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Challenges of Approaching Climate Neutral Society in V4 Countries

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ABSTRACT

The paper deals with challenges of transition to carbon neutral carbon transition of Visegrad countries (V4), namely Poland, Hungary, Slovakia and Czech Republic. The paper provides analysis of the main problems for these countries in implementing targets set by energy and climate package. The analysis of energy vulnerability and poverty issues in V4 countries is also delivered in the paper. Comparative assessment of progress towards climate neutral society is carried for his group of countries to highlight the best practices and problems encountered. The paper also provides policy recommendations based on study conducted for implementing transition towards climate neutral, inclusive society for Visegrad countries.

INTRODUCTION

European Union (EU) has set ambitious targets in European Green Deal (EGD) policy document for transition to carbon neutral society by 2050. However, Covid 19 crisis had negative influence on advancement of penetration of renewable energy sources (RES) and energy efficiency improvements necessary to implement 100% RES scenario by 2050 (EC, 2019). The best results in low carbon energy transition were achieved in power sector however, in other sectors such as transport and buildings transition is just started by providing different outcomes on energy savings and penetration of renewable energy sources for specific EU Member States (MS). Though, RES have reached 18% in overall final energy consumption of EU in 2018, progress achieved in transport and buildings sectors is very low, especially for some EU MS. Though, EGD initiated a review of the CO2 standards for road vehicles to deliver towards zero-emission mobility since 2025, however, it is necessary to note that RES have very low share in final energy consumption in transport (8%). Though, the share of RES in heating and cooling sector was just 20% in 2018, it is far bellow of expectations risen in EU energy policy documents (IRENA, 2020).

The buildings sector requires more attention, especially in central Europe countries which inherited energy inefficient buildings stock from their socialist past (EC, 2010). Overall buildings in EU account for about 40% of the overall final consumption and provide many options for deployment of RES and GHG emission reduction (EC, 2018). The EU developed new Renovation Wave initiative presented in EGD to promote the large scale energy retrofitting of present building stock by addressing the most important obstacles of energy renovation and putting main focus on old multi-flat buildings, social housing, public buildings etc. The Visegrád Four countries (V4 group) – the Czech Republic, Hungary, Poland and Slovakia – is an influential political group of Central Europe countries in EU sharing a number of important features which provides that working together allows to achieve mutual benefits. These common features cover geographical proximity, shared socialist legacies linked to Soviet rule, similar transition experiences from socialistic past having also impact on institutions and social capital of these countries.

In 2017 during the first discussions of on EC Clean Energy Package, Visegrád Group countries have jointly issued a short statement about serious concerns regarding the very short timeframe of the negotiations, and the significance of Member States' right to freely determine their own low carbon energy transition paths. Visegrád Group countries with regards of energy and climate issues, prefer to relay on nuclear energy and coal without concerning energy security issues. There is also some resistance in these countries linked to high initial costs of the low-carbon transition without taking into account the long-term benefits of such transition for social and economic development of countries. In addition, the GHG emissions decline in these countries since 1990 was the result of the economic recession following the collapse of the Soviet Union. Therefore, there is a lack a robust policy framework to ensure a low-carbon energy transition in place in V4 group countries.

There are some important differences and nuances in their paths towards carbon neutral society, such as the high share of renewables in Slovakia, higher GHG per capita rate in Czech Republic than in Poland. For example, Hungary has low the lowest energy intensity in V4 group. The main fuels used by households also differ substantially in countries of Visegrad group (Renewable Networking platform, 2020). There are also many different national policy approaches on transitions towards climate neutral society to 2050 (Liao et al., 2019; Savitz, Gavriletea, 2019). Though there are several studies dealing with challenges of transition (Diesendorf & Elison, 2018; Breyer & Lund, 2017; Virglerova et al., 2020), however the situation of V4 group countries requires special attention in terms of progress achieved in low carbon energy transition and related energy vulnerability and poverty challenges. The V4 countries have many similarities and important differences therefore it is important to compare them in terms of their success towards climate neutral society and define the main reasons of lagging or leading in this low carbon transition.

The paper aims to overcome this gap and provides comparative assessment of progress achieved by V4 countries in terms of transition to carbon neutral society by applying robust indicators framework to track and compare results and achievements and the main drivers of these. 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 results of comparative assessment; section 4 discusses findings of study conducted and section 5 concludes.

