy generation costs and several methodologies were developed how to deal with this issues in terms of energy security (Mansson et al., 2014; Ren, Sovacool, 2014).

The World Energy Council (WEC) provided the following definition of energy sustainability based on 3 main energy supply dimensions: energy security, energy equity, and environmental sustainability (WEC, 2018). The Energy Trilemma Index was developed by WEC for ranking of world countries based on their performance according this three economic, social and environmental dimensions and to benchmark progress of countries. Energy security according WEC definition encompasses well-organized management of energy supply systems, high trustworthiness of energy infrastructure to ensure reliable energy supply, and ability of energy suppliers to ensure that energy demand is met. Energy equity encompasses energy accessibility and affordability for customers. Environmental sustainability includes energy efficiency and extent of the use of renewable energy sources, implementation of the sustainable supply chain management (Kovács & Kot, 2017; Popovic et al., 2017) as well as other low carbon energy carriers.

The Energy Trilemma Index developed by WEC counts the energy trilemma index and comparatively ranks 125 countries according to their capacity to deliver accessible, affordable, secure and

environmentally sustainable energy supply. Besides that, countries assessed by a balance score that shows how well the countries afford to trade-off between the three economic, social and environmental energy trilemma dimensions and categorises top doing countries by calculating the triple-A score.

The security of energy supply is among the most important and difficult to achieve issues in promoting sustainable energy development, low carbon energy transition and Green new deal objectives. The security of energy supply guarantees secure and reliable energy supply to all customers, during which very little or no disruption can be experienced (Sovacool, Saundrs, 2014). The monopolistic structure of energy sector allowed vertically integrated energy suppliers to make decision by themself how much energy security they need to provide and to invest in necessary precautionary measures due to their ability to pass these energy security cost to the final consumer by including these costs in energy price. The energy security provided by monopolistic energy suppliers can be too little or too much as there was no benchmark to assess it. The security of energy supply in liberalised energy markets is linked to different approach as energy security is being treated as a public good or externality which need to be internalized in the price of energy. Liberalised energy markets can't provide energy security by themselves as due to competition in energy markets they aim to reduce their energy supply costs and are tempted to 'free-ride' on the security issues. Similar situation was noticed in other network industries like airlines, railways and transport (Sovacool, Mukherjee, 2011, Lyulyov at al, 2105).

Usually, energy security is being treated as the problem which state or government should be responsible for. Small energy customers like households, who are not able to assess their energy security needs clearly would be satisfied with standard contract setting that the level of energy security should be decided by the regulator. The security of energy supply in households and small commercial establishments is primarily used for cooking and water-heating. In energy disruption situation, all these issues can be reasonably controlled to some degree. However, not all energy consumers need protection against energy supply disruptions. In liberalised energy markets, energy consumers have a choice of whether to assume responsibility for energy supply security by themselves or to forward this duty to energy supply company and to pay a risk premium by paying higher energy prices set by energy supplier because of guaranteed security of energy supply. This is typical situation with large industrial energy consumers. For large energy consumers short-term energy security issues are not problem as well as they have abilities to switch fuels. A large industrial energy consumer has few options: to buy more expensive energy from energy supplier providing guarantees for security of energy supply or to buy energy from a risky but cheap energy supplier by accepting the risk of disruption and for risk mitigation to install a dual-firing capability or a to arrange back-up from another energy supplier (Markandya, Pemberton, 2010, Mentel at al, 2018).

Power generation and network failures imply high costs associated with interruption in electricity supply. This can be expressed by damage caused by not delivered power divided by the amount of power not delivered in kWh. The Value of Lost Load (VOLL) is applied to provide monetary assessmnet of costs associated with electricity supply disruption in case of power generation, transmission and distribution failures. VOLL is applied to asses the energy supply security of a country, region or economic sector. Though the uncertainty of damage cost is quite high however even in the case of high uncertainties external costs estimates can support decision making in energy sector. The external costs of climate change and energy security can be used for policies impact assessment in monetary terms and help to cope with the problems of trade-off between policies. The assessment external costs of energy security obtained during EU Cases (2008) project can be treated as the first step in creating framework for integration of such type of costs in decision making in energy policy and selecting harmonized policy packages able to achieve sustainable energy development policy goals at least cost. However, the new data on valuation and verification of energy security costs are missing therefore other approach can be selected for assessing

energy supply security level in selected EU MS. In next section of the paper indicators framework was developed and MCDM tools were selected for ranking Baltic countries in terms of energy security of supply.

