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### Low Carbon Energy Transition of Baltic States

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#### ABSTRACT

*The paper deals with challenges of low carbon transition of Baltic States and provides discussion of energy and climate policies and ranking of countries based on achievements in low carbon transition including energy poverty issues which are key issues during transition towards low carbon future. The study applies MCDM tool - COPRAS for ranking Baltic States in terms the most important climate change mitigation and energy poverty indicators. For this purpose, the framework of indicators was developed based on literature review. Three scenarios were developed for ranking of countries based on results of just low carbon energy transition. The paper provides also policy recommendations based on study conducted in three Baltic States.*

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#### INTRODUCTION

During the last years, the European Union (EU) has made significant progress in developing electricity and gas markets, promoting energy efficiency, renewable energy sources, greenhouse gas (GHG) emissions reductions (European Commission, 2010). In 2019, the EU proposed the European Green Deal (EGD), a set of 50 actions for the coming five years across all sectors of economy to prepare the EU economy for development of climate neutral society by 2050 (EC, 2019). Energy sector action is central to the EGD. The EGD puts the aim to achieve a 90% reduction of greenhouse gas (GHG) emissions from transport by 2050. To support the low carbon transition in transport, 75% of inland road freight should shift onto rail and inland waterways and zero- and low-emission vehicles should appear on the road. Under EGD, the EU initiated review of energy and climate package to scale up GHG emissions reductions, boost the deployment of renewables and energy efficiency, and review the Energy Taxation Directive. The new Industrial Strategy for Europe, along with the Circular Economy Action Plan and the SME Strategy set for developing a competitive, climate-neutral and digital industry in EU. The EU Sustainable Transport and

Smart Mobility Strategy aims at transport sector and addresses measures to achieve expected GHG emission reductions in 2050 (EC, 2018).

Current covid-19 pandemic and crisis tests the EU's resilience in clean energy transitions. EU will experience about 10% economic downturn in 2020 as a result of the Covid-19 pandemic. The longer the Covid-19 crisis lasts, the higher negative influence will be on economy and energy sector of EU Member States (MS). Ensuring security of energy supply is critical during pandemic, as this sector is vital for all sectors of economy and public health. The physical resilience of the EU energy sector is quite however, however the financial resilience is currently under severe stress. In 2020 energy demand and supply has fallen down including fall of GHG emissions. It is expected that EU energy demand will decline by 10% comparing with year 2019 level. It is expected that energy-related GHG emissions will shrink by 8% during 2020 compared to 2019. However, the investment in RES is expected to be lower by 25% in 2020, compared to 2019. The rebound effect can be also high due to currently very low global commodity prices. As the energy sector responsible for 75% of total GHG emissions, actions are necessary to deal with rebound effect (IRENA, 2020).

One can notice that EU energy transitions progressed fast just in electricity sector. Outside the electricity sector, energy transitions have only just begun with varied results for energy efficiency and renewable deployment in sectors such as transport, buildings and industry. Though, RES have reached 18% in the EU's gross final consumption in 2018; results in transport and heating and cooling are, however, below expectations. The EGD initiated a revision of the CO<sub>2</sub> standards for road vehicles to ensure a clear pathway from 2025 onwards towards zero-emission mobility, however it is necessary to note that renewables play a minor role in gross final consumption in transport (8%). The share of renewables in heating and cooling was 20% in 2018. Overall, the transport target for renewables will be increasingly met through the promotion of electric vehicles (EVs). Rail is providing the highest contribution to the target in terms of renewable electricity. Advanced biofuels and biomethane are expected to play a significant role in a number of transport sectors, notably aviation and maritime (IRENA, 2019).