1. LITERATURE REVIEW

Carbon neutral society means having a balance between emitting GHG and absorbing them from the atmosphere in carbon sinks (Dahal & Niemela, 2019; Laine et al., 2020). Removing carbon from the atmosphere and then storing it is called as carbon sequestration. In order to achieve net zero emissions, overall GHG emissions have to be counterbalanced by carbon sequestration. Under the Green Deal EU aims to become the first continent that removes as many GHG emissions as it produces by 2050 (Jacobson et al, 2019). This goal will be set binding then new Climate Law will be adopted. On 7 October 2020, the European Parliament supported climate neutrality by 2050 and a 60% GHG emission reduction target was set for 2030 compared to 1990 levels. It is more ambitious than proposed 55% target by EC. In addition, all EU MS need individually to become climate neutral by 2050, and afterwards more carbon should be removed from atmosphere than it is emitted (EU, 2018; 2019). However, the economy affects

society, and this becomes exceedingly important in this dynamic, i.e. when moving towards the desired change and transformation of energy systems (Brown et al., 2018; Cherr et al., 2018). Therefore, society also has to significantly change and invest efforts towards building sustainable communities, which means that today's cities and settlements should transform towards becoming carbon neutral cities and settlements (Disendorf & Elliston, 2018; Jetoo, 2019). The independence of external sources of energy and drinking water will strongly affect the form and structure of future cities as well as interpersonal relations living with particular emphasis on their relationships in terms of energy production, and consumption (Sepulveda et al., 2018; Grubb et al., 2020). Several cities in Europe has established carbon neutral development strategies and aims upon 2050 (City of Berlin, 2020; City of London, 2020; City of Copenhagen, 2020). For example, Copenhagen decided to be carbon neutral until 2025 and can be considered as the first carbon neutral capital in the world. To achieve carbon neutral transition goals it is necessary to transform energy supply, renovation of building, waste management and public infrastructure including mobility and for this new climate change mitigation policies and measures are necessary.

Majority of studies on climate neutral society development and achievement of 100% RES scenarios were performed in US (Afhahosseini et al., 2019), Japan (Esteban et al., 2018); Australia and New Zeland (Blakers et al., 2017), however there are several studies conducted in developing countries like China (Liu et al., 2018), Pakistan (Sadiqa et al., 2018; Buthan (Yangka et al., 2019), Colombia (Zapata et al., 2018). There are also several studies conducted in Europe to assess feasibility of moving towards climate neutral society by 2050 (Wood et al., 2020; Moran et al., 2020; Pollitt et al., 2020; Breyer & Lund, 2019; Child et al, 2018; Tantau & Santa, 2019; Eber et al., 2017. The studies found that one of the most important technical issues are storage technologies necessary for wide penetration of renewables (Mathiesen et al, 2020; Chil et al., 2018) and carbon capture and storage technologies (Haszeldine et al., 2018). The public perception is also crucial in moving towards carbon neutral society (Cherry et al, 2018; Laine et al., 2020). The implications of transition to carbon neutral society on energy poverty are also very important and these issues were stressed in several studies (Scott et al., 2019; Weber & Cabras, 2017).

This paper aims to compare low carbon energy transition paths in Visegard countries by applying comparative assessment approach to grasp the differences between countries in achievement of the main energy and climate targets and addressing together energy vulnerability issues.

2. DATA AND METHODOLOGY

The main approach applied in this paper – comparative assessment. The quantitative indicators of tracking transition towards climate neutral society were selected based on EU energy and climate legislation. As one can notice the main ways to reduce GHG emission is energy sector are: increase in the share of renewables in overall final energy consumption as well as in other sectors: electricity, transport, heating and cooling; increase of energy efficiency which can be expressed by energy intensity of GDP indicator as well as energy consumption per capita, showing overall energy consumption level in the country and number of GHG emission indicators like GHG emission reduction from base year (1990), GHG intensity of energy supply, GHG intensity of GDP and total GHG per capita. These GHG emission indicators also indicates the drivers of GHG emission trends, as reduction of GHG intensity of energy supply indicates GHG emission reduction due to increase of the share of RES in energy consumption and reduction of GHG intensity of GDP indicates reduction of GHG emissions due to increase in energy efficiency. Three main headline indicators for assessing progress towards zero carbon energy are based on 2020 and 2030 climate and energy package goals: cutting in GHG emissions (from 1990 levels); The share of enewables in final energy consumption and improvement in energy efficiency or reduction of energy intensity of GDP.