3. METHODS AND DATA

Security of energy supply is the priority of the European energy union strategy and the following indicators are established for the monitoring of security of energy supply in EU. The following indicators of energy security were applied current study:

Overall energy import dependency, %. This is the core energy security indicator calculated by EUROSTAT annually for each EU member state and the whole EU. This indicator assesses the level of total net imports as a proportion of total gross inland energy consumed in a country during the specific year. This core indicator is supplemented by several sub-indicators or supporting indicators reflecting net energy import dependency for solid fuels, hard coal, crude oil and NGL and natural gas.

As energy import dependency does not provide information on the diversification degree of import, it is important to have another core security of energy supply indicator- country-specific supplier concentration index (SCI) to extend the assessment of energy security dimension.

Country-specific supplier concentration index (SCI), measured in unit 0-100 where 100 means maximal concentration. This is also a core energy security indicator calculated by EUROSTAT annually. This indicator provides assessment of the importance of total imports of main energy carriers to a Member State from suppliers outside EU. The aggregate SCI is supplemented by several sub-indicators, i. e. SCIs for hard coal, natural gas and oil and NGL.

Also, capacities of interconnections play important role for security of energy supply therefore indicators to monitor electricity interconnection capacities are necessary.

Electricity interconnection capacity, MWh assesses the interconnection capacity of EU MS as a share of its total generation capacity.

For competition and market concentration in energy markets two core indicators were established: market concentration index for power generation and for wholesale natural gas supply. These two core indicators measure the degree of competition on wholesale power and natural gas markets: the lower the values, the higher the degree of potential competition. Also these indicators are supplemented by sub-indicators measuring the cumulative market share in power generation and in power capacities of main entities in % as well as cumulative market share of main entities bringing natural gas to the country in %.

Market concentration index for electricity generation is calculated on the basis of Herfindahl Hirschman Index (HHI) and evaluated as the sum of the squared market shares of the 3 largest power generation entities measured in percentages of total installed capacity, with 10 000 corresponding to a total monopoly or a single supplier). The unit is 0-10000.

Market concentration index for wholesale gas supply is also calculated on the basis of HHI and is assessed as the sum of the squared market shares of the wholesale natural gas supply entities measured in percentages of total wholesale natural gas supply The unit is 0-10000 and 10000 means total monopoly or single supplier in the gas market.

In implementing the internal energy market objectives there are other important factors of energy security, such as wholesale gas and electricity price developments across Member States. However, there are problems in monitoring of these prices. For natural gas, available price data is not comparable across Member States.

There are other two core indicators of energy security for assessment of the degree to which consumers are empowered on retail energy markets. These are annual switching rates on electricity and natural gas retail markets

Annual switching rates on electricity retail markets expressed by % of total consumers evaluates the percentage of final electricity household consumers changing power suppliers in a given year.

7. Annual switching rates on gas retail expressed by % of total consumers evaluates the percentage of final household consumers changing natural gas suppliers in a given

8. Energy affordability indicator is a core indicator which measures the energy-related expenditure as a proportion of total household expenditure for the lowest quintile (i.e. poorest 20 %) of population. It is calculated based on Eurostat's Household Budget Survey (HBS), where data is being collected every five years.

There are several sub-indicators supplemented energy affordability indicator. The harmonised index of consumer prices (HICP) for energy-related expenditure assesses the proportion of total household expenditure used for energy services and is applied in EU MS central banks for evaluation of inflation. Another sub- indicator is inability to keep the home adequately warm. This indicator is by SILC and calculated as the proportion of the total population at risk of poverty (i.e. below 60 % of the median national income).

Electricity and natural gas retail prices for households are also used as sub-indicators providing additional information on energy affordability issues.

The most important energy security indicators and sub-indicators for ranking EU MS in terms of progress achieved in meeting European energy union strategy goals are provided in Table 1.

Table 1

Criteria for ranking countries on energy security based on European energy union strategy goals

Criteria	Description
C1	**Total Energy Import Dependency - %**
C1.1	Energy import dependency on solid fossil fuels, %
C1.2	Energy import dependency on hard coal, %
C1.3	Energy import dependency on oil products and oil, %
C1.4	Energy import dependency on NGL, %
C1.5	Energy import dependency on natural gas, %
C2	Aggregate supplier concentration index, unit 0-100 (100 means maximum)
C2.1	Supplier concentration index - Natural gas
C2.2	Supplier concentration index oil
C2.3	Supplier concentration index Hard coal
C3	Electricity interconnection capacity, %
%	Market concentration index for power generation, unit 0-10000 (10000 means a single supplier
C4.1	Cumulative market share in power generation, main entities, %
C4.2	Cumulative market share in power capacities, main entities, %
C5	Market concentration index for wholesale gas supply unit 0-10000 (10000 means a single supplier
C5.1	Cumulative market share of main entities bringing gas in the country, %
C6	Annual switching rates -electricity (household customers), % of total consumers
C7	Energy affordability - energy expenditure share in final consumption expenditure for the lowest quintile, %
C7.1	Harmonized Index of consumer prices - weight of electricity, gas and other fuels in total household expenditure, %

C7.2	Inability to keep home adequately warm (share in total population at risk of poverty), %
C7.3	Household electricity prices EUR/kWh
C7.4	Household natural gas prices, EUR./kWh

Source: own compilation

The most important indicators for ranking Baltic States in terms of progress achieved in meeting energy union strategy goals are provided in Table 2.