Though enhanced efficiency gains have been most apparent in the buildings and industry sectors, buildings account for 40% of the total final consumption in the EU and offer large opportunities for renewables penetration and GHG emission reduction. The EU is developing a new Renovation Wave initiative presented in EGD in order to stimulate the renovation of the existing building stock at a faster and deeper pace, by addressing the main barriers to building renovation by focusing on old multi-flat buildings, social housing, public buildings etc. Due to Covid 19 crisis the EU is not yet on track towards the targeted increase of the RES share to 32% nor energy efficiency savings of 32.5% by 2030. The targets set for 2030 require a significant energy system transformation. Therefore, it is necessary to accelerate the implementation of the policies and regulations set in Clean Energy Package adopted in 2019. The new policies are necessary to decarbonise the heat and transport sectors, and improve situation in buildings sector (IRENA, 2020). The higher efforts from national measures under the National Energy and Climate Plans (NECPs). Are necessary. Taken together, the NECPs should ensure the EU meets its energy and climate targets set in Clean Energy Package. However, the implementation of the NECPs and the CEP has just started in 2020. The European Commission will assess all final NECPs and discuss the possible revisions of energy sector legislation during 2020-21. This will create new opportunities for strengthening policies and developing new actions under the EGD.

There are many different ways to approach low carbon energy transitions for the period 2030 to 2050. Few EU member states have decided to set climate neutrality aim for 2050 and have established ambitious targets in buildings and transport sectors to achieve 100% renewables scenarios. EC has developed EU Climate Law in March 2020, aiming to establish novel climate change mitigation governance framework for 2030-50 period based on reviews in terms of progress achieved in low carbon energy transition and EU MS NECPs (EC, 2019). Therefore, the road to net-zero carbon energy and economy requires new actions in EU MS. The implementation of "energy efficiency first" principle is crucial for meeting 2030 and 2050 energy and climate targets. The energy efficiency improvement in transport, industry and buildings is necessary. Achieved energy efficiency gains across all sectors are vital to meet renewable energy targets in 2030 and 2050. The need for energy system flexibility is crucial though interconnections and smart grids, demand response, and energy storage are currently developing slower than renewable energy source deployment in EU. Another issue is energy poverty. For moving towards

low carbon future, energy vulnerability and energy justice issues should be dealt as priority as rise of share of renewable energy sources needs to be accompanied by energy equity and just low carbon transition pathways are necessary for all EU MS. Though there are some studies dealing with energy poverty issues in terms of low carbon energy transition this research area needs more attention especially this is important for new EU member states having high inequality and risk at poverty rates including energy poverty (Bouzarovski and Petrova, 2015; Bouzarovski et al., 2017; Bartiaux et al., 2019). Some results in analysis of low carbon energy transition and its impacts are contradictory. Hicks and Ison (2018) and Kozubikova and Kotaskova (2019) found that motivations are lacking for engagement in community renewable energy projects as they do not guarantee reduction of energy vulnerability. Hillerbrand (2018) showed that that capacity approach should be enrolled in dealing with clean affordable energy supply. Ntanos et al (2019) tried to assess contributions of renewables towards increase in quality of life in Greece and also have obtained ambiguous results.

The paper aims to review and compare Baltic States in terms of achievement of low carbon energy transition tasks and the implications to energy poverty for these countries during the pathway towards carbon neutral society. The paper is structured in the following way: section 1 presents literature review in the field of investigation; section 2 provides methodology and data for assessment progress achieved in moving towards carbon neutral society for countries; section 3 presents results of case study for Baltic States on ranking countries based on achievements towards zero carbon energy; section 4 discusses results and provides policy implications, section 5 concludes.

## 1. LITERATURE REVIEW

Several studies were conducted to analyse the low carbon energy transition in EU Member States. Rogge and Johnstone (2017) investigated how most prominently Germany's nuclear phase-out policy – may have on technological change in renewable energies and transformations of German electricity system towards renewable energies – the so-called *Energiewende*. Sorman et al. (2020) analysed various stakeholder insights on low-carbon energy transitions in Spain. (2020). Pettifor et al (2020) study in UK investigated the main attributes of low carbon innovations: private functional, public functional, private symbolic, and public symbolic and perceived attributes of 12 consumer innovations in mobility, food, homes and energy were analysed. The study found that that carbon innovations are relatively unappealing against the money saving, time saving, ease of access, ease of use, trust, and private identity. Other studies analysed public preferences of low carbon energy transition. The study by Papadopoulou et al. (2019) investigated the attitudes of citizens of the Thessaloniki conurbation towards RES. The structured questionnaires were used, which were completed through personal interviews. The study found that most of respondents supported the replacement of lignite plants with renewables as they perceived that they constitute a necessary solution providing some opportunities for economic growth and improvement to their quality of life. In times of increasing energy poverty, the use of RES can be characterized as an economic salvage. At a national level, renewable energy sources can constitute a long-term solution to international dependence on fuel imports, pan-European energy security and eliminate financial abuse of energy imports (Ntanos et al., 2018).