EUROSTAT and Energy Poverty observatory data was applied for comparative assessment of results of low carbon energy transition in Visegrad countries. As in some years, data is unavailable, the 2005 and 2018 data was applied for assessment of progressing of V 4 countries to carbon neutral society and it's implications to energy poverty. In Table 1 the main energy and climate indicators for Visegrad countries in 2005 and 2018 are given for tracking they transition towards climate neutral society.

Table 1. Main energy and climate indicators for Visegrad countries in 2005 and 2018

EU Member States	*EU28*	*CZ*	*HU*	*PL*	*SK*
2005					
Renewable energy indicators					
Overall Renewable share, %	9,1%	7,1%	6,9%	6,9%	6,4%
RE-T - Renewable energy in Transport, %	1,8%	1,0%	0,9%	1,6%	1,6%
RES-E - Renewable Electricity Generation, %	14,8%	3,8%	4,4%	2,7%	15,7%
RES-H&C - Renewable Heating and Cooling, %	11,1%	10,8%	9,9%	10,2%	5,0%
Energy efficiency indicators					
Energy Intensity [gross inland energy consumption/GDP2015]- toe/M€'15	141,0	331,4	278,3	316,3	338,1
Energy per Capita [gross inland energy consumption/ pop] - kgoe/cap	3 717	4 465	2 823	2 425	3 480
GHG emission indicators					
GHG national total emissions / index 1990	93,9%	75,1%	80,7%	85,2%	69,9%
Total GHG per capita - t CO2 eq./cap	10,9	14,7	7,5	10,6	9,6
GHG Intensity of Energy - kg CO2 eq./toe	2 246,5	2 648,5	1 961,0	3 584,2	1 978,6
Total GHG - GDP Intensity - ton CO2 eq./M€'15	401,5	1 091,3	744,1	1 380,3	929,6
2018					
Renewable energy indicators					
Overall Renewable share, %	17,88	15,15	12,49	11,28	11,9
RE-T - Renewable energy in Transport, %	8,03	6,52	7,68	5,63	6,96
RES-E - Renewable Electricity Generation, %	32,06	13,71	8,29	13,03	21,50
RES-H&C - Renewable Heating and Cooling, %	19,67	20,65	18,12	14,80	10,60
Energy efficiency indicators					
Energy Intensity [gross inland energy consumption/GDP2015]- toe/M€'15	107,84	235,11	212,45	218,79	195,22
Energy per Capita [gross inland energy consumption/ pop] - kgoe/cap	3248,43	4104,76	2731,77	2811,83	3131,59
GHG emission indicators					
GHG national total emissions / index 1990	76,76	64,83	67,82	87,42	59,16
Total GHG per capita - t CO2 eq./cap	8,57	12,19	6,55	10,95	8,00
GHG Intensity of Energy - kg CO2 eq./toe	1970,19	2224,38	1704,04	3203,55	1719,46
Total GHG - GDP Intensity - ton CO2 eq./M€'15-	276,95	698,49	509,55	849,92	498,60
Change during 2005-2018, %					
Renewable energy indicators					
Overall Renewable share, %	96,48	113,38	81,01	63,48	85,94
RE-T - Renewable energy in Transport, %	346,11	552,00	753,33	251,88	335,00
RES-E - Renewable Electricity Generation, %	116,62	260,79	88,41	382,59	36,94
RES-H&C - Renewable Heating and Cooling, %	77,21	91,20	83,03	45,10	112,00
Energy efficiency indicators					
Energy Intensity [gross inland energy consumption/GDP2015]- toe/M€'15	-23,53	-29,05	-23,67	-30,84	-42,26
Energy per Capita [gross inland energy consumption/ pop] - kgoe/cap	-12,60	-8,06	-3,25	15,94	-10,02
GHG emission indicators					
GHG national total emissions / index 1990-	-12,60	-8,06	-3,25	15,94	-10,02
Total GHG per capita - t CO2 eq./cap	-18,25	-13,68	-15,96	2,61	-15,36
GHG Intensity of Energy - kg CO2 eq./toe	-21,11	-17,06	-13,20	3,12	-16,42
Total GHG - GDP Intensity - ton CO2 eq./M€'15	-12,30	-16,01	-13,10	-10,62	-13,10

In Table 2 the main energy poverty indicators for Visegrad countries in 2005 and 2018 are given for assessing the influence of transition towards climate neutral society on energy poverty.