Table 2

Energy security indicators for Baltic States in 2018 based on criteria given in Table 1

No.	Area	Estonia (EE)	Latvia (LV)	Lithuania (LT)	Goal
C1	**Total Energy Import Dependency - %**	0.7%	44.3%	74.2%	Min
C1.1	of Solid fossil fuels	85.2%	91.3%	99.0%	Min
C1.2	of Hard Coal	88.0%	91.3%	98.8%	Min
C1.3	of Oil and petroleum products	84.3%	98.1%	98.4%	Min
C1.4	of Crude and NGL	0.0%	0.0%	99.2%	Min
C1.5	of natural gas	100.0%	98.8%	98.9%	Min
C2	**Aggregate supplier concentration index. unit 0-100 (100 means maximum)**	76.05	42.32	47.75	Min
C2.1	Supplier concentration index - natural gas	100	97.68	34.48	Min
C2.2	Supplier concentration index- oil	0	0	51.04	Min
C2.3	Supplier concentration index- hard coal	77.44	99.2	97.68	Min
C3	**Electricity interconnection capacity, %**	67.6	53.9	86.5	Max
C4	**Market concentration index for power generation, unit 0-10000 (10000 means a single supplier**	7134.23	9080.26	5055.44	Min
C4.1	Cumulative market share in power generation, main entities, %	74	86.3	54.2	Min
C4.2	Cumulative market share in power capacities, main entities, %	80	63.4	39.2	Min
C5	**Market concentration index for wholesale gas supply unit 0-10000 (10000 means a single supplier**	4926	10000	6375.52	Min
C5.1	Cumulative market share of main entities bringing gas in the country, %	100	91.0	97.6	Min
C6	**Annual switching rates -electricity (household customers), % of total consumers**	1.4	0	0	Max
C7	**Energy affordability - energy expenditure share in final consumption expenditure for the lowest quintile, %**	12.41	12.21	11.46	Min
C7.1	Harmonised index of consumer prices - weight of electricity, gas and other fuels in total household expenditure, %	6.7	9.04	5.67	Min
C7.2	Inability to keep home adequately warm (share in total population at risk of poverty), %	4.2	15.4	35.5	Min
C7.3	Household electricity prices EUR/kWh	0.142	0.151	0.11	Min
C7.4	Household natural gas prices, EUR/kWh	0.043	0.045	0.041	Min

Source: own compilation

The collected data provided in Table 2 was processed using COPRAS MCDM tool. Zavadskas and Kaklauskas proposed the COPRAS (COmplex Proportional ASsessment) method in 2008 to deal with decision-making and ranking issues (Zavadskas et al., 2008). The COPRAS presume both direct and proportional dependence of the priority of alternatives regarding the identified criteria. Also, In conventional COPRAS, criteria weights and alternatives' ratings are crisp (Ajalli et al., 2017). The COPRAS can be applied in a vast verity of the field, such as energy issues. For instance, Alkan and Albayrak (2020) applied and integrated the Fuzzy COPRAS-MULTIMOORA method to rank Turkey's renewable resources (Alkan and Albayrak, 2020). Dhiman and Deb applied an integrated fuzzy COPRAS-TOPSIS method to rank hybrid wind farms and find the best strategy (Dhiman and Deb, 2020). In the following, the steps of the COPRAS method are presented.

Step 1. (Das et al., 2012) Decision-making matrix Construction
In the first step, the decision-making matrix (D) should be constructed to compare all alternatives regarding criteria. The experts' opinions can be asked for comparing processes, while it is possible to use pre-prepared data. The decision-making matrix (D) is presented below, which n is the number of criteria, m is the number of alternatives.

