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Energy Supply Security in Baltic States

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ABSTRACT

The aim of this paper is to analyse energy supply security concept and indicators used to measure energy security based on the main issues such as energy import dependency, energy supplier concentration/diversification and available energy infrastructure. The framework of energy security indicators was developed based on literature review. The framework was applied to evaluate Baltic States based on energy security indicators. The advanced MCDM tool was applied to rank Baltic States based on energy security indicators as countries have very different performance in terms of specific aspects of energy security making their ranking impossible. MCDM applied allowed to define that the best performing country in terms of energy security was Estonia mainly due to very low level of total energy import dependency. The policies and measures to promote security of energy supply were developed based on results and findings of research conducted.

INTRODUCTION

Energy security is one of the most important sustainable energy development targets in economic pillar of energy sustainability. If energy poverty reduction is the main objective in social pillar, and GHG emission reduction is the main goal in environmental pilar, energy security is the main focus of economic pillar of sustainable energy development (World Energy Council, 2020; Istudor et al., 2021). All three energy sustainability pillars are equally important and sustainable energy development aims to implement they all together (Connolly et al., 2016). International Energy Agency (IEA, 2007) is defining energy security as 'reliable, affordable access to all energy sources. EU Member states are unfavourably dependent on energy imports and have problems with reliability of energy supply. Energy import makes almost 60 % of the EU's energy supply and was constantly increasing. Such high reliance of EU on energy imports makes EU states vulnerable. The biggest problems in 2021 with security of energy supply in EU were connected to reliability of the natural gas supplier – Gazprom. Russia's invasion of Ukraine in February 2022 made additional threats of energy supplies from Russia to EU.

In May 2022 European Commission introduced the REPowerEU Plan, to achieve a global, clean and just energy transition to ensure sustainable, secure and affordable energy in EU Member States. The plan seeks to diminish the overall energy consumption by improvements of energy efficiency and further penetration of renewable energy. The plan supports Ukraine and aims to prepare for further EU energy market integration repairing energy infrastructure paving the pathway for a low carbon energy transition and green energy future for Europe (Streimikiene, 2022).

Though there are many studies (Vicini et al., 2005; Yergin, 2006; APERC, 2007; Elkind, 2009; Huges, 2012; Axon et al., 2013; Elbassoussy, 2019; Bolino & Galkin, 2021; Yu et al., 2022; Krikstolaitis et al., 2022) dealing with security of energy supply and there are various definitions of energy security including various energy security indicators (Cabalu, 2010; Cohen, Loungani, 2011; Song et al., 2019) it is important to develop a simple and transparent energy security indicators framework covering main aspects of energy security ranging from energy import dependency and energy supply concentration to energy infrastructure development. Such indicators framework should include indicators available in Eurostat database in order to make comparison among EU member states and to assess the positive or negative trends of energy security development in EU countries. Such indicators system is very useful for identifying the strengths and weakness of countries in terms of various aspects of energy security and allows to learn from best practices and to develop policies and measures targeting the weakest items in energy security of selected countries. The rest of the paper is structured in the following way: section 1 presents literature review, section 2 introduces methods and data; section 3 provides discussion of the main energy security metrics and section and section 4 concludes.

1. LITERATURE REVIEW

The IEA defines energy security as the uninterrupted availability of energy sources at an affordable price. Energy security is multi-faceted issue. The long-term energy security covers necessary investments to ensure reliable energy isupply for economic development (IEA, 2007). Study by Vicini et al. (2005), analysed the main elements of energy security risk ranging from physical disruption, economic, social and environmental one. Physical disruption of energy supply can happen because of interruptions in energy production. Economic disruption of energy supply is linked to prices fluctuations in international energy markets. Social disruption is related to instability of energy supplies to households. Environmental disruption can occur because of the environmental damage caused by energy systems like nuclear accidents, or GHG emissions which need to be controlled. The shortterm and long-term ernergy security are distinguished.

Yergin (2006) defined energy security as ensuring adequate energy suppliers at affordable and reasonable prices. According to Yergin (2006) energy exporting countriesare mainly putting emphasis on, security of demand" of their energy export, however energy importing countries put main focus on security of supply. Developing countries are mostly concerned with energy price fluctuations on internal energy markets having negative impact on their balance of payments

Asia-Pacific Energy Research Center (APERC, 2007) has defined energy security based on the man issues linked to energy security described in the following way: availability of adequate energy carriers reserves and capacity of economy to supply energy to meet the energy demand; the energy resources and energy supplier diversification; availability of energy infrastructure transportation infrastructure; the geopolitical situation linked to resources acquisition. Elkind (2010) introduced new dimensions of energy security, i.e. environmental sustainability to the already existing three dimensions which are availability, reliability, and affordability. He also highlighted the importance of negative impacts of energy supply due to climate change.

