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CRECIMIENTO ECONÓMICO, CONSUMO DE ENERGÍA DEL SECTOR RESIDENCIAL Y EMISIONES DE CO2 EN LOS PAÍSES EN TRANSICIÓN

MEMORIA DE LA **TESIS DOCTORAL** REALIZADA POR

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CONTENT

RESUMEN

Hoy en día, el mundo se enfrenta a muchos desafíos globales, y el cambio climático es uno de ellos. Para abordar el cambio climático y prevenir un mayor calentamiento global, se necesitan con urgencia esfuerzos conjuntos y cambios importantes en todos los aspectos de nuestra sociedad. Bajo el Acuerdo de París, todos los países firmantes deben desarrollar programas nacionales e introducir objetivos para reducir sus emisiones.

Esta tesis doctoral está impulsada por la necesidad de desarrollar políticas energéticas en economías en transición, conocidas por su alto consumo de energía junto con altos niveles de intensidad energética. Establecer estrategias apropiadas relacionadas con la energía es esencial para cumplir los compromisos del Acuerdo de París, en un contexto de creciente demanda de energía. Por tanto, el objetivo de esta tesis doctoral es incrementar el conocimiento sobre el patrón energético de las economías en transición, para que pueda ser utilizado en el proceso de desarrollo de políticas energéticas adecuadas para reducir las emisiones de CO2 en la región. Las principales aportaciones de esta tesis se describen brevemente a continuación:

En primer lugar, esta tesis analiza la relación entre el crecimiento económico y el consumo de energía residencial en 12 economías en transición durante el período 1995-2013, utilizando la versión ampliada de la hipótesis de la curva de Kuznets ambiental (CKA). Los resultados de la estimación son compatibles con la hipótesis de la CKA. Sin embargo, el punto de inflexión no se ha alcanzado, aunque Rusia está cerca de él. Los resultados obtenidos varían entre países de renta alta y países de renta baja. Los resultados también muestran que los valores de elasticidad no son constantes en el tiempo y entre los países. Estas diferencias hacen recomendable adaptar la política energética a cada país.

En segundo lugar, esta tesis analiza las medidas adoptadas para promover el uso de energías renovables para el uso eléctrico en 17 economías en transición. El estudio muestra que la tarifa regulada es el mecanismo más utilizado (vigente en doce países), mientras que el balance neto se ha introducido en siete países. El sistema de subastas se está extendiendo rápidamente. Además, también existen incentivos fiscales en cuatro países. El estudio encuentra

importantes diferencias en las medidas aplicadas y mejoras de la capacidad instalada por los países. Ucrania, Rusia y Serbia son los que más han aumentado su capacidad instalada de energía renovable. Este estudio muestra que las recientes medidas adoptadas parecen tener un impacto positivo en la capacidad de generar electricidad a partir de las energías renovables.

Esta tesis doctoral contribuye al conocimiento sobre las economías en transición que debería ser útil en varios niveles: desde los investigadores hasta las autoridades responsables de diseño de políticas. Los principales hallazgos nos llevan a concluir que los países seleccionados deberían continuar trabajando para mejorar la eficiencia energética y reducir la intensidad del carbono. Sin embargo, si bien los países de la región comparten algunos desafíos comunes, se han identificado diferencias significativas en su nivel económico y el uso de energía. Por tanto, las políticas energéticas deben adaptarse de acuerdo con las características y circunstancias especiales de cada país.

ABSTRACT

There are many global challenges the world is facing today, and climate change is one of them. To tackle climate change and prevent the further global warming, joint efforts, and wide-ranging changes in all aspects of our society are urgently needed. Under the Paris Agreement, all signatory parties should enhance their mitigation efforts, developing national programs and introducing targets to reduce their emissions.

This doctoral thesis is driven by the need to develop energy policies in transition economies, known for their high energy consumption along with high energy intensity levels. The appropriate energy-related strategies are essential to fulfil the commitments under the Paris Agreement in the context of meeting increasing energy demand. Therefore, the aim of this doctoral thesis is to increase the knowledge on transition economies that can be used in the process of developing the adequate energy policies to reduce CO2 emissions in the region. The main contributions of this thesis can be briefly described as follows:

In the first place, this research analyses the relationship between economic growth and residential energy consumption in 12 transition economies during the 1995–2013 period, by testing the expanded version of the EKC hypothesis. The estimate results are compatible with the EKC hypothesis. However, the turning point has not been reached, although Russia is close to it. The obtained results vary for low-income and high-income countries. The results also show that the elasticity values are not constant over time and countries. These differences make it recommendable to adapt the energy policy to each country.