Table 3

The decision-making matrix

Criteria / Alternative	C_1	C_2	...	C_n
A_1	X_{11}	X_{12}	...	X_{1n}
A_2	X_{21}	X_{22}	...	X_{2n}
⋮	⋮	⋮	...	⋮
A_m	X_{m1}	X_{m2}	...	X_{mn}
W_J	W_1	W_2	...	W_n

Step 2. Normalization
The constructed decision-making matrix (D) must be normalized in the second step to construct Normalized Decision-making (ND) matrix. This is due to the fact that the criteria have been measured in different units; thus, it is impossible to compare alternatives regarding the criteria unless they are normalized. To this end, equation one is used in COPRAS.

$$\tilde{x}_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} \quad for\ (j = 1, ..., n) \tag{1}$$

Step 3. Weighted-Normalized Decision-making (WND) matrix Construction
The importance of criteria is different so that they have different weights. Thus, each element of the Normalized Decision-making matrix should be multiplied by criteria weight. To this end, equation two is used, subject to $\sum_{i=1}^{n} W_i = 1$.

$$\hat{x}_{ij} = \tilde{x}_{ij} * w_j \quad (i = 1, ..., m; j = 1, ..., n) \tag{2}$$

Step 4. S_i^+ and S_i^- Calculation
In the fourth step, S_i^+ and S_i^- must be calculated. In the COPRAS method, alternatives are described by the summation of maximizing attributes S_i^+ and minimizing attributes S_i^-. Put simply, the S_i^+ and S_i^-

can be calculated using equation three and four. $\hat{x}_{ij}^+$ is the $\hat{x}_{ij}$ of the maximizing criterion and $\hat{x}_{ij}^-$ is the $\hat{x}_{ij}$ of the minimizing criterion.

$$S_i^+ = \sum_{j=1}^{n} \hat{x}_{ij}^+ \tag{3}$$

$$S_i^- = \sum_{j=1}^{n} \hat{x}_{ij}^- \tag{4}$$

Step 5. Relative Weight Calculation

The relative weight of each alternative can be calculated regarding the S_i^+ and S_i^-. To this end, the relative weight Q_i of i_{th} alternative is calculated using equation five.

$$Q_i = S_i^+ + \frac{\sum_{i=1}^{n} S_i^-}{S_i^- \sum_{i=1}^{n} \frac{1}{S_i^-}} \tag{5}$$

Step 6. Priority Order Determination

Finally, the priority order of alternatives U_i should be calculated concerning the relative weight. To this end, equation six is used. The alternative with the greater U_i is the best alternative. U_i Usually is presented in percent.

$$\left[U_i = \frac{Q_i}{Q_{Max}} \right] * 100 \tag{6}$$

4. DISCUSSION OF RESULTS

For Multi-criteria decision analysis (MCDA) and ranking of Baltic States in terms of progress achieved in terms of security of energy supply under European energy union strategy two assessment scenarios were completed by applying 2018 year data. COPRAS MCDM tool applied and equal weights for criteria are allocated to ensure holistic approach in MCDM ranking exercise.

Scenario1 for MCDA of Baltic States includes ranking of Baltic States according 7 main criteria (C1-C7): Total energy import dependency; Aggregate supplier concentration index; Electricity interconnection capacity; Market concentration indexes for power generation and wholesale gas supply; Annual; switching rates of power households customers and Energy affordability.

Scenario 2 for MCDA of Baltic States includes ranking of Baltic States according all main criteria and all sub-criteria (total 22 criteria).

In the following Tables 4-7 results of first scenario were provided for Baltic States.

Table 4

Decision-making Matrix (D)

D	C1	C2	C3	C4	C5	C6	C7
Estonia	0.007	76.05	67.6	7134.23	4926	1.4	12.41
Latvia	0.443	42.32	53.9	9080.26	10000	0	12.21
Lithuania	0.742	47.75	86.5	5055.44	6375.52	0	11.46
Weight	Equal Weight → Wi=1/7						
Type	Min	Min	Max	Min	Min	Max	Min

Table 5

Normalized Decision-making Matrix (ND)

ND	C1	C2	C3	C4	C5	C6	C7
Estonia	0.0062	0.4578	0.3250	0.3354	0.2313	1.0000	0.3440
Latvia	0.3714	0.2548	0.2591	0.4269	0.4695	0.0000	0.3384
Lithuania	0.6224	0.2874	0.4159	0.2377	0.2993	0.0000	0.3176
Weight	Equal Weight → Wi=1/7						
Type	Min	Min	Max	Min	Min	Max	Min

Table 6

Weighted-Normalized Decision-making Matrix (WND)

WND	C1	C2	C3	C4	C5	C6	C7
Estonia	0.0009	0.0654	0.0464	0.0479	0.0330	0.1429	0.0491
Latvia	0.0531	0.0364	0.0370	0.0610	0.0671	0.0000	0.0483
Lithuania	0.0889	0.0411	0.0594	0.0340	0.0428	0.0000	0.0454
Weight	Equal Weight → Wi=1/7						
Type	Min	Min	Max	Min	Min	Max	Min

Table 7

Final Results

Results	S_i^+	S_i^-	Q_i	U_i	Rank
Estonia	0.189	0.196	0.473	100%	1
Latvia	0.037	0.266	0.247	52.1%	3
Lithuania	0.059	0.252	0.280	59.3%	2

Source: own compilation

As one can see on information provided in Tables above Estonia is the best performing country in terms of energy security and Latvia is the worst performing country according to scenario1 results. Taking a look on very low total energy import dependency rate in Estonia these results do not require many explanations as Estonia distinguishes among other EU MS with the lowest total energy import dependency due to availability of huge oil shale resources in the country as well on well developed usage of renewable energy systems.