Table 2. Energy poverty indicators for Visegrad countries in 2005 and 2019

Energy poverty indicators	*EU*	*CZ*	*HU*	*PL*	*SK*
2005					
Areas on utility bills, %	7.3	7.2	15.9	24.2	8.5
Inability to keep home warm, %	10.9	9.3	17.7	33.6	13.6
2018					
Areas on utility bills, %	6.6	2.1	11.1	6.3	7.9
Inability to keep home warm, %	7.3	2.7	6.1	5.1	4.8
Change during 2005-2018, %					
Areas on utility bills, %	-9.5	-70.0	-30.1	-74.0	-7.1
Inability to keep home warm, %	-33.0	-71.0	-65.5	-84.8	-64.7

The results of comparative assessment of Visegrad 4 countries is presented in the next section of paper.

3. RESULTS

Results of comparative analysis show that in 2005 Czech Republic distinguished with the highest share of RES in overall final energy consumption as well in the share of RES in heating and cooling however, this level was lower than EU average in the same year. The highest share of RES in electricity generation and transport in 2005 was in Slovakia however it was bellow EU average level. In 2005 energy intensity was the lowest in Hungary and highest one in Slovakia exceeding EU average more than twice. In all other V4 group countries energy intensity of GDP was also twice higher than EU average.

With regards of GHG emission indicators the highest GHG emission reduction since 1990 in 2005 was in Slovakia, following by Czech Republic. The modest reduction was achieved by Poland following by Hungary. In term of drivers of GHG emission the lowest carbon intensity of GDP in 2005 was in Hungary and Slovakia and it was bellow even EU average level. The lowest carbon intensity of GDP in the same year was also in Hungary and Slovakia however it was almost twice EU average level in the same year. Total GHG per capita is distributed in the same way like GHG intensity of GDP among Visegrad countries.

The changes in the main energy and climate indicators of Visegrad countries indicates the leading countries in term of low carbon energy transition. In increase of the share of RES in final energy consumption the best results during 2005-2018 period were achieved by Czech Republic as the share of RES more than doubled during this period, the share of in electricity generation increased more than 3 times and in transport almost 6 times. In other Visegrad countries the increase of the share of RES was also very significant. Poland showed the most modest results as the overall share of RES in final energy consumption has increased by more than 60% and the share in heating and cooling by 45%.

Energy consumption per capita has increased just in Poland during investigated period while in other V4 group countries it has reduced however energy intensity of GDP have declined in all Visegrad countries during 2005-2018 leading by Slovakia in all indicators of energy efficiency. In terms of total GHG emission reduction during 2005-2018 the most advanced country was Slovakia. GHG per capita have declined by 15, GHG intensity of energy by 16% and GHG intensity of GDP by 13% in Slovakia. In Poland even some increase in GHG emission comparing with year 2005 can be observed. Total GHG per capita

increased by 2.6% and GHG intensity of energy has increased by 3% in Poland during investigated period showing alarming trends. In all other V4 group countries GHG emission indicators have declined showing positive trends. In Table 3 the ranking of Visegrad countries based on comparative assessment are provided, the first rank is allocated for the best performing country according specific indicator and in the end all ranks are summed up giving final ranking of V4 group countries based on all indicators showing results in progress towards low carbon energy future.

Table 3. The ranking of Visegrad countries based on the changes of energy and climate indicators during 2005-2018

Visegrad countries	*CZ*	*HU*	*PL*	*SK*
Overall Renewable share, %	1	3	4	2
RE-T - Renewable energy in Transport, %	2	1	4	3
RES-E - Renewable Electricity Generation, %	2	3	1	4
RES-H&C - Renewable Heating and Cooling, %	2	3	4	1
The sum of ranks on renewable energy indicators	7	10	13	10
Energy Intensity [gross inland energy consumption/GDP2015]- toe/M€'15	3	4	2	1
Energy per Capita [gross inland energy consumption/ pop] - kgoe/cap	2	3	4	1
The sum of ranks on energy efficiency indicators	5	7	6	2
GHG national total emissions / index 1990-	2	3	4	1
Total GHG per capita - t CO2 eq./cap	3	1	4	2
GHG Intensity of Energy - kg CO2 eq./toe	1	3	4	2
Total GHG - GDP Intensity - ton CO2 eq./M€'15	1	2	4	2
The sum of ranks on GHG emission indicators	7	9	12	7
The sum of total ranks on progress towards low carbon energy transition	19	26	31	19

As one can see from table 3, the best performing countries in terms of progression towards low carbon energy and economy in V4 group are Czech Republic and Slovakia, both received the same sum of ranks however Czech Republic was the leading country in penetration of renewables and Slovakia was the most advanced country in terms of energy efficiency improvements while in term of GHG emission reduction countries have achieved similar results and obtained the same sum of ranks. Poland distinguishes with the lowest results in penetration of RES providing for the lowest results in all GHG emission reduction indicators. Hungary can be assessed like country somewhere in between of the best and worst performing countries.