Other scholars were also analysing energy security based on two issues availability and affordability in terms of prices (Cabalu, 2010; Axon et al., 2013). Other scholars were putting more emphasis on diversification of energy supplier linked to energy sources and suppliers (Cohen, Loungani, 2011; Bolino & Galkin, 2021; De Rosa et al., 2022). Sovacool (2011) defined energy security as Equitable providing of available, affordable, reliable, efficient, environmentally benign, proactively governed, and socially acceptable energy services to end users. Huges (2012) analysed the role of government in ensuring security of energy supply. Huges (2012) defined energy security as governmental policies and actions to ensure access to safe, reliable and affordable energy supply to communities. Based on analysis of energy security definitions the most comprehensive definition is that energy security is availability of adequate production and supply of energy sources at affordable prices. The availability is the main issue and energy security indicators are mainly dealing with energy affordability issues (Krikstolaitis et al., 2022; Streimikiene, 2020).

2. DATA AND METHODOLOGY

The main approach applied in this paper analysis of energy security indicators and their dynamics in Baltic States and use of MCDM tools for ranking of Baltic States based on their achievements in energy security. The quantitative indicators of energy security were selected from Eurostat based on data availability. The selected indicators cover three main areas: energy import dependency, supplier concertation and available energy infrastructure in natural gas and power sector. Therefore, the data was used for analysis of the main energy security indicators in Baltic States. Table 1 presents the framework of indicators applied for energy supply security assessment.

Table 1. Main energy security indicators and desirable trends

Indicator	*Description*	*Abbreviation*	*Desirable trend*	*Source*
Energy import dependency indicators				
1. Net energy import dependency	Net Import dependency (NET) (total and by main energy carriers) indicates the percentage of energy that country is importing or the extent to which an economy relies on energy imports due to meeting its energy needs, %	ID 1	↓	Eurostat database (http://ec.europa.eu/eurostat/data/database).
Supplier concentration indicators				
2. Total Supplier concentration index:	Supplier concentration index (SCI) (total is calculated based on HHI and shows the degree of concentration of main energy sources imports from energy suppliers situated outside of the European Economic Area, index , 0-100 (100 means maximum concentration)	SC 1	↓	Eurostat database: http://ec.europa.eu/eurostat/data/database
Energy infrastructure indicators				
***3.** N-1 rule for gas infrastructure*	N-1 rule for gas infrastructure indicator shows the capability of available natural gas infrastructure to cover overall natural gas demand in case of a interruption of the single largest natural gas infrastructure during days of extremely high demand like enormously cold days, % of total demand that can be satisfied if the largest item of gas supply infrastructure is disrupted	EI 1	↑	Member States' Risk Assessments and Preventive Action Plans:.https://ec.europa.eu/energy/topics/energy-security/secure-gas-supplies_en
***4.** Electricity interconnection capacity*	Electricity interconnectivity level is the ratio between interconnection capacity of power import specific country and its overall power genera-	EI 2	↑	ENTSO-E winter outlook reports: https://www.entsoe.eu/out-

Source: created by authors based on (European Commission, 2022)

As one can see from energy supply security indicators framework given in Table 1, the main energy security indicators selected are covering energy import dependency and energy import diversification or energy supply concentration of the main energy carriers imports from suppliers outside of EEA. These concentration indicators are calculated as HHI and are scaled in the range of 0-100 where 100 indicates that the given country imports all its energy carriers from an unique supplier, and 0 indicates that the country is fully independent of energy imports.

There are two additional indicators of security of energy supply linked to energy infrastructure: N-1 indicator and electricity interconnectivity indicator. N-1 criteria for gas infrastructure is an indicator of natural gas supply infrastructure adequacy by testing the resilience of the natural gas supply system. The indicator is defined in the Annex II of the Regulation (EU) 2017/1938 concerning measures to safeguard security of gas supply and is available for all EU Member States. Electricity interconnectivity level indicators shows the share of electricity import interconnection capacity of a given Member State and its total power generation capacity. It is calculated as the ratio of the synchronous import interconnection capacity and the total generation capacity at 19:00 around the date of 10th January each year.