In the following Tables 8-11 results of second scenario were provided for Baltic States.

Table 8

Decision-making Matrix (D)

D	C1	C1.1	C1.2	C1.3	C1.4	C1.5	C2	C2.1	C2.2	C2.3	C3	C4	C4.1	C4.2	C5	C5.1	C6	C7	C7.1	C7.2	C7.3	C7.4
EE	7.4-E3	0.9	0.9	0.8	0	1.0	76.1	100.0	0	77.4	67.6	71.3-E2	74.0	80.0	4.9+E3	100.0	1.4	12.4	6.7	4.2	0.1	4.3-E2
LV	0.4	0.9	0.9	1.0	0	1.0	42.3	97.7	0	99.2	53.9	9.1+E3	86.3	63.4	1.+E4	91.0	0	12.4	9.0	15.4	0.2	4.5-E2
LT	0.7	1.0	1.0	1.0	1.0	1.0	47.8	34.5	51.0	97.7	86.5	5.0+E3	54.2	39.2	6.5+E3	97.6	0	11.5	5.70	35.5	0.1	4.1-E2
Weight	Equal Weight → Wi=1/22																					
Type	Min	Min	Min	Min	Min	Min	Min	Min	Min	Min	Max	Min	Min	Min	Min	Min	Max	Min	Min	Min	Min	Min

Table 9

Normalized Decision-making Matrix (ND)

ND	C1	C1.1	C1.2	C1.3	C1.4	C1.5	C2	C2.1	C2.2	C2.3	C3	C4	C4.1	C4.2	C5	C5.1	C6	C7	C7.1	C7.2	C7.3	C7.4
EE	6.0-E3	0.3	0.3	0.3	0	0.3	0.5	0.4	0	0.3	0.33	0.33	0.33	0.43	0.23	0.4	1.0	0.3	0.3	0.1	0.4	0.3
LV	0.4	0.3	0.3	0.4	0	0.3	0.3	0.4	0	0.4	0.4	0.4	0.4	0.4	0.5	0.3	0	0.3	0.4	0.3	0.4	0.4
LT	0.6	0.4	0.5	0.4	1.0	0.3	0.3	0.2	1.0	0.4	0.5	0.2	0.3	0.2	0.3	0.3	0	0.3	0.3	0.6	0.3	0.3
Weight	Equal Weight → Wi=1/22																					
Type	Min	Min	Min	Min	Min	Min	Min	Min	Min	Min	Max	Min	Min	Min	Min	Min	Max	Min	Min	Min	Min	Min

Table 10

Weighted-Normalized Decision-making Matrix (WND)

WND	C1	C1.1	C1.2	C1.3	C1.4	C1.5	C2	C2.1	C2.2	C2.3	C3	C4	C4.1	C4.2	C5	C5.1	C6	C7	C7.1	C7.2	C7.3	C7.4
EE	2.8-E4	1.4-E2	1.4-E2	1.3-E2	0	1.5-E2	2.1-E2	2.0-E2	0	1.3-E2	1.5-E2	1.5-E2	1.6-E2	2.0-E2	1.1-E2	1.6-E2	4.6-E2	1.6-E2	1.4-E2	3.5-E3	1.6-E2	1.5-E2
LV	1.7-E2	1.5-E2	1.5-E2	1.6-E2	0	1.5-E2	1.6-E2	1.9-E2	0	1.6-E2	1.2-E2	1.9-E2	1.8-E2	1.6-E2	2.1-E2	1.4-E2	0	1.5-E2	1.9-E2	1.3-E2	1.7-E2	1.6-E2
LT	2.8-E2	1.6-E2	1.6-E2	1.6-E2	4.5-E2	1.6-E2	1.3-E2	6.8-E3	4.5-E2	1.6-E2	1.9-E2	1.1-E2	1.1-E2	9.8-E3	1.4-E2	1.5-E2	0	1.4-E2	1.2-E2	2.9-E2	1.2-E2	1.4-E2
Weight	Equal Weight → Wi=1/22																					
Type	Min	Min	Min	Min	Min	Min	Min	Min	Min	Min	Max	Min	Min	Min	Min	Min	Max	Min	Min	Min	Min	Min

