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Analysis of the Main Drivers of GHG Emissions in Visegrad Countries: Kaya Identity Approach

Dalia Streimikiene 

ABSTRACT

There are two main ways to reduce anthropogenic GHG emissions: energy efficiency improvement and increase usage of renewable energy sources. Taking these two main ways into account, it is possible to analyze the main drivers of GHG emissions in the country and to make forecast of future GHG emissions based on historical trends. The Visegrad group (V4) countries, including Poland, Hungary, Slovakia, and Czech Republic were selected to provide comparative assessment of their GHG emission drivers and to evaluate effects of climate change mitigation policies in energy sector on GHG emission trends. The Kaya identity approach was applied allowing to perform simple multiplication. Kaya identity equation substitutes the factors with well-established and measurable quantities, which leave little space for ambiguity. The multiplying population size by GDP per capita, energy intensity, and carbon intensity of energy allows to get total GHG emissions in the country and define its energy efficiency or use of renewables are the main drivers of GHG emissions, including the effect of economic growth expressed by GDP per capita.

KEY WORDS:

Kaya identity, greenhouse gas emissions, renewable energy, energy efficiency policies, Visegrad Countries.

JEL Classification: H30, P18, Q20, Q30.

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1. Introduction

All EU member states should follow strict climate change mitigation commitments set by the EU. The EU set a target to achieve carbon neutrality by 2050 and member states should pre-prepare their national energy and climate plans (NECP) to deal with climate change reduction targets set for 2030 and 2050, as 2020 targets have been already to be achieved.

The NECPs are the framework for Member States to outline their climate and energy goals, policies, and measures from 2021 to 2030. The development of these Plans is a legal requirement under the Governance Regulation adopted in December 2018.

The most difficult issue of EU 2030 Framework is

that, unlike in the previous 2020 Package, the new EU targets are not translated into national binding targets through EU legislation. The proposals, set out in the Energy Union Package, aim to provide a coherent approach to climate change, energy security and competitiveness, and to achieve the goals agreed under the 2030 Framework.

The main targets of EU 2030 Framework are:

- To achieve at least 55% cuts in greenhouse gas (GHG) emissions from 1990 levels in 2030;
- To achieve at least 32% share for renewable energy in 2030 and
- To achieve at least 32.5% improvement in energy efficiency.

There are plenty of papers analyzing climate change mitigation policies in energy sector and

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their impacts in EU MS in terms of decoupling of energy consumption from GHG emissions or discussing Kuznets curve application results for selected countries (Ramanathan, 2006; Allard et al., 2018; Wang et al., 2019; Apeaning, 2020; Rus et al., 2020; Hafner, Paoplo, 2020; Su et al., 2020; Hwank et al., 2020; Dolge et al., 2021; Istudor et al., 2021; Mastini et al., 2021), however the main drivers of this decoupling of GHG emissions from economic growth are not analysed and compared by applying simple and easy to track and understand frameworks like Kaya identity. There are several studies that applied Kaya identity for analysis of climate change mitigation (Streimikiene & Balezentis, 2016; Liobikiene et al., 2016) however most of these studies were demonstrating advanced decomposition analysis tools without analysis of results and their implications (Zhan et al., 2009; Karmelos et al., 2016; Lima et al., 2016; Tavakoli, 2018; Mahony, 2018; Ortega-Ruiz et al., 2020; Gonzales-Torres et al., 2021). There are two main ways to achieve GHG emission reduction in energy sector - energy efficiency improvement and decarbonization of energy supply. Therefore, these issues need to be addressed in the beginning of macro level to identify the main contributors for GHG emission reduction.

This paper aims to overcome this gap. In this paper, the Kaya identity approach was applied to analyze historical drivers of GHG emissions in 4 selected countries and to discuss the similarities and differences between countries having similar economic development level and EU accession experience including geopolitical situation and climate. allows to generate pertinent policy implications and recommendations for decision makers.

2. Literature Review

Scholars agree that the main factors having impact on anthropogenic GHG emissions are: energy intensity of economy, reduction carbon intensity of energy consumption, and economic growth which is also linked to population increase (Brody, Tutak, 2021;

To implement the EU 2030 Climate and Energy Policy Framework, countries have decided to implement various policies and measures targeting all three aims of this framework: energy efficiency

improvement in all supply and demand sectors and increase usage of carbon free energy supply sources, mainly renewables. Carbon capture and storage are also important measures, however more economically efficient and effective are the increase in energy savings and usage of renewables. Therefore targets for these areas were put aside GHG emission reduction goals (Kulovesi & Oberthur, 2020).