In Table 4 the ranking of Visegrad countries based on comparative assessment of energy poverty indicators are provided, the first rank is allocated for the best performing countries like in the case of energy and climate indicators (Table 3).

Table 4. The ranking of Visegrad countries based on progress in energy poverty reduction during 2005-2018

Visegrad countries	*CZ*	*HU*	*PL*	*SK*
Areas on utility bills, %	2	3	1	4
Inability to keep home warm, %	2	3	1	4
The sum of total ranks on progress towards energy poverty reduction	4	6	2	8

As one can see from Table 4 the best results in energy poverty reduction during 2005-2018 were achieved by Poland and the worst results were achieved by Slovakia following Hungary. The trends in energy poverty alleviation during investigated period are opposite to energy and climate indicators progression among Visegrad countries.

4. DISCUSSIONS

The Visegrad Group was founded in 1991 as a cultural and political alliance between Czech Republic, Hungary, Poland and Slovakia. The specific political situation and inherited nuclear energy capacities from their past created situation that transition from fossil fuels to renewables has been quite slow in these countries compared to others EU Member States. This is obvious from National Energy and Climate Plans (NECP) submitted by Visegrad countries in 2019. The low ambitions in fostering penetration of renewables can be treated even as a lost opportunity for these countries to innovate, to phase out dirty industries and to build a basis for future economic growth and prosperity provided by transition to climate neutral society. Analysis of NECPs of V4 countries show, that the share of RES in final energy consumption and targeted sectors in recent years is stagnating in all countries of V4 group.

One can suppose that Visegrad countries will implement their targets set in NECPs, but V4 group members certainly are not between overachievers in the share of RES. Also, lower than average EU targets are determined in these countries because decision makers in these countries often perceive renewables as a measure of last resort and focus more on the nuclear path.

EU average target for RES is 32% of renewables in final energy consumption by 2030. Poland has established 21-23% RES in final energy by 2030 (Ministry of Foreign Assets, 2019), Czech Republic (2019)- 22%, Hungary - 21% (Ministry of Innovation and Technology, 2019) and Slovakia 19.2% (Slovak Ministry of Economy, 2019). All Visegrad countries fail in meeting the recommendations of the European Commission to the draft NECPs from June 2019 to increase their renewable energy targets.

Though, the Visegrad countries are lacking ambition to set RES targets, they are no longer a unified block opposing RERS and strict climate policies (EC, 2020). The views of policy makers on RES penetration are changing, especially in Czech Republic and Slovakia. Some RES technologies attracted high interest from private business and households even in the situation of modest climate change governance policies. It is necessary to highlight, that the implementation of the revised in 2018 Renewable Energy Directive creates a new opportunities to support the low carbon energy transition of V4 countries even in the case of set low targets for RES. The Renewable Energy Directive propose new public support schemes; promote energy prosumers and renewable energy communities; and European and national funding will continue financing the low carbon energy transition in EU Member States (Renewable Networking Platform, 2020). Nonetheless, results in RES penetration achieved during transition to climate neutral society in Visegrad countries depend on policies and measures and extend of public funding for RES. Some very successful programs were implemented in Czech Republic and Slovakia such as the Green Savings Programme in Czechia and the Green Savings Programme for households in Slovakia however the successful implementation of these programmes would not be possible without favorable regulatory framework.

Conducted ranking of V4 countries indicated, that Czech Republic and Slovakia are the best performing countries in low carbon energy transition. Czech Republic is superior in penetration of RES among V4 group members. The increase in the share of RES in power generation in country is based on the fact that the power generation capacities are expected to decrease in the next decade due to the closure of coal-fired power stations (Czech Republic, 2019). Therefore, Czech Republic could take full advantage of the positive synergy effects of using RES inside buildings and increasing energy efficiency to include the energy produced by renewables into the energy efficiency target. Although the amended Directive 2012/27/EU on energy efficiency limits the inclusion of from RES by set conditions, it is possible to negotiate with the European Commission. Therefore, the development and utilisation of RES potential available to the Czech Republic should be a strategic priority for the country in future as well. Renewables are the most economically efficient energy sources providing public service, reducing greenhouse gas emissions and air pollution, improving public health and creating opportunities for industrial modern-

isation. They also enable the citizens and municipalities to participate in the energy system and implement energy justice principles necessary to just low carbon energy transition of the country.