In the second place, this research analyses the measures adopted to promote the use of renewable energy (RE) in 17 transition economies for electricity generation. The study shows that feed-in tariffs (FITs) are the most used mechanism in force (in 12 countries), while net metering has been introduced in seven countries. Tendering is spreading rapidly. In addition, tax incentives are also in place in four countries. The study finds important differences in the measures applied, and installed capacity improvements, by country. Ukraine, Russia and Serbia

have most increased their RE installed capacity. This study shows that the recent measures adopted seems to be having a positive impact on the capacity to generate electricity from RE.

This doctoral thesis contributes to the knowledge on transition economies that should be useful on many levels: from researchers to policy makers. The main findings led us to conclude that selected countries should continue working on improving energy efficiency and reducing carbon intensity. However, while the countries of the region share some common challenges, significant differences in their economic level and energy use have been identified. Therefore, the energy policies should be adapted in accordance with the special characteristics and circumstances of each country.

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CHAPTER 1. INTRODUCTION

1.1. Presentation.

There are many global challenges the world is facing today, and climate change is one of them. It is impacted by a fast majority of factors and, at the same time, itself has impacts on them. Some of these factors are population growth, poverty, economic growth, sustainable development and resource management. All these issues are complex and difficult to tackle since most of them are interconnected and interdependent. Consequently, it is evident that not only they must be studied from different angles, but also need to be addressed at the international level.

The history of the international regulation on climate change begins with the foundation of the Intergovernmental Panel on Climate Change (IPCC) in 1988, as an intergovernmental body of the United Nations. IPCC reports cover the "scientific, technical and socio-economic information relevant to understanding the scientific basis of risk of human-induced climate change, its potential impacts and options for adaptation and mitigation" (IPCC, 1998).

In this regard, according to the IPCC First Assessment Report (IPCC, 1992), emissions resulting from human activities are substantially increasing the atmospheric concentrations of the greenhouse gases (GHG): carbon dioxide (CO2), methane (CH4), chlorofluorocarbons (CFCs) and nitrous oxide (N2O), enhancing the greenhouse effect and resulting on average in an additional warming of the Earth's surface. It also was pointed out that some gases are potentially more effective than others at changing climate, and CO2 has been responsible for over half the enhanced greenhouse effect.

To address climate change, the United Nations Framework Convention on Climate Change (UNFCCC) was signed in 1992. Its main objective is "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner” (United Nations, 1992). According to the treaty, the countries were divided into three categories with differential responsibilities: industrialized countries and economies in transition (Annex I), developed countries with special financial responsibilities (Annex II) and developing countries (Non-Annex I Parties).

The next important step was the adoption in 1997, within the UNFCCC, of the Kyoto Protocol, that entered into force in 2005 due to a complex ratification process. Following the principles and the annex-based structure of the Convention, the Kyoto Protocol only binds the countries listed in Annex I. In addition, the targets for each country were specified in its Annex B. Initially, those targets implied the overall reduction of GHG emissions to an average of 5% against 1990 levels, during the first commitment period from 2008 to 2012 (UNFCCC, 1997). Afterwards, the Kyoto Protocol was extended, by adopting The Doha Amendment in 2012. During the second commitment period, from 2013 to 2020, Parties committed to reduce GHG emissions by at least 18% below 1990 levels (UNFCCC, 2012). However, the composition of countries in the second commitment period is different from the first.

Later, the Kyoto Protocol was replaced by the Paris Agreement (UNFCCC, 2015). In 2015, the Paris Agreement was adopted at the 21st Conference of Parties (COP21) within the UNFCCC and entered into force in 2016. Its main objective is to reinforce the measures applied to combat climate change by holding the increase in the global average temperature to well below 2˚C above pre-industrial levels (Art. 2a, Paris Agreement). In order to achieve this long-term temperature goal, it is necessary to reach a global peak of GHG emissions, as soon as possible (Art. 4, Paris Agreement).

The definitions for these technical terms can be found in the IPCC Special Report on Global Warming of 1.5°C (IPCC, 2018). In this sense, to define the pre-industrial temperature levels, the reference period 1850–1900 is used. Regarding global average temperature, it states that human-induced warming reached 1°C above pre-industrial levels around 2017, rising by 0.2°C per decade, and it would reach 1.5°C around 2040 (see Figure 1).