However, according some authors energy transition provided by technological innovations are often incompatible with the principles of energy justice and can contribute to increase of energy poverty, especially among the most vulnerable groups. Some studies found that the transition towards a low carbon energy system lacks a societal and inclusive vision. It overlooks the fact that some groups bear most of its burdens (Kowalska-Pyzalska, 2018; Sareen and Haarstad, 2018; Sovacool and McCauley, 2018; Sovacool et al., 2019; Wilker and Day, 2012). Energy deprivation in low carbon energy transition was assessed through the lens of the energy justice principles in works by Bouzarovski et al. (2014), Sovacool and Dworkin (2015), Sovacool et al. (2017), Sovacool et al. (2019); Sovacool (2011), Walker and Day (2012). These studies examined several concepts of energy justice. The energy justice requires policy-makers to address energy vulnerability and to take into consideration the consequences of their climate change mitigation decisions by addressing the risk of energy poverty. The procedural justice means the lack of participation in policy making process and the lack of empowerment of most vulnerable citizens. Distributional energy justice means discrepancy between energy needs and the ability to satisfy them.

(Sovacool 2011, Walker and Day 2012). Other authors Bartiaux et al, (2019) stressed that the influences of energy transitions on social inequity are multidimensional. For addressing their social correlates, policies aiming to implement a low carbon energy transition have also to be evaluated with regards of their influences on social inequalities, namely energy poverty. A capability-based approach was applied to address the social correlates of the governance of low carbon energy transitions in Austria, Belgium, and Bulgaria. These countries were selected because of the different characteristics in terms of low carbon energy transitions. The capability approach could be usefully adopted to evaluate future implementation of energy transitions and to assess how they could influence inequalities in various aspects of citizen's daily life. The main focus is put on the links between low carbon energy transitions and energy inequalities (Wood, Roelich, 2019).

Study by Hargrove et al (2019) tested how various multilateral environmental treaties with an energy focus have impact on CO<sub>2</sub> emissions per capita, CO<sub>2</sub> emissions per gross domestic product, and total CO<sub>2</sub> emissions for 162 nations and found that environmental treaty ratifications are associated with decreases in GHG emissions, increase of renewable energy consumption, GDP per capita. Other studies also applied several indicators and frameworks to measure progress in low carbon energy transition (Zheng et al., 2019; Huchang et al., 2019; Monni et al., 2017; Igaliyeva et al., 2020; Mazzoni et al., 2020; El Idrissi et al., 2020). Energy poverty measurements were addressed in several studies (Bouzarovski, Tirado Herrero, 2017; Gillard et al, 2017; Fzaine, Kahouli, 2019; Fortier et al., 2019; Nussbaumer et al., 2012). The studies by Sovacool et al., (2017) and Hetffron et al (2019) tried to develop frameworks to link energy poverty with other sustainable energy development aims by applying energy trilemma principle which ranks countries on their ability to provide sustainable energy through 3 dimensions: Energy security, Energy equity (accessibility and affordability) and Environmental sustainability. Grossman (2019) and Streimikiene et al. (2020) illustrated how energy efficiency policies positively influence energy poverty reduction and ensure energy justice. Hetffron and McCauley (2018) provided framework for assessment of just energy transition however there is lack of firm indicators framework for comparing and ranking countries in terms of results in low carbon energy transition and success in dealing with energy injustice.

## 2. DATA AND METHODOLOGY

According to Climate and Energy Framework the main targets for 2030 are the following:

At least 40% cuts in greenhouse gas emissions (from 1990 levels);

At least 32% share for renewable energy;

At least 32.5% improvement in energy efficiency;

All EU MS have adopted national renewable energy action plans including sectorial targets for electricity, heating and cooling, and transport; planned policy measures to achieve them.