Therefore, energy security framework of indicators covers three groups of indicators addressing energy supply security: energy import dependency, energy import concentration/diversification and energy infrastructure indicators. The countries will be ranked based on energy security indicators by applying MCDM tool MEREC-TOPSIS in order to find the best performing country in terms of energy security. MCDM method based on the Removal Effects of Criteria (MEREC) is used to calculate the objective weights and applied the Technique for Order of Preference by Similarity to the Ideal Solution (TOPSIS) to rank countries according to weighted criteria. The steps of the proposed method are presented in the following.

Step 1. Decision matrix

Let $\{b_1, b_2, \dots, b_m\}$ a set of Baltic countries, and $\{cr_1, cr_2, \dots, cr_n\}$ a set of criteria; thus, $\mathbb{Z} = \left(x_{ij}\right)_{m\times n}$, where $x_{ij}\ \forall\ i = 1, \dots, m; j = 1, \dots, n$, is the given score to i_{th} Baltic country, according to j_{th} criteria (Keshavarz-Ghorabaee et al., 2021).

Step 2. Normalized matrix

Equation one normalizes the decision matrix, where $\tilde{\Xi} = \left(\dot{x}_{ij}\right)_{m\times n}$ is a normalized matrix.

$$\dot{x}_{ij} = \begin{cases} \dfrac{\min\limits_{x} x_j}{x_{ij}}, j \in N_b \\ \dfrac{x_{ij}}{\max\limits_{x} k_j}, j \in N_n \end{cases} \qquad 1$$

Step 3. Overall performance of countries

Equation two calculates the overall performance $\wp_i$.

$$\wp_i = \ln\left(1 + \left(\frac{1}{m}\sum_{j}\left|\ln\left(\dot{x}_{ij}\right)\right|\right)\right) \qquad 2$$

Step 4. Overall performance of alternatives by removing each criterion

$\wp_{ij}$ the overall performance of i_{th} alternative concerning the removal of j_{th} criterion. Equation three calculates $\wp_{ij}$:

$$\wp_{ij} = \ln\left(1 + \left(\frac{1}{m}\sum_{k,k\neq j}\left|\ln\left(\dot{x}_{ij}\right)\right|\right)\right) \qquad 3$$

Step 5. Absolute deviations

$\mathcal{E}_j$ shows the consequence of eliminating the jth condition. Equation four determines the values of $\mathcal{E}_j$:

$$\mathcal{E}_j = \sum_i |\wp_{ij} - \wp_i| \quad 4$$

Step 6. Final weights

Equation five calculates W_j:

$$W_j = \frac{\mathcal{E}_j}{\sum_k \mathcal{E}_k} \quad 5$$

Step 7. Weighted matrix

Equation six calculates the weighted matrix, subject to $\sum_{i=1}^{n} W_i = 1$.

$$\hat{x}_{ij} = \tilde{x}_{ij} * w_i \quad (i = 1, \dots, m; j = 1, \dots., n) \quad 6$$

Where $\tilde{x}_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}}$ for $(j = 1, \dots, n)$.

Step 8. PIS and NIS

Equations seven and eight calculate the positive and negative ideal solutions (Kamali Saraji, et al., 2022).

$$A^+ = \left\{ \left(\max_i \hat{x}_{ij} \mid j \in J \right), \left(\min_i \hat{x}_{ij} \mid j \in \acute{J} \right) \mid i = 1, \dots, m \right\} = \{x_1^+, x_2^+, \dots, x_n^+\} \quad 7$$

$$A^- = \left\{ \left(\min_i \hat{x}_{ij} \mid j \in J \right), \left(\max_i \hat{x}_{ij} \mid j \in \acute{J} \right) \mid i = 1, \dots, m \right\} = = \{x_1^-, x_2^-, \dots, x_n^-\} \quad 8$$

Where $J = \{j = 1,2, \dots, n | j \text{ associated with the benefit criteria}\}$, and $\acute{J} = \{j = 1,2, \dots, n | j \text{ associated with the cost criteria}\}$.