With regards of studies dealing with decoupling of GHG emissions from energy consumption, the majority of studies are built on environmental Kuznets curve (EKC) concept. However, the empirical evidence of the EKC is mixed (Allard, 2018; Al-Mulali, Ozturk, 2016). Methodological approaches are varied. Some scholars have investigated the correlation between income and environmental outcomes of a country or set of countries over time however arrived on different conclusions with regards of the shape of EKC (Jebli et al., 2016; Bilgili et al., 2016; Farhani et al., 2014).

There were studies trying to apply Shapley technique to the Kaya Identity to test the EKC hypothesis. The study by Garrett-Peltier (2018) grouped countries based on the income level, and assessed the importance of income on GHG emissions for countries at various stages of development. The study found global EKC as for lower income countries, rising income is the most important determinant of emissions, but for higher income countries the economic growth is offset by improvements in energy efficiency. Based on these assumptions the inverted-U-shaped EKC was justified.

However, all studies dealing with the climate change mitigation policies and their effects on GHG emission reduction do not distinguish the importance of interlinked measures of climate change mitigation in energy sector: energy efficiency improvement and carbon intensity of primary energy reduction based on case study approach. The case study based on qualitative and quantitative data can shed lighter on the main drivers of GHG emissions in selected countries from the same region. It also allows to learn from results of one country and apply good practice case studies to another country in the region.

In next section of the paper Kaya identity indicators were applied and analysed in Visegrad coun-

tries: Poland, Hungary, Slovakia, and Czech Republic. These countries were selected for case study as neighbouring countries which have entered EU in the same year and have similar economic, social, and geographical conditions.

3. Data and Methods

The Kaya identity (Kaya, 1990) is a decomposition method that shows the level of energy related CO₂ emissions due to the following factors: (a) carbon intensity (CO₂ emissions per unit of total primary energy supply (TPES), (b) energy intensity (TPES per unit of GDP), (c) gross domestic product per capita (GDP/cap) and (d) population.

Population growth and economic growth are the main factors which influence GHG emission trends. The GDP per capita is the best description of economic growth (Tavakoli, 2018).

The next important GHG emission driver is “En-

ergy Intensity” as it measures energy efficiency, or provides the amount of economic output that can be generated by one standardized unit of energy used. The higher energy efficiency the lower are associated GHG emissions. The carbon intensity of energy supply is the most important driver of energy related GHG emissions in the country as it shows the low carbon energy transition trends and the increasing share of renewables is the major reason of decrease of carbon intensity of energy consumption.

Table 1 provides and describes the main indicators of Kaya identity.

The Kaya identity formula can be presented in the following form:

$$CO_2 \text{ Emissions} = \text{Population} \times (\text{GDP/Population}) \times (\text{Energy/GDP}) \times (\text{CO}_2/\text{Energy})$$

In the next section of paper, the main trends of Kaya identity indicators will be analyzed and discussed among V4 group countries.

Table 1

Kaya Indicators Framework

Main indicators	Description and measurement units	Abbreviation
Population growth		
Population	millions	Population
Economic growth		
GDP per capita	Gross domestic product per capita, thousand EUR/inhabitant at PPP	GDP/Population
Energy efficiency		
Primary energy intensity of GDP	Primary energy intensity is the primary energy consumption per unit of GDP, toe/Million EUR 2010 prices	Energy/GDP
Renewable energy sources		
Carbon intensity of energy supply	Carbon intensity (CO ₂ emissions per unit of total primary energy supply (TPES), kgCO ₂ eq/toe	CO ₂ /Energy
GHG emissions		
GHG emissions	The total energy related greenhouse gas emissions (without LULUCF, with international aviation) as declared by countries to UNFCCC, MtCO ₂ eq	CO ₂ emissions

4. Discussion of Results

The indicators of Kaya identity framework provided in Table 1 were collected for 4 Visegrad countries (Hungary, Czech Republic, Slovakia, and Poland) are analyzed below.

In Figures 1-5 the trends of the main indicators constituent to Kaya identity are given in V-4 countries during 30 years period.

As Figure 1 indicates, the Poland is dominating with the high size of population among V-4 countries however the trend of population decline can be noticed in Poland. Slovakia is the country having the lowest number of inhabitants however the number of populations was not declining during 1990–2020-year period. During investigated period, the number of populations has declined by 6% just in Hungary, however it increased by 3% in Slovakia and Czechia and remain stable in Poland during the same period.