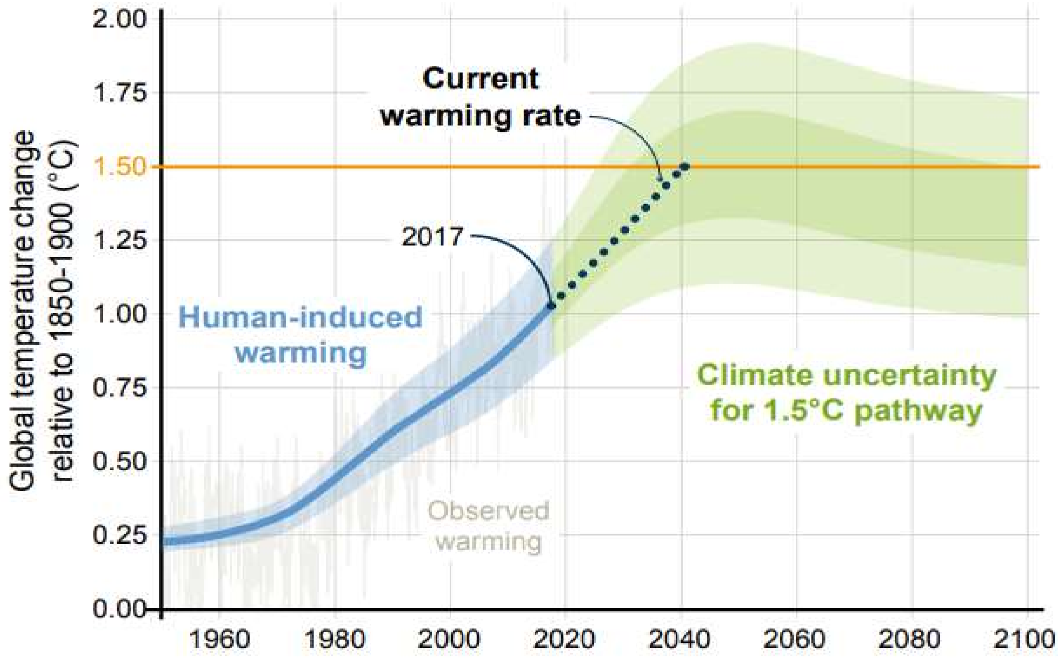


Figure 1. Global temperature change relative to 1850-1900 (°C).
Source: IPCC (2018).

Moreover, the IPCC report (IPCC, 2018) provides the CO2 emissions reduction amounts and the remaining carbon budget for 1.5°C and 2.0°C scenarios. As Table 1 shows, in order to archive the goals under the Paris Agreement, CO2 emissions must decline by approximately 25% by 2030, and reach net zero by 2075-2085. On the other hand, to limit global warming to 1.5˚C, global net anthropogenic CO2, emissions must decline by 40–60% by 2030 and reach net zero by 2050-2055.

Table 1. Global warming scenarios and CO2 emission reduction targets.

	Reduction of CO2 emissions by 2030, %	Reaching net zero emissions deadline	Remaining carbon budget, including 2018, Gt CO2
1.5 ˚C scenario	40 – 60	2050 (2055)	420
2.0 ˚C scenario	25	2075 (2085)	1178

Source: Own elaboration from IPCC (2018).

In terms of the remaining carbon budget, the total amount of future net global CO2 emissions, including emissions from 2018, should not exceed 420 Gt CO2, to limit global warming to 1.5˚C, while in the 2˚C scenario, it should not exceed 1178 Gt CO2.