As EC in 2020 proposed in European Green Deal to increase greenhouse gas emission reduction target for 2030, to at least 55% GHG emission reduction compared to 1990, three pieces of climate legislation will be updated in 2021 with to achieve at least 55% net greenhouse gas emissions reduction target. Therefore, Climate and Energy framework concentrates on the increase of the share of renewables, improvement of energy efficiency and reduction of GHG emissions. The main indicators for low carbon energy transition are selected based on Energy and Climate package goals set by EU member states and includes: the share of renewables in final energy consumption, the share of RES in transport, in electricity and heating and cooling; energy intensity or gross inland energy consumption per GDP and per capita and the main GHG emission indicators: carbon intensity of economy, carbon intensity of energy, reduction of GHG emissions comparing with year 1990 and GHG per capita.

For assessment of energy poverty four main energy poverty indicators were applied, proposed by EU Energy Poverty (EPOV). Two energy poverty indicators are based on self-reported experiences of limited access to energy services provided by EU-SILC data. The other two energy poverty indicators are evaluated using household income and energy expenditure data provided by HBS data (EC, 2020). The EURO-STAT data was used for analysis. The year 2018 was selected for ranking countries based on availability of data. In Table 1 data used for MCDM and ranking of countries is provided.

**Table 1.** Indicators for MCDM and ranking of countries towards progress achieved on low carbon transition and energy poverty implications

Countries	Estonia	Latvia	Lithuania
Low carbon energy transition indicators			
The share of RES in final energy consumption, %	30,00	40.30	24.50
RE-T - Renewable energy in Transport, %	3.30	4.70	4.30
RES-E - Renewable Electricity Generation, %	19.70	53.50	18.40
RES-H&C - Renewable Heating and Cooling, %	53.70	55.90	45.60
Energy Intensity [Gross inland energy consumption /GDP2015]- toe/M€'15	278.78	179.57	193.35
Energy per Capita [Gross inland energy consumption/pop] - kgoe/cap	4774.01	2477.93	2775.12
GHG national total emissions / index 1990, %	50.00	45.9	42.6
Total GHG per capita - t CO2 eq./cap	15.30	6.31	7.35
GHG Intensity of Energy - kg CO2 eq./toe	2793.16	1605.82	1527.47
Total GHG - GDP Intensity - ton CO2 eq./M€'15	854.22	453.42	499.28
Energy poverty indicators			
Areas on utility bills, %	6.5	11.6	9.2
Inability to keep home warm, %	2.3	7.5	27.9
Low absolute energy expenditure (M/2), %	18.9	10.7	14.4
High share of energy expenditure in income (2M), %	18.7	12.7	13.9

For MCDM of low carbon energy transition results COPRAS methods applied. 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.

Criteria Alternative	C <sub>1</sub>	C <sub>2</sub>		C <sub>n</sub>
A <sub>1</sub>	X <sub>11</sub>	X <sub>12</sub>		X <sub>1n</sub>
A <sub>2</sub>	X <sub>21</sub>	X <sub>22</sub>		X <sub>2n</sub>
				
A <sub>m</sub>	X <sub>m1</sub>	X <sub>m2</sub>		X <sub>mn</sub>
W <sub>j</sub>	W <sub>1</sub>	W <sub>2</sub>		W <sub>n</sub>

## 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, the equation one is used in COPRAS.

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

## 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, the equation two is used, subject to  $\sum_{i=1}^n W_i = 1$ .

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

## 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.  $\tilde{x}_{ij}^+$  is the  $\tilde{x}_{ij}$  of the maximizing criterion and  $\tilde{x}_{ij}^-$  is the  $\tilde{x}_{ij}$  of the minimizing criterion.

$$S_i^+ = \sum_{j=1}^n \tilde{x}_{ij}^+ \quad (3)$$

$$S_i^- = \sum_{j=1}^n \tilde{x}_{ij}^- \quad (4)$$

## 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.

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

## 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.

$$U_i = \frac{Q_i}{Q_{Max}} * 100 \quad (6)$$

In next section of paper results of ranking Baltic States according three scenarios (low carbon transition, energy poverty and just low carbon transition) are given.