As one may notice from Figure 2, Czechia distinguishes from other V-4 countries with the highest GDP per capita, following Slovakia. Hungary and Poland have GDP per capita more than 20% lower than in Czech Republic. Comparing economic growth results achieved during 1990-2020 one can

notice that the highest achievement in economic growth was achieved by Poland during investigated period and the lowest economic growth per capita was recorded in Czech Republic. The GDP per capita increased by almost 3 times in Poland (186%) and by at the same time it has increased just by 65% in Czechia and by 67% in Hungary and almost by 118% in Slovakia.

Figure 3 showed that energy intensity in V-4 countries was declining during all investigated period however energy intensity in Czechia is significantly lower than in other V-4 countries. In Czechia energy intensity has declined by 56% and in Hungary by 41%. The highest declined in energy intensity during investigated period was achieved by Poland and Slovakia as energy intensity of economy dropped by 65% during 20-year period. Now all V-4 countries have quite similar energy intensity of economy though GDP per capita levels are different.

As one can see in Figure 4, Poland has the highest carbon intensity of primary energy supply among V-4 countries. Slovakia and Hungary are countries having the lowest carbon intensity of energy supply though during investigated period countries showed

Figure 1
Development of Population Growth in V-4 Countries During 1990-2020 Period

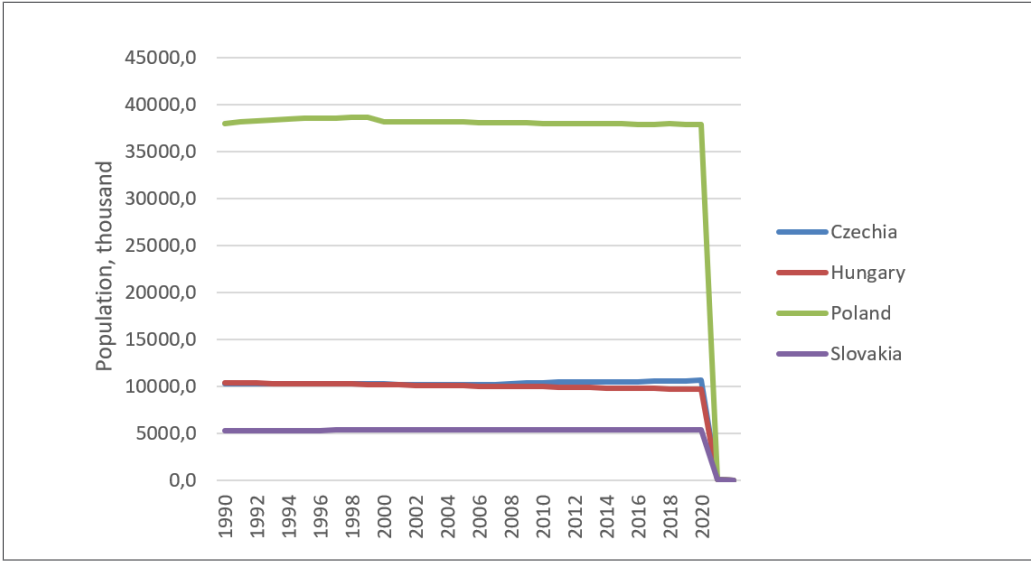
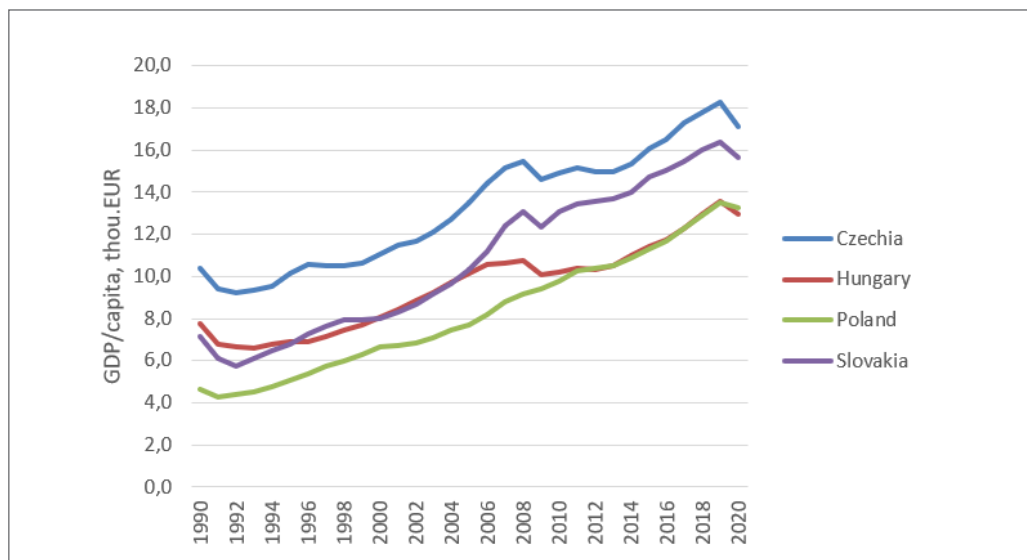
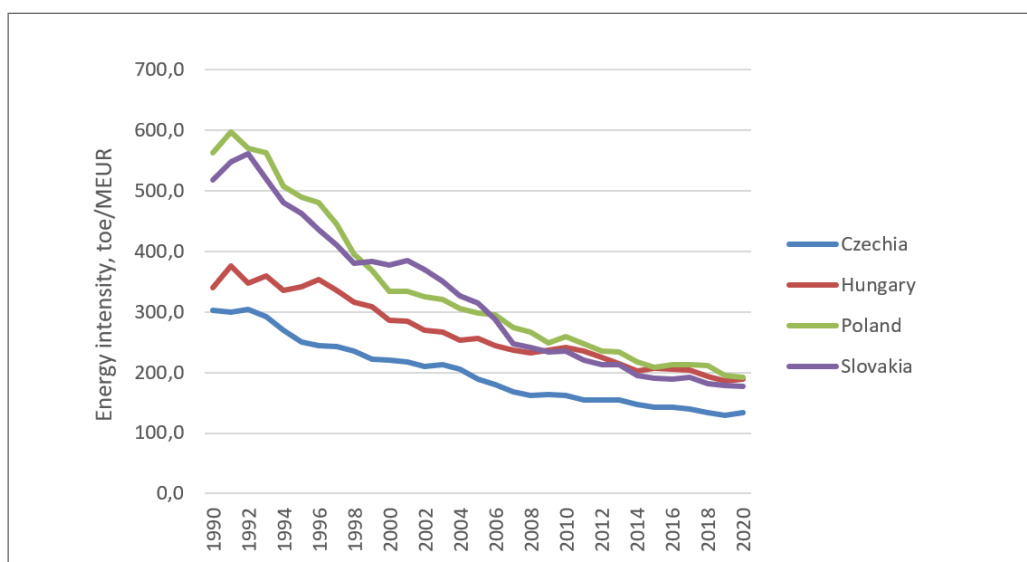