The ranking of V4 countries showed that Slovakia is superior in implementation of energy efficiency targets. High share of nuclear in power generation and very high level of gasification makes the Slovakia less eager to develop an ambitious RES targets by 2030 (Slovak Ministry of Economy, 2019). The Slovak Republic has set target in NECP to increase installed power in solar photovoltaic and wind power plants. A high degree of centralization of heat supply should constitute good technical conditions for the use of biomass, biomethane and geothermal energy in the country (Renewable Networking Platform, 2020). Important challenge is high necessary investment costs for modernization and reconstruction of district heating systems, therefore Slovak Republic show low ambition for RES development in heating and cooling sector. Besides that, the advantage of Slovakia's relatively low-emission energy caused low targets in plans of decarbonization of transport sector as well.

The ranking provided that Poland has lowest position in low carbon energy transition progress. Poland's electricity consumption has been constantly growing within the last decade and reached 175 TWh in 2019. 73,6% of power in country was produced in coal and lignite power plants. Though, the RES position in the Polish energy mix is becoming stronger, however it is still not good enough to meet the set 15% target in the gross final energy consumption by 2020. GHG emission reduction trend has stopped in 2017 and in 2018 and 2019 greenhouse gases emission were stagnating (Ministry of Foreign assets, 2019). A significant part of the energy transition cost may be borne by Polish industry which is fast growing in recent years. There are many advantages that RES can bring to industries in Poland. Onshore wind is currently the cheapest new energy generation source in Poland and PV costs are also decreasing and becoming more and more attractive. Another factor is the high carbon footprint of goods produced in Poland which makes them less competitive in world markets (Renewable Networking Platform, 2020).

The ranking of V4 group of countries putted Hungary in better position than Poland however there are serious problems in moving towards carbon neutral society in this country as well. It is necessary to highlight that Hungary is the only EU Member State where the share of RES in gross final energy consumption was declining in recent years and the target set by 2030 is significantly below the EU average (32%) and lower than the recommended 23% for Hungary by the EC. Such a low ambition can be explained by a Hungarian government plan to rely on nuclear energy - dependent on Russian technology and fuel - as a means to achieve "energy sovereignty". NECP also assumes that the domestic energy consumption will increase by 15% between 2017 and 2030 (Ministry of. Innovation and Technology, 2019). Serious concerns arise due to low interest in RES deployment and weak policies to promote investments in RES technologies and energy efficiency improvements which can provide for prosperous carbon neutral society development by 2050.

CONCLUSIONS

Climate neutral society is not simply a goal for climate change mitigation, it is the way to deal with the man challenges of development and to address 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.

The comparative assessment of Visegrad countries based on energy and climate indicators changes during 205-2018 period indicated that the best performing countries in terms of progression towards low carbon energy and economy in V4 group are Czech Republic and Slovakia, as both received the same sum of ranks. Czech Republic was the leading country in penetration of renewables and Slovakia was the most advanced country in terms of energy efficiency improvements while in term of GHG emission reduction countries have achieved similar results and obtained the same sum of ranks.

Poland distinguishes with the lowest results in penetration of RES providing for the lowest results in all GHG emission reduction indicators. Hungary can be assessed like country somewhere in between of the best and worst performing countries.

The ranking of Visegrad countries based on the energy poverty indicators changes during 2005-2018 period indicated that the best results in energy poverty reduction during investigated period were achieved by Poland and the worst results were achieved by Slovakia following Hungary. The trends in energy poverty alleviation during investigated period are opposite to energy and climate indicators progression among Visegrad countries.

The main policy recommendations for V4 group countries would be to promote investments in RES technologies by developing policies and measures targeting specific consumer groups from households to business entities and energy suppliers. Though high share of nuclear in power generation balance provides low GHG emission intensity of energy supply however increase of the share of renewables in final energy generation can provide additional benefits linked with economic growth, and new jobs creation as well as reduction of energy poverty. Energy efficiency improvement through large scale energy renovation of buildings can provide for extra benefits like costs savings and improved living conditions, quality of life including energy poverty reduction as well as positively influence public health.

The study has limitations as just period 2005-2018 of transition towards carbon neutral society was addressed. The future research is necessary to address issues of dynamics as well as provide policy assessments by identifying their influence on carbon neutral society transition. The policy analysis and more in depth policy discussion can provide better understanding of results and explain the progress achieved by countries towards low carbon transition.

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