Table 11

Final raking results

Results	S_i^+	S_i^-	Q_i	U_i	Rank
Estonia	0.060	0.252	0.416	100%	1
Latvia	0.012	0.294	0.317	76.2%	2
Lithuania	0.019	0.362	0.267	64.1%	3

Source: own compilation

As one can see on information provided in Tables 8-11 above Estonia is again the best performing country in terms of energy security and this time is Lithuania is the worst performing country according to scenario 2 results. This is linked with very low indicators of Lithuania for sub-criteria: inability to keep home adequately warm under energy affordability dimension. This indicator in Lithuania is almost ten time worse then in Estonia and twice worse than in Latvia, showing big problems of high energy vulnerability and energy poverty and low energy affordability in Lithuania. This problem is linked to low quality of multi-flat buildings stock inherited from soviet past and low renovation rate as households are trapped in the inefficient multi-flat buildings without any ability to regulate temperature or switch to another supplier. Another problematic issue in Lithuania is highest total energy important dependence (ten times higher than in Estonia and almost twice higher than in Latvia. According other indicators of energy security Lithuania set in European energy union strategy there are no such big differences between Baltic States.

5. CONCLUSION

The aim of sustainable energy development is to provide secure, accessible, affordable and clean energy to all consumers. The ultimate goal of sustainable energy development is to find a coherent and long-lasting balance between economic, social and environmental aspects of energy supply.

Now the main sustainable energy policy goal for EU is achieving climate neutral society by 2050. Climate neutral society is not simply a goal for climate change mitigation in energy sector. There are many important challenges of low carbon energy transition in addressing the major environmental, economic and social problems under the broad sustainability agenda. Climate neutrality is presumed to provide also individual benefits, such as reduced expenditures, increased quality of life and improved public health however important energy security of supply issues need to be addressed simultaneously.

Energy security is one of the most important challenges of sustainable energy development and low carbon energy transition as achieving 100% renewable energy scenarios causes a lot of energy security problems liked to intermittency of renewable energy supply. There are several important areas linked to increase of energy security: reduction energy import dependency, increasing interconnection capacities and diversification of energy supply as well as reducing market concentration and promoting energy market liberalization to all consumers.

As there are several important areas for assessing the security of energy supply the application of MCDM tools for assessment of results achieved by Baltic States in energy supply security goals under European energy strategy provided in this paper allows to trade-off between important social, economic and environmental criteria of just low carbon energy transition in selected countries.

For sensitivity analysis two scenarios for MCDA of Baltic States were developed: scenario 1 including just core 7 criteria and indicators for assessment of security of energy supply and scenario 2 including 22 criteria as well core and sub-indicators for assessment of security of energy supply.

The results of conducted MCDA analysis provided that Estonia is the best performing country in terms of energy security according bot scenarios as this country distinguishes from other Baltic states with good performance in terms of energy import dependency and energy affordability indicators.

Latvia was founds as worst performing country in terms of energy security according to MCDA Scenario 1 which includes just 7 core energy security criteria. This is because of the highest market concentration index for power generation and wholesale natural gas supplier.

Lithuania was found as the worst performing country according to scenario 2 including all sub-criteria results. This is linked with low performance of Lithuania in terms of several sub-criteria: inability to keep home adequately warm under energy affordability dimension. This indicator in Lithuania is almost ten time worse than in Estonia and twice worse than in Latvia, showing big problems of high energy vulnerability and energy poverty and low energy affordability in Lithuania. This problem is linked to low quality of multi-flat buildings stock inherited from soviet past and low renovation rate as households are trapped in the inefficient multi-flat buildings without any ability to regulate temperature or switch to another supplier. Another problematic issue in Lithuania is highest total energy important dependence (ten times higher than in Estonia and almost twice higher than in Latvia.

REFERENCES

Ajalli, M., Azimi, H., Balani, A. M., & Rezaei, M. (2017). Application of fuzzy AHP and COPRAS to solve the supplier selection problems. *International Journal of Supply Chain Management*, *6*, 112-119.

Alkan, Ö., & Albayrak, Ö. K. (2020). Ranking of renewable energy sources for regions in Turkey by fuzzy entropy based fuzzy COPRAS and fuzzy MULTIMOORA. *Renewable Energy, 162*, 712-726.