Figure 2*Development of GDP per Capita Growth in V-4 Countries During 1990-2020 Period***Figure 3***Development of Primary Energy Intensity in V-4 Countries During 1990-2020 Period*

significant reduction of carbon intensity of primary energy supply. Slovakia has achieved 35% reduction of carbon intensity of energy supply following by Czechia which has achieved 30% reduction of the same indicator. However, Poland experiences a very modest reduction of carbon intensity of final energy – just 19% during 30 years period. Hungary reduced carbon intensity of primary energy supply by 26%.

Such differences among V-4 countries can be explained by the differences in fast deployment of renewables. Slovakia has achieved significant carbon intensity of energy decrease due to the sharp increase of the share of renewables in final energy consumption in 2020.

As one can see from Figure 5, Poland has the highest GHG emissions among V-4 countries and this is linked with the size of country and number of populations. Analysis of GHG emission trends shows that Czechia has achieved the highest energy related GHG emission reduction during 1990-2020. GHG emissions have declined by 50% in Czechia during 30 years period. Slovakia is the next best performing country having achieved 47% of energy

related GHG emission reduction during investigated period. Poland has achieved just 21% of GHG emission reducing during 1990-2020 period and in Hungary by 35%.

In Table 2 the V-4 the main drivers of GHG emission reduction are compared among V-4 countries during 1990-2020 period.

Table 2 provides results of Kaya identity indicators based on the newest available data form EUROSTAT (European Union, 2022).

Information available in Table 2 shows that Czechia has achieved highest GHG emission reduction during 30 years due to energy intensity decrease. GDP per capita growth had positive impact on the growth GHG emissions however, energy intensity reduction by 65% outweighed impact of economic growth. The input from carbon intensity decrease of primary energy consumption has lower impact on GHG emission reduction in comparison with energy intensity decrease, but overall, both policies for energy efficiency improvement and promotion of carbon free energy suppliers resulted in positive decline of energy related GHG emissions by 47% during investigated period.