## 3. RESULTS

Three Baltic States (Estonia, Lithuania, Latvia) were selected for case study on assessment of progress towards low carbon energy transition and it's implications for energy poverty. The selected countries have similar geographical location, climate and GDP per capita and similar climate change mitigation policies in place however based on the main low carbon energy transition indicators in 2018

achieved quite different results. In order to trade-off between various low carbon energy transition measured in different units and showing different advancement of countries MCDM tools for ranking countries according three scenarios was performed. First scenario provides ranking of Baltic States based on low carbon energy transition indicators, second scenario provides ranking of Baltic States based on energy poverty indicators and third scenario provides ranking of Baltic States based on low carbon energy transition and energy poverty indicators. All criteria for ranking Baltic States are provided in Table 2.

**Table 2.** Criteria for multi-criteria ranking of Baltic States base on COPRAS method

Criteria	Description
C1	Overall Renewable share in final energy consumption (with aviation cap) [%]-
C2	RE-T - Renewable energy in Transport [%]
C3	RES-E - Renewable Electricity Generation [%]
C4	RES-H&C - Renewable Heating and Cooling [%]
C5	Energy Intensity [GAE/GDP2015]- toe/M€'15
C6	Energy per Capita [GIC/pop] - kgoe/cap
C7	GHG national total emissions / index 1990
C8	Total GHG per capita - t CO2 eq./cap
C9	GHG Intensity of Energy - kg CO2 eq./toe
C10	Total GHG - GDP Intensity - ton CO2 eq./M€'15
C11	Areas on utility bills, %
C12	Inability to keep home warm, %
C13	Low absolute energy expenditure (M/2), %
C14	The high share of energy expenditure in income (2M), %

Scenario 1 was created and COPRAS method was applied for ranking Baltic States according 10 Criteria indicating low carbon energy transition results (C1-C10) provided in Table 2 above.

The Decision Making Matrix is presented in Table 4, Normalized Decision Making Matrix is given in Table 5 and Weighted-Normalized Decision Making Matrix is provided in Table 6. The equal weights were applied for all criteria.

**Table 4.** Decision Making Matrix (D)

D	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
Estonia	0.300	0.033	0.197	0.537	278.779	4774.008	50.000	15.301	2793.162	854.220
Latvia	0.403	0.047	0.535	0.559	179.570	2477.933	45.900	6.307	1605.820	453.418
Lithuania	0.245	0.043	0.184	0.456	193.353	2775.124	42.600	7.351	1527.472	499.277
Weight	Equal Weight → $W_i=1/10$									
Type	Max	Max	Max	Max	Min	Min	Min	Min	Min	Min

**Table 5.** Normalized Decision Making Matrix (ND)

ND	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
Estonia	0.32	0.27	0.22	0.35	0.43	0.48	0.36	0.53	0.47	0.47
Latvia	0.43	0.38	0.58	0.36	0.28	0.25	0.33	0.22	0.27	0.25
Lithuania	0.26	0.35	0.20	0.29	0.30	0.28	0.31	0.25	0.26	0.28
Weight	Equal Weight → $W_i=1/10$									
Type	Max	Max	Max	Max	Min	Min	Min	Min	Min	Min

**Table 6.** Weighted-Normalized Decision Making Matrix (WND)

WND	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
Estonia	0.032	0.027	0.022	0.035	0.043	0.048	0.036	0.053	0.047	0.047
Latvia	0.043	0.038	0.058	0.036	0.028	0.025	0.033	0.022	0.027	0.025
Lithuania	0.026	0.035	0.020	0.029	0.030	0.028	0.031	0.025	0.026	0.028
Weight	Equal Weight → $W_i=1/10$									
Type	Max	Max	Max	Max	Min	Min	Min	Min	Min	Min

Ranking results according to Scenario 1 are provided in Table 7 below

**Table 7.** Ranking results for Scenario 1

Results	$S_i^+$	$S_i^-$	$Q_i$	$U_i$	Rank
Estonia	0.115	0.274	0.252	61%	3
Latvia	0.175	0.159	0.412	100%	1
Lithuania	0.110	0.167	0.336	82%	2

As one can see from Table 7, the best performing country was Latvia and worst performing Estonia. This is linked with high RES share and low energy and carbon intensity of GDP in Latvia.