Augutis, J., Krikštolaitis, R., Martišauskas, L., Urbonienė, S., Urbonas, R., & Ušpurienė, A. B. (2020). Analysis of energy security level in the Baltic States based on indicator approach. *Energy*, *199*, 117427,

Badea AC, Rocco CM, Tarantola S, Bolado R. (2011). Composite indicators for security of energy supply using ordered weighted averaging. *Reliability Engineering and System Safety,* 96, 651e62. https://doi.org/10.1016/j.ress.2010.12.025

Bartiaux, F., Maretti, M., Cartone, A., Biermann, P. & Krasteva, V. (2019). Sustainable energy transitions and social inequalities in energy access: A relational comparison of capabilities in three European countries. *Global Transitions, 1*, 226-240, https://doi.org/10.1016/j.glt.2019.11.002

Bilan, Y., Raišienė, A. G., Vasilyeva, T., Lyulyov, O., & Pimonenko, T. (2019). Public governance efficiency and macroeconomic stability: Examining convergence of social and political determinants. *Public Policy and Administration*, 18(2), 241-255. doi:10.13165/VPA-19-18-2-05

Bilan, Y., Brychko, M., Buriak, A., & Vasilyeva, T. (2019). Financial, business and trust cycles: The issues of synchronization. *Zbornik Radova Ekonomskog Fakultet Au Rijeci*, 37(1), 113-138. doi:10.18045/zbefri.2019.1.113

Das, M. C., Sarkar, B. & Ray, S. (2012). A framework to measure relative performance of Indian technical institutions using integrated fuzzy AHP and COPRAS methodology. *Socio-Economic Planning Sciences,* 46, 230-241.

Dhiman, H. S. & Deb, D. (2020), Fuzzy TOPSIS and fuzzy COPRAS based multi-criteria decision making for hybrid wind farms." Energy*, 202*, 117755.

European Commission (2011). Communication from the Commission (2020), Europe 2020: A Strategy for Smart, Sustainable and Inclusive Growth. Available online: http://ec.europa.eu/europe2020/index_en.htm (accessed on 10 March 2020).

European Commission. (2014) European energy security Strategy. EU, European union. Brussels: European Commission, 2014. Brussels, 28.5.2014, COM(2014) 330 final. Available online: https://www.eesc.europa.eu/resources/docs/european-energy-security-strategy.pdf (accessed on March 10 2020).

European Commission. (2015) Communication From the Commission to the European Parliament, The Council, The European Economic and Social Committee, The Committee of the Regions and the European Investment Bank a Framework Strategy for a Resilient Energy Union with a Forward-Looking Climate Change Policy. COM/2015/080 final. Available online: https://eur-lex.europa.eu/resource.html?uri=cellar:1bd46c90-bdd4-11e4-bbe1-01aa75ed71a1.0001.03/DOC_1&format=PDF (accessed on March 10 2020).

European Commission (2019). Communication From the Commission to the European Parliament, The European Council, The Council, The European Economic and Social Committee and the Committee of the Regions. The European Green Deal. Brussels, 11.12.2019 COM (2019) 640 final. Available online https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1596443911913&uri=CELEX:52019DC0640#document2 (accessed on March 10 2020).

European Commission (2018). Communication From the Commission A Clean Planet for all. A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy, Brussels, 28.11.2018. COM(2018) 773 final. Available on online: https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52018DC0773&from=EN (accessed on March 10 2020).

Fang, D., Shi, S., & Yu, Q. (2018), Evaluation of Sustainable Energy Security and an Empirical Analysis of China. *Sustainability* 10, 1685.

Goldthau, A., & Sovacool, B.K. (2012). The uniqueness of the energy security, justice, and governance problem. *Energy Policy,* 41, 232–240.

Gracceva, F., & Zeniewski, P. (2014). A systemic approach to assessing energy security in a low-carbon EU energy system. *Applied Energy*, 123, 335–348.

Heffron R.-J., & McCauley D. (2018), What is the 'just transition. *Geoforum, 88*, 74-77.

Heffron, R. J., McCauley, D., & Sovacool, B. J. (2015). Resolving society's energy trilemma through the Energy Justice Metric. *Energy Policy*, 87, 168-176, https://doi.org/10.1016/j.enpol.2015.08.033.

Hillerbrand, R. (2018). Why affordable clean energy is not enough. A capability perspective on the sustainable development goals. *Sustainability, 10*, 2485 https://doi.org/10.3390/su10072485.

Huchang L., Long, Y., TMing, T., Mardani, A., & Juping Xu, J. (2019). Low Carbon Supplier Selection Using a Hesitant Fuzzy Linguistic SPAN Method Integrating the Analytic Network Process. *Transformations un Business & Economics*, 18, 2(47), 67-87.

Kovács, G., & Kot, S. (2017). Economic and social effects of novel supply chain concepts and virtual enterprises. *Journal of International Studies*, 10(1), 237-254. doi:10.14254/2071-8330.2017/10-1/17

Kozubikova, L., & Kotaskova, A. (2019). The Impact of Technological Factors on the Quality of the Business Environment. *Transformations un Business & Economics*, 18,1 (46), 95-108.