Step 9. Separation measure

Equations nine and ten calculate the positive and negative ideal separations.

$$S_i^+ = \sqrt{\sum_{j=1}^{n} \left(\hat{x}_{ij} - x_j^+ \right)^2} \quad (i = 1, \dots, m) \quad 9$$

$$S_i^- = \sqrt{\sum_{j=1}^{n} \left(\hat{x}_{ij} - x_j^- \right)^2} \quad (i = 1, \dots, m) \quad 10$$

Step 9. Relative closeness

Equation eleven calculates relative closeness.

$$C_i^* = \frac{S_i^-}{S_i^- + S_i^+}, \quad 0 < C_i^* < 1, i = 1, \dots, m \quad 11$$

Where $C_i^* = 1 \; if \; A_i = A^+$, and $C_i^* = 0 \; if \; A_i = A^-$. Alternatives are ranked according to the descending order of C_i^*.

The results of assessment of energy supply security in Baltic States based on developed framework of indicators and MCDM tool by using available data in EUROSTAT are discussed in section 3.

3. DISSCUSSION OF RESULTS

The main energy security indicators of Baltic States are shown in Table 2 for 2014-2020 period based on available data.

Table 2. Development of energy supply security indicators in Baltic States during 2012-2020 period

Country	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*
ID 1							
Estonia	11.56	11.18	8.07	4.58	1.23	4.84	10.5
Latvia	40.59	51.18	47.15	44.05	44.31	43.91	45.48
Lithuania	74.94	75.45	74.78	71.97	73.9	75.2	74.91
SC 1							
Estonia	50.55	53.1	48.47	65.8	76.05	NA	NA
Latvia	23.23	41.92	30.16	39.68	42.32	NA	NA
Lithuania	87.63	71.61	51.58	45.62	47.75	NA	NA
EI 1							
Estonia	NA	NA	NA	NA	105	105	NA
Latvia	NA	NA	NA	NA	248.59	248.59	NA
Lithuania	NA	NA	NA	NA	153.4	153.4	NA
EI 2							
Estonia	NA	NA	NA	NA	NA	67.62	67.62
Latvia	NA	NA	NA	NA	NA	53.86	42.13
Lithuania	NA	NA	NA	NA	NA	86.49	77

Source: Created by authors based on European Commision (2022)

As one can notice from information presented in Table 2 very limited data is available for electricity infrastructure indicator (EI 2) showing the electricity interconnectivity level as the ratio between interconnection capacity of power import and the overall power generation capacity. The data provided for 2019 and 2020 reveals that Lithuania distinguishes with the highest electricity interconnectivity level among Baltic States. Latvia has lowest electricity interconnectivity level due to high share of hydro in electricity generation. This indicator has declined inn 2020 for Latvia and Lithuania though it remained stable in Latvia.

Also, there is limited data available for gas infrastructure indicator (EI 1) or N-1 rule gas infrastructure indicator showing the capability of available natural gas infra-structure to cover overall natural gas demand in case of disruption. As one can notice from Table 2 this indicator remain stable for all Baltic States in 2018 -2019 and Latvia distinguishes among other Baltic States with high N-1 rule gas infrastructure indicator as country has Incukalnis underground gas storage with capacity of 4.47 billion cubic meters, from which 2.32 billion cubic meters is active or constantly pumped natural gas.

As more data is available for assessing security of energy supply for Baltic States based on net energy import dependency in Figure 1 the development of net energy import dependency of Baltic States during 2014-2020 period is given.