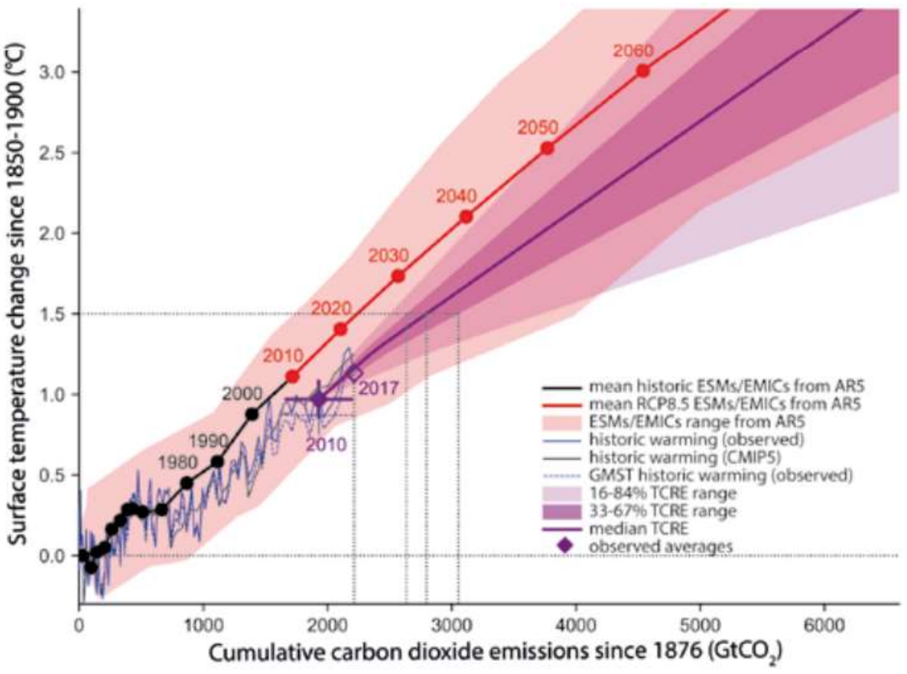


Figure 2. Temperature changes from 1850–1900 versus cumulative CO2 emissions since 1876.
Source: IPCC (2018).

In other words, to tackle climate change and prevent the further global warming, wide-ranging changes in all aspects of our society are urgently needed. In this regard, all signatory parties of the Paris Agreement are held responsible for taking action on the subject of the reduction of CO2 emissions, which can be achieved through reduction of energy consumption, especially from fossil fuel combustion, and by shifting towards low-carbon alternatives, such as renewable energy sources.

1.2. Justification of the doctoral thesis.

The main contributor to increasing atmospheric CO2 is fossil fuel combustion, accounting for about 70% of total emissions (IPCC, 2013). In fact, global CO2 emissions from fuel combustion reached a historical high of 33.5 GtCO2 in 2018, as a result of higher energy consumption (IEA, 2020b). Therefore, in order to achieve the targets under the Paris Agreement, all signatory parties should reduce energy consumption from fossil fuel combustion and move towards a larger use of renewable sources of energy.

For a radical reduction of emissions, joint efforts are needed on a global scale. The list of the signatory parties of the Paris Agreement includes 17 countries of South-Eastern Europe and the Commonwealth of Independent States (CIS). These countries, chosen for this doctoral thesis, are considered to be transition economies, according to the classification of the 2019 Annual Report on the world economic situation and prospects, published by the United Nations (United Nations, 2019). The countries included in this research are Albania, Armenia, Azerbaijan, Belarus, Bosnia and Herzegovina, Georgia, Kazakhstan, Kyrgyzstan, the Republic of Macedonia, the Republic of Moldova, Montenegro, Russian Federation, Serbia, Tajikistan, Turkmenistan, Ukraine and Uzbekistan.