According scenario 2 Baltic States were ranked based on 4 criteria (C11-C14) addressing energy poverty issues.

In Table 8 the ranking of Baltic States based on energy poverty indicators is provided. As all indicators are given in the same measurement units, the best performing country were identified based on the lowest value obtained by summing up all energy poverty indicators for Baltic States.

**Table 8.** Ranking results for scenario 2

Results	C11	C12	C14	C14	Rank
Estonia	6.5	2.3	18.9	18.7	46.4 (2)
Latvia	11.6	7.5	10.7	12.7	42.5 (1)
Lithuania	9.2	27.9	14.4	13.9	65,4 (3)

As one can see from ranking provided according to Scenario 2 Latvia is the best performing country in terms of energy poverty and Lithuania is worst performing country as almost all energy poverty indicators in Lithuania are significantly higher (sometimes even more than 10 times as in the case of inability to keep homes warm).

Scenario 3 for ranking Baltic States includes all 14 Criteria provided in Table 2.

The Decision Making Matrix is presented in Table 9, Normalized Decision Making Matrix is given in Table 10 and Weighted-Normalized Decision Making Matrix is provided in Table 11. The equal weights were applied for all criteria

**Table 9.** Decision Making Matrix (D)

D	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14
Estonia	0.3	0.0 33	0.1 97	0.5 37	278.77 903	4774.00 762	50	15.3 013 5	2793.16 203	854.22 046	0.06 5	0.02 3	0.18 9	0.18 7
Latvia	0.4 03	0.0 47	0.5 35	0.5 59	179.56 976	2477.93 323	45.9	6.30 681	1605.81 961	453.41 772	0.11 6	0.07 5	0.10 7	0.12 7
Lithuania	0.2 45	0.0 43	0.1 84	0.4 56	193.35 284	2775.12 379	42.6	7.35 093	1527.47 187	499.27 703	0.09 2	0.27 9	0.14 4	0.13 9
Weight	Equal Weight $\rightarrow W_i=1/14$													
Type	Max	Max	Max	Max	Min	Min	Min	Min	Min	Min	Min	Min	Min	Min

**Table 10.** Normalized Decision Making Matrix (ND)

ND	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14
Estonia	0.32	0.27	0.22	0.35	0.43	0.48	0.36	0.53	0.47	0.47	0.24	0.06	0.43	0.41
Latvia	0.43	0.38	0.58	0.36	0.28	0.25	0.33	0.22	0.27	0.25	0.42	0.20	0.24	0.28
Lithuania	0.26	0.35	0.20	0.29	0.30	0.28	0.31	0.25	0.26	0.28	0.34	0.74	0.33	0.31
Weight	Equal Weight $\rightarrow W_i=1/14$													

Type	Max	Max	Max	Max	Min									
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**Table 11.** Weighted-Normalized Decision Making Matrix (WND)

WND	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14
Estonia	0.023	0.019	0.015	0.025	0.031	0.034	0.026	0.038	0.034	0.034	0.017	0.004	0.031	0.029
Latvia	0.030	0.027	0.042	0.026	0.020	0.018	0.024	0.016	0.019	0.018	0.030	0.014	0.017	0.020
Lithuania	0.018	0.025	0.014	0.021	0.021	0.020	0.022	0.018	0.018	0.020	0.024	0.053	0.023	0.022
Weight	Equal Weight → $W_i=1/14$													
Type	Max	Max	Max	Max	Min									

Ranking results according to Scenario 3 are provided in Table 12 bellow.

**Table 12.** Final ranking results according to Scenario 3

Results	$S_i^+$	$S_i^-$	$Q_i$	$U_i$	Rank
Estonia	0.082	0.277	0.282	69%	3
Latvia	0.125	0.196	0.409	100%	1
Lithuania	0.079	0.241	0.309	76%	2

As on can notice from Table 12, according scenario 3 results Latvia again was found as best performing in term of just low carbon transition and Estonia is the worst performing country according Scenario 3 like in the case of Scenario 1.