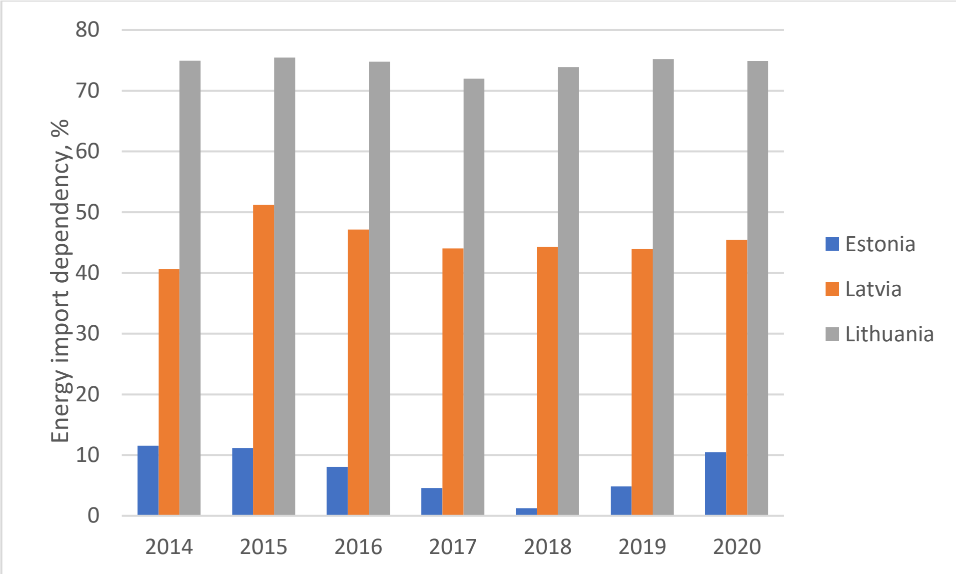

Figure 1. Net energy import dependency (ID 1 indicator) development in Baltic States during 2014-2020 period

Source: Created by authors based on European Commission (2022)

The data presented in Figure 1 shows that Lithuania distinguishes with very high energy import dependency among Baltic States. This is due to the fact that Lithuania does not have own energy resources like Estonia having high share of local oil shale in primary energy supply or Latvia having high hydro energy resources and thus, having a high share of hydro (more than 40%) in electricity generation.

In Figure 2 the development of supplier concentration index (SC 1) of Baltic States during 2014-2018 data is given.

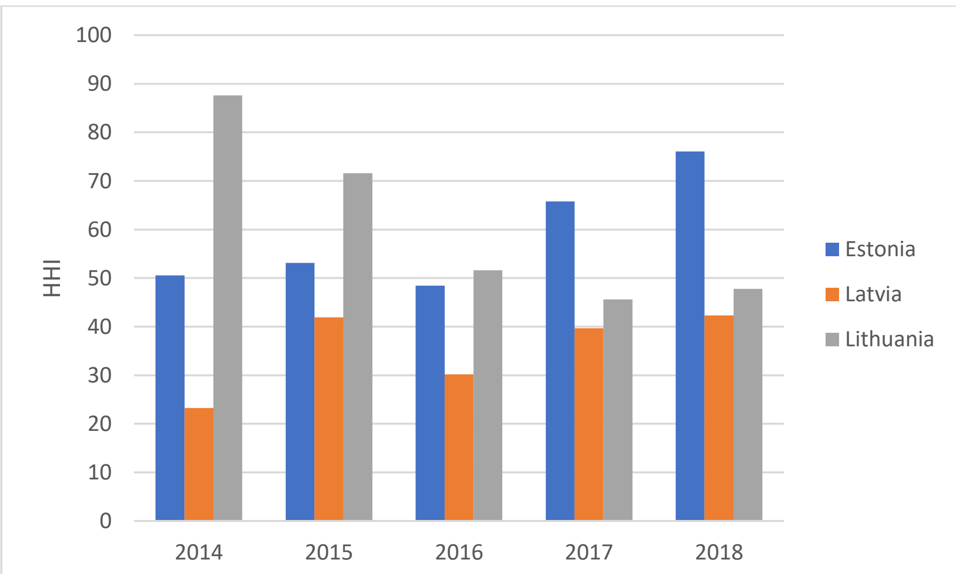

Figure 2. Total supplier concentration index (SC 1 indicator) development for Baltic States during 2014-2018 period

Source: Created by authors based on European Commission (2022)

One can notice from data presented in Figure 2, supplier concentration index has dropped from almost 90 in 2014 to 48 in 2018 for Lithuania showing the increased diversification of energy import from from energy suppliers situated outside of the European Economic Area. However, the SC1 indicator has increased from 50 in 2014 to 76 in 2018 for Estonia. In Latvia supplier concentration index was fluctuating during investigated period however in 2018 it reached 50 though in 2014 it was 23 in Latvia showing negative trend.

Therefore, Baltic States have very different positions in terms of energy security indicators covering different areas, i.e. Lithuania is in the worst position according net energy import dependency but in the best position in terms of electricity interconnectedness. Latvia is in the worst position in terms of electricity interconnectedness but in the best position in terms of N-1 rule for gas infrastructure indicator. At the same time Estonia is in the worst position in terms of supplier concentration index but in the best position in terms of net energy import dependency.