Figure 4
Development of Carbon Intensity of Energy in V-4 Countries During 1990-2020 Period

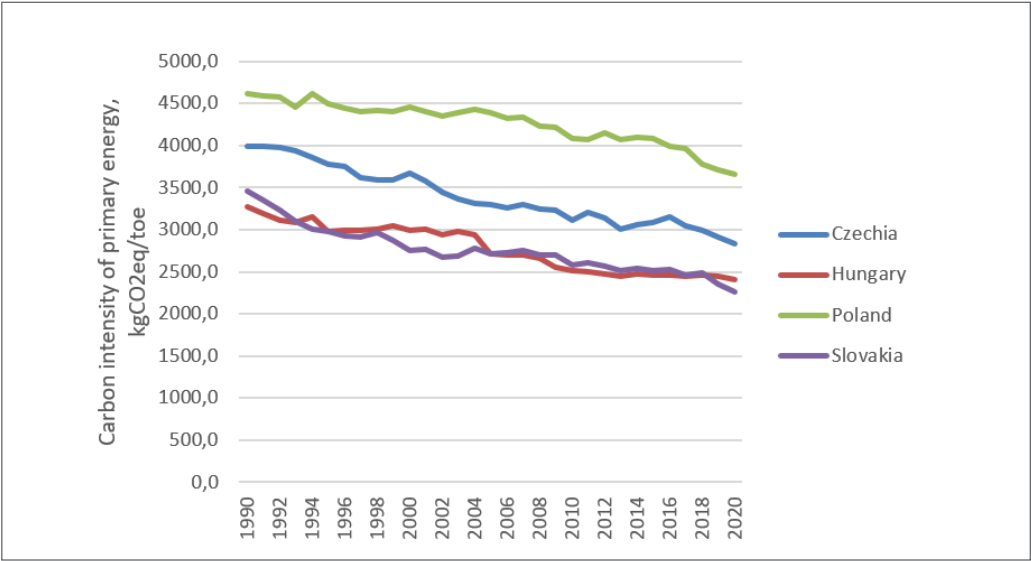
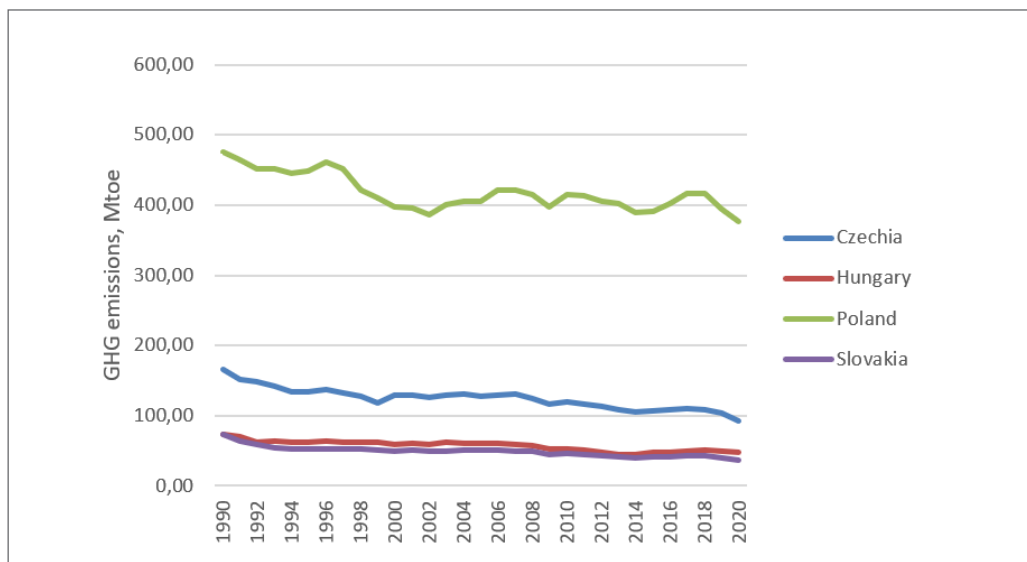


Figure 5*Development of GHG Emissions in V-4 During 1990-2020 Period***Table 2***Kaya Identity Indicators in 1990 and 2020 and Changes*