## 4. DISCUSSIONS

Latvia was found as the best performing country according to low carbon energy transition indicators and according energy poverty indicators. Estonia was found the worst performing country according to low carbon energy transition indicators however according energy poverty indicators the worst performing country was Lithuania. Therefore, the conducted study based on MCDM provided some contradictory results. The example of Latvia shows that good results in low carbon energy transition can accompany good results in energy poverty alleviation and can ensure just low carbon energy transition however example of Lithuania shows that quite good achievements in low carbon energy transition haven't provided good results in energy poverty alleviations and haven't ensured just low carbon energy transition.

Therefore, conducted study provided that significant energy transformations can be accompanied even by energy poverty increase. To maintain energy supply stability and reduce energy poverty, the government needs to develop balanced climate change mitigation policies to promote low carbon energy transition by taking into account social impact of such transition. The more targeted climate change mitigation policies are necessary by addressing the needs of different energy consumers groups by putting emphasize on most vulnerable consumer groups. The findings are in line with other studies conducted in this field like study by Grossman (2019) conducted in Germany and in Gillard et al (2019) study conducted in UK. Study by Grossman (2019) provided that though energy efficiency improvement in multi-flat buildings has been praised as a win-win strategy reducing GHG emissions, saving energy and together alleviating energy poverty, however policies to foster energy efficiency improvements have led to rising protests and conflicts in Germany because investments made into retrofitting became a means of speculation and displacement of low-income residents. Study by Gillard et al (2019) showed that though there is widely recognized multiple injustices faced by disabled people and low-income families in UK and these groups are nominally prioritized within fuel poverty policy, but their complex situations are not always fully appreciated and results of building retrofit policies targeting these vulnerable groups do not provided expected results in energy poverty alleviation through large scale renovation of multi-flat buildings or social housing.

Though the study by Papadopoulou et al (2019) conducted in Greece showed that majority of energy customers expressed increased interest in future investment in renewables thinking that it could contribute to improving air quality and quality of life of households, the fast growing share of RES in Lithuania so far haven't provided for desirable I energy poverty reduction and increase of quality of life of most

vulnerable groups of population.

## CONCLUSIONS

Conducted study for assessment low carbon energy transition and its implications for energy poverty reduction in Baltic States by applying MCDM tools and three scenarios provided that in 2018 Latvia was found as the best performing country according to low carbon energy transition indicators and according energy poverty indicators. This allows to state a good path on just low carbon energy transition in the country showing that approaching 100% renewables target haven't negative impact on energy vulnerability of population.

MCDM analysis showed that Estonia was the worst performing country according to low carbon energy transition indicators in 2018 however according energy poverty indicators Estonia was performing quite well.

Results of MCD analysis provided that Lithuania was quite well performing country in low carbon energy transition but worst performing country based on energy poverty indicators.

The example of Latvia shows that good results in low carbon energy transition can accompany good results in energy poverty alleviation and can ensure just low carbon energy transition however example of Lithuania shows opposite results.

The study has limitations as just 2018-year data was applied for MCDM analysis and ranking countries. The dynamic framework needs to be applied in the future to track progress of countries towards just low carbon energy transition. The assessment of policies impact on just low carbon energy transition needs to be discussed as well by providing some explanations of different results achieved in approaching zero carbon energy and economy.

Some policy recommendations can be developed for Baltic States by taking into account findings of the current study.

The boosting of energy sector is necessary for Baltic States by implementing the large-scale programmes for renovation, and by lifting barriers for investment in sustainable energy projects and promoting the development of carbon free clean energy industries and infrastructure.

Therefore, the main recommendations are: to scale up energy action towards climate neutrality while ensuring competitiveness, security of supply, sustainability and affordability; to foster the integration of climate change mitigation policies linked to energy efficiency, renewables in end use sectors, strengthening carbon pricing signals by reducing regulatory and pricing barriers and enabling digitalisation and smart metering; to develop further internal energy market and the level playing field for new carbon free energy technologies penetration in the market; to promote investments in new carbon free technologies to keep all technology options open for achieving net-zero emissions; to keep under regular review the energy poverty situation and develop relevant climate change mitigation policies targeting first of all energy poor households; to keep under review the energy security position based on foresight and long-term energy modelling and develop relevant policies to address energy security issues.

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