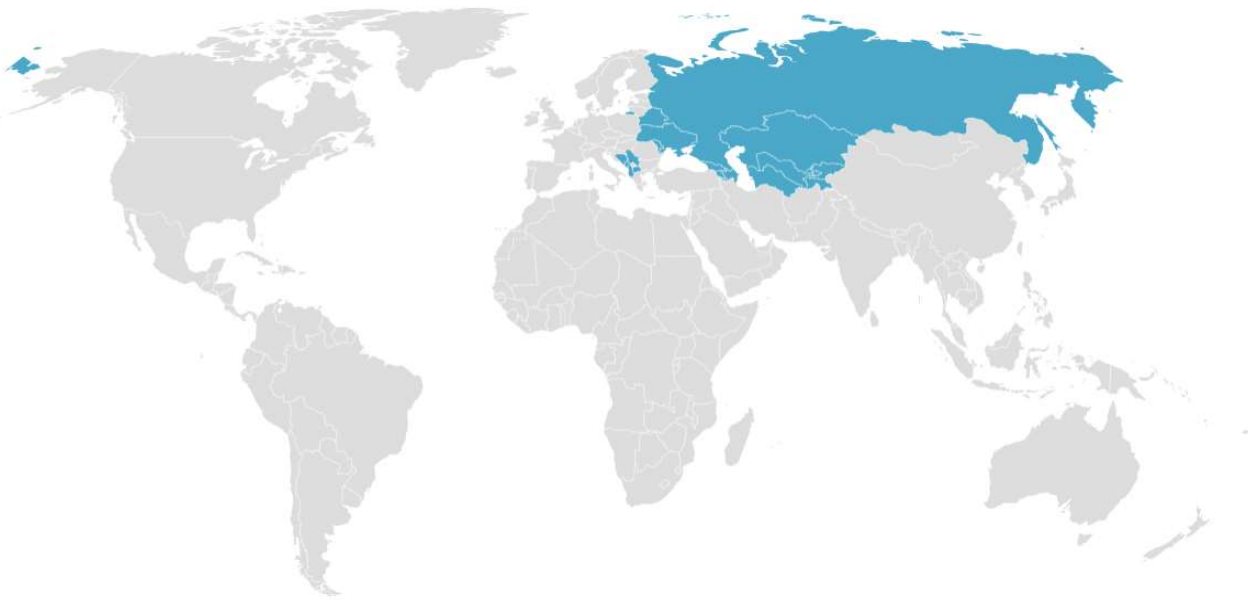


Figure 3. Transition economies.
Source: Own elaboration.

Transition economies have not been extensively studied as some other regions. There are very few studies dedicated to their analysis in the energy economics literature. However, according to the International Energy Agency (IEA, 2020b), the CO2 emissions from fuel combustion in this region accounted for 2,368.2 MtCO2 in 2018, this way being responsible for 7.07% of total emissions. In terms of the final energy consumption, these countries used 719,580 Ktoe, which represented 7.24% of the global energy consumption, a significant share which makes an analysis of the region relevant.

In addition, the study of these countries is particularly interesting as they began their transition with the inheritance of wasteful energy use, which still generally weighs on the carbon intensity values of their economies. Up to date, energy and CO2 intensity in transition economies remains about two times higher than, for instance, in the EU.

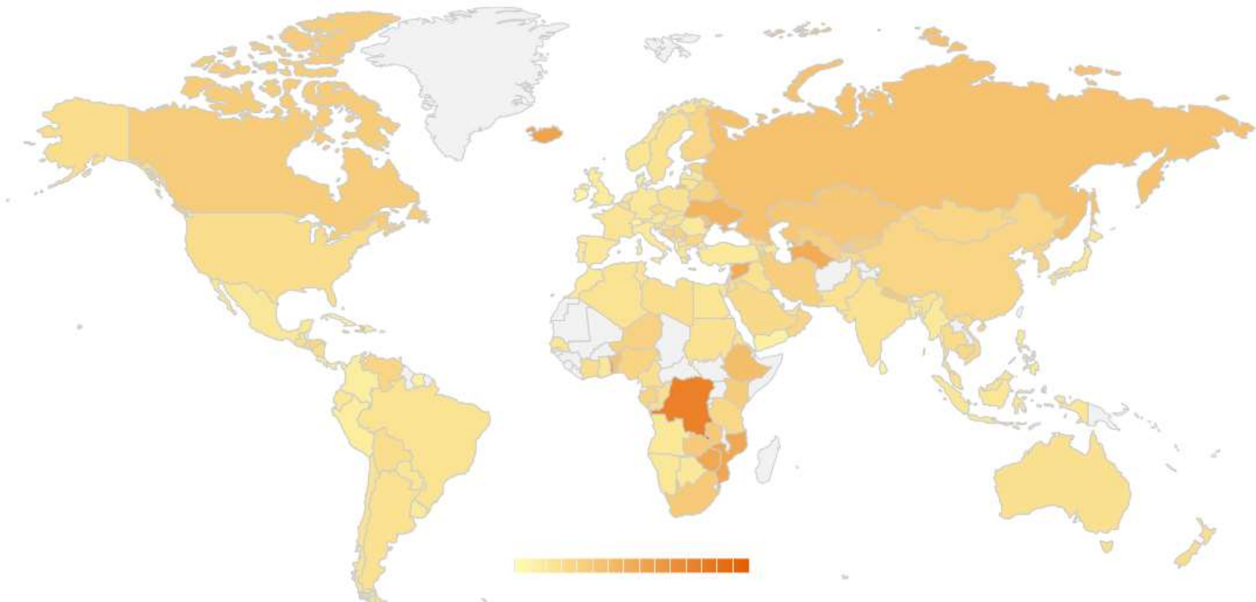


Figure 4. Energy intensity measured in terms of primary energy and GDP, 2017.
Source: (IEA, 2020a)

Moreover, several countries of the region are net fuel-exporting economies, which makes a transition to a low-carbon economy more difficult. They thus require additional efforts to achieve low emission targets (EBRD, 2015).