Main indicators	Hungary									Slovakia		
	Czechia			Hungary			Poland			Slovakia		
	1990	2020	Change, %	1990	2020	Change	1990	2020	Change	1990	2020	Change
Population, thousand	10362	10694	3	10375	9770	-6	38038	37958	-0.3	5288	5498	3
GDP/Population, thou EUR/inhabitant PPP PPP	10.4	17.1	65	7.8	13.0	67	4.6	13.2	186	7.2	15.6	118
Energy/GDP, toe/Million EUR 2010 prices	303.0	133.7	-56	3339.6	188.8	-41	536	193	-65	518.6	177.7	-65
CO ₂ /Energy, kg-CO ₂ eq/toe	3991	2827	-30	3270	2414	-26	4611	3665	-19	3455	2256	-35
CO ₂ emissions, MtCO ₂ eq	166.8	92.8	-47	73.8	47.6	-35	476.5	377.0	-21	73.5	31.1	-50

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

As one can see in information provided in Table 2, Hungary has achieved 35% of energy related GHG emission during 30 years mainly due to energy intensity decrease. The impact from carbon intensity decrease to GHG emission reduction was significantly lower. Economic growth of the country also has contributed significantly to the GHG emission growth which was mitigated by policies to promote energy efficiency and use of renewable energy sources.

Poland has achieved the modest reduction of energy related GHG emissions due to very high economic growth during 30 years as GHG per capita almost tripled in the country. Energy intensity decrease was the main driver of GHG emission reduction in the country as the input of carbon intensity of primary energy supply was less significant in Poland.

Slovakia has achieved 50% of energy related GHG emission reduction during investigated period due to sharp energy intensity decrease (by 65%) and significant carbon intensity of primary energy decrease (-35%). The economic growth of 118% since 1990 also provided input on GHG emission growth however strict and effective measures of climate change mitigation in energy sector have overweighted negative impact of economic growth on GHG emissions.

In all V-4 countries investigated the clear decoupling of GDP per capita growth from GHG emission growth can be noticed if climate change mitigation policies implemented in selected group of countries were successful.

The example of Slovakia can be inspiring as country achieved the best results in overall GHG emission reduction and with fast economic growth (118%) was able to reduce its GHG emissions by 50%. In addition, in Slovakia both policies to promote energy efficiency and renewable energy sources contributed significantly to GHG emission reduction in contrast to the other V-4 countries where energy efficiency improvement was the key factor of GHG emission reduction.

5. Conclusions and Policy Implications

The results of conducted analysis provided all Visegrad countries achieved the decoupling of GDP per capita growth from GHG emission growth during 30 years period since 1990. Therefore, the imple-

mented climate change mitigation policies in analysed countries were successful.

The input from carbon intensity decrease of primary energy consumption has lower impact on GHG emission reduction in comparison with energy intensity decrease, but overall, both policies for energy efficiency improvement and promotion of carbon free energy suppliers resulted in positive decline of GHG emission in Czechia, Slovakia, Hungary, and Poland.

Czechia has achieved the highest GHG emission reduction during 30 years due to energy intensity decrease. GDP per capita growth had positive impact on the growth GHG emissions however, energy intensity reduction by 65% overweighted impact of economic growth. Energy related GHG emissions by 47% during investigated period.

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Poland has achieved a modest reduction of energy related GHG emissions due to very high economic growth during 30 years as GHG per capita almost tripled in the country. Energy intensity decrease was the main driver of GHG emission reduction in the country as the input of carbon intensity of primary energy supply was less significant in Poland.

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improvement was the key factor of GHG emission reduction.

The main policy recommendations are to put more emphasis on energy efficiency for achieving GHG emission reduction targets set by 2030 as these policies provided the best results in GHG emission reduction during 1990-2030.

Other V-4 countries can take example from Slovakia which distinguished among the members of V-4 group with the best results in GHG emission reduction and especially efficient use not only energy efficiency reduction measures but also measures for energy sector decarbonization and increase share of renewables.

Poland has demonstrated tripled GDP per capita during 3 years and achieved also significant decoupling of economic growth from GHG emission reduction. Though this country was mainly relying on energy efficiency improvements, there is high potential for renewable energy deployment in country as current share of renewables in final energy consumption in Poland makes just 16%. And in 2030 it should almost double be based on Energy and Climate framework for 2030.

6. Limitation and future research

Speaking about the limitation of our research, several issues come to mind: the analysis performed in this paper is based on comparative assessment of selected.

Future research is necessary in order to analyze and compare policies and measures to promote energy efficiency and renewable in Baltic States. More advanced and robust methods of decomposition analysis based on Kaya identity indicators will be applied in the future, to determine exact input of the main drivers of GHG emissions on reductions achieved by Visegrad countries.

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