Further the MCDM tool - MEREC-TOPSIS was applied to rank Baltic States based on energy security indicators as it is not possible to define the best performing country and to rank Baltic States based on energy security indicators therefore, it is necessary trade-off between these indicators. The decision matrix for MEREC-TOPSIS is shown in Table 3.

Table 3. Decision matrix based on energy supply security indicators in Baltic States for 2018

	Estonia	*Latvia*	*Lithuania*	*Desirable trend*
Net energy import dependency, %	1.23	44.31	73.90	↓
Supplier concentration index, 1-100	76.05	42.32	47.75	↓
N-1 rule gas infrastructure indicator, %	105.00	248.59	153.40	↑
Electricity interconnection, %	67.62	53.86	86.49	↑

Source: European Commission (2022)

Afterward, the MEREC is applied to calculate the objective weights. Table 4 shows the results of the MEREC.

Table 4. MEREC results

MEREC	$\wp_i$	$\wp_{ij}$			
		Net energy import dependency, %	*Supplier concentration index, 1-100*	*N-1 rule gas infrastructure indicator, %*	*Electricity interconnection, %*
Estonia	0.734	0.058	0.734	0.734	0.705
Latvia	0.399	0.309	0.295	0.242	0.399
Lithuania	0.287	0.287	0.195	0.213	0.192
Absolute deviations	$\mathcal{E}_j$	0.766	0.195	0.230	0.124
Final weights	W_j	0.583	0.148	0.175	0.094
Criteria rank		1	3	2	4

Source: Created by authors

The most crucial criterion is “net energy import dependency.” Subsequently, the TOPSIS is applied to rank countries according to weighted criteria. Table 5 shows the obtained results of the TOPSIS.

Table 5. TOPSIS results

TOPSIS	*Net energy import dependency, %*	*Supplier concentration index, 1-100*	*N-1 rule gas infrastructure indicator, %*	*Electricity interconnection, %*
A^{+}	0.008	0.063	0.140	0.067
A^{-}	0.500	0.114	0.059	0.041
	S_i^{+}	S_i^{-}	C_i^{*}	*Country rank*
Estonia	0.096	0.491	0.836	1
Latvia	0.292	0.222	0.431	2
Lithuania	0.494	0.056	0.102	3

Source: Created by authors

The results given in Table 5 shows that Estonia is the highest ranked country in terms of energy security among Baltic States. Lithuania was defined as the worst performing country in terms of energy security due to the same reason.

CONCLUSIONS

Energy supply security is the major policy concern for EU member states due to high energy import dependency from single supplier-Russia. The Russian-Ukrainian war showed high energy vulnerability of EU member states due to high dependence on natural gas and oil supply from Russia. Energy security indicators can be applied to analyze energy security situation in EU Member States based on the main energy security issues: energy import dependency, supplier concentration and energy infrastructure development and using relevant energy security indicators provided by Eurostat database

The conducted case study showed that Baltic States have very different positions in terms of energy security. Lithuania is in the worst position according net energy import de-pendency but in the best position in terms of electricity interconnections. Latvia is in the worst position in terms of electricity interconnections but in the best position according to of N-1 rule for gas infrastructure indicator. Estonia is in the worst position according to supplier concentration index but in the best position in terms of net energy import dependency. In order to define the best performing country in terms of overall energy security the MCDM tool-MEREC-TOPSIS was applied to trade-off between various energy security aspects and Estonia was found as the highest ranked country in terms of energy security. As the most crucial criterion was found- “net energy import dependency”, Estonia was defined as the best performing country and Lithuania – as the worst performing country in terms of energy security among Baltic States.

The main policy recommendations to increase energy security for Lithuania is to reduce energy import dependency and supplier concentration. For Latvia the main policy recommendations are to increase electricity interconnection capacities. For Estonia the decrease of supplier concentration level is priority in terms of promotion of energy security. Fast penetration of renewable energy sources together with enhanced energy efficiency measures, provides that Baltic States would become less energy import dependent in long-term however in short-term policies and measures to increase energy storage capacities and development of energy infrastructure plays a crucial role.

The study has limitations due to limited energy security data available for Baltic States in Eurostat. The future research is necessary to address issues of energy security development in Baltic States as well as provide in-depth assessments of policies and measures to promote energy security in Baltic States. The in-depth analysis of energy sector ‘s of Baltic States is also necessary to reveal differences in energy supply and consumption structure which is highly linked with availability of energy resources, deployment of renewable energy and energy infrastructure developments.

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