Kruyt, B., van Vuuren, D.P.V., de Vries, H.J.M., & Groenenberg, H. (2009). Indicators for energy security. *Energy Policy*, *37*, 2166–2181.

Kumar, S. (2016). Assessment of renewables for energy security and carbon mitigation in Southeast Asia: The case of Indonesia and Thailand. *Applied Energy,* 163, 63–70.

Le Coq, C., Paltseva, E. (2009). Measuring the security of external energy supply in the European Union. *Energy Policy* 38, 4474-4481.

Lee, S., Yoon, B., Shin, J. (2016). Effects of Nuclear Energy on Sustainable Development and Energy Security: Sodium-Cooled Fast Reactor Case. *Sustainability, 8*, 979.

Lyulyov, O., Chortok, Y., Pimonenko, T., & Borovik, O. (2015). Ecological and economic evaluation of transport system functioning according to the territory sustainable development. *International Journal of Ecology and Development*, 30(3), 1-10.

Markandya, A., & Pemberton, M. (2010). Energy Security, energy modelling and uncertainty. *Energy Policy,* 38, 1609-1613

Mentel, G., Vasilyeva, T., Samusevych, Y., & Pryymenko, S. (2018). Regional differentiation of electricity prices: Social-equitable approach. *International Journal of Environmental Technology and Management*, 21(5-6), 354-372. doi:10.1504/IJETM.2018.100583

Newiadomsky, C., & Seeliger, A. (2016). Security of energy supply: Will it stand the test of climate change—And what will it cost? *Electrical Engineering,* 98, 385–393.

Popovic, T., Kraslawski, A., Barbosa-Póvoa, A., & Carvalho, A. (2017). Quantitative indicators for social sustainability assessment of society and product responsibility aspects in supply chains. *Journal of International Studies*, 10(4), 9-36. doi:10.14254/2071-8330.2017/10-4/1

Radovanovic M, Filipovic S, & Pavlovic D. (2017). Energy security measurement e a sustainable approach. *Renewable and Sustainable Energy Reviews* 68, 68:1020-32. https://doi.org/10.1016/j.rser.2016.02.010

Ren, J., & Sovacool, B.K. (2015). Prioritizing low-carbon energy sources to enhance China's energy security. *Energy Conversion and Management* 92, 129–136.

Ren, J., & Sovacool, B.K. (2014). Quantifying, measuring, and strategizing energy security: Determining the most meaningful dimensions and metrics. *Energy,* 76, 838–849.

Shindina, T., Streimikis, J., Sukhareva, Y., & Nawrot, Ł. (2018). Social and Economic Properties of the Energy Markets. *Economics and Sociology*, 11(2), 334-344. doi:10.14254/2071-789X.2018/11-2/23

Sovacool, B.K. (2013). An international assessment of energy security performance. *Ecological Economics,* 88, 148–158.

Sovacool, B.K., & Mukherjee, I. (2011). Conceptualizing and measuring energy security: A synthesized approach. *Energy,* 36, 5343–5355.

Sovacool, B.K., & Saunders, H. (2014). Competing policy packages and the complexity of energy security. *Energy* 67, 641–651.

Turton, H., & Barreto, L., (2006). Long-term security of energy supply and climate change. *Energy Policy*, 34, 2232-2250.

Van Benthem, A., & Romani, M. (2009). Fuelling growth: what drives energy demand in developing countries? *Energy Journal, 30*, 91-114.

World Energy Council. (WEC). World energy Trilemma index. 2018. https://trilemma.worldenergy.org/reports/main/2018/2018%20Energy%20Trilemma%20Index.pdf. [Accessed 16 October 2020].

Wang, Q, & Zhou, K. (2017). A framework for evaluating global national energy security. *Applied Energy, 188*, 19-31. https://doi.org/10.1016/j.apenergy.2016.11.116

Wang, W., & Liu, Y. (2015). Geopolitics of global climate change and energy security. *Chinese Journal of Population Resources and Environment*, *13*, 1-8.

Zavadskas, E. K., Kaklauskas, A., Turskis, Z., & Tamošaitiene, J. (2008). Selection of the effective dwelling house walls by applying attributes values determined at intervals. *Journal of civil engineering and management*, 14, 85-93.

Zeng, S, Streimikiene, D, & Balezentis, T. (2017). Review of and comparative assessment of energy security in Baltic States. *Renewable and Sustainable Energy Review,* 76, 185-192. https://doi.org/10.1016/j.rser.2017.03.037