Table 2. Main targets in the INDCs: Transition economies.

Country	Targets
Albania	Reduction of CO2 emissions by 11.5% below 'business as usual' (BAU) in 2030 (708 kt CO2 reduction in 2030).
Armenia	Cap emissions at 633 million tons of carbon dioxide equivalent between 2015 and 2050.
Azerbaijan	GHG emissions reduction: 35% below its 1990 level by 2030.
Belarus	GHG emissions reduction: 28% below its 1990 level by 2030.
Bosnia and Herzegovina	Unconditional reduction of GHG emissions by 2% below BAU in 2030 (18% increase compared to 1990 level). Conditional reduction by 23% below BAU (3% below compared to 1990 level) is claimed in case of international support availability.
Georgia	Unconditional GHG emissions reduction by 15% below BAU in 2030. GHG emissions possible reduction by 25% below BAU (40% below the 1990 level) is claimed in case of international cooperation and financial support.
Kazakhstan	GHG emissions unconditional reduction by 15% below the1990 level by 2030. Conditional reduction of GHG emissions by 25% below the 1990 level by 2030 is claimed in case of international cooperation and financial support.
Kyrgyz Republic	Reduction of GHG emissions by up to 13.75% and 15.69% below BAU in 2030 and 2050, respectively. Conditional reduction by up to 30.89% and 36.75% below BAU in 2030 and 2050, in case of international support.
Macedonia, FYR	Reduction of CO2 emissions from fossil fuels by 30%–36% below BAU in 2030.
Republic of Moldova	Unconditional reduction of GHG emissions by 64–67% below its 1990 level by 2030. Possible reduction by 78% in case of financial assistance and technical support.
Montenegro	Reduction of GHG emissions by 30% below the 1990 levels by 2030.
Russia	Reduction of GHG emissions by 25–30% from 1990 levels by 2030.
Serbia	Reduction of GHG emissions by 9.8% below the 1990 levels by 2030.
Tajikistan	Reduction of GHG emissions by 10–20% below the 1990 level by 2030. Possible reduction by 25–35% below the 1990 level by 2030 in case of international funding and technical support.
Turkmenistan	Unconditional target: lower growth rate of GHG emission compared to the country's GDP growth rate between 2015 and 2030. Conditional target if financial and technological support is provided: zero growth, or even a reduction of emissions, between 2015 and 2030.
Ukraine	Not to exceed 60% of the 1990 GHG emissions level in 2030.
Uzbekistan	Reduction of specific GHG emissions per unit GDP by 10% below the 2010 level by 2030.

Source: Own elaboration from UNFCCC (2015).

To fulfil the obligations under the Paris Agreement, the signatory parties were required to submit the so-called Intended Nationally Determined Contributions (INDCs), with the respective targets, to mitigate climate change. Table 2 shows the main targets included in the INDCs of the transition economies. As can be observed, these targets are generally expressed in percentage of reduction of GHG or CO2 emissions, and include different measures that should be adopted, in order to achieve them. Furthermore, several countries established more than one target of unconditional and conditional (additional) reduction of emissions.

In order to achieve these targets, transition economies should reduce energy consumption or move towards a greener energy use, as energy consumption is the main cause of CO2 emissions (Soytas et al., 2007). However, while emissions growth could be controlled by reducing energy consumption, this reduction could also have negative effects on economic growth (Lotfalipour et al., 2010). Therefore, to be able to develop environmental and energy policies and not to negatively affect economic growth, it is necessary to understand the relationship between the latter and environmental degradation and/or energy consumption.

In this sense, it may be considered of special interest to focus on the residential energy consumption. The analysis of the residential energy use is relevant, as the sector currently represents 21% of global energy consumption (IEA, 2020b). In addition, the residential sector is key to undertaking rapid emission reductions (Pablo-Romero et al., 2017). Moreover, energy consumption in this sector is an area with great potential for implementing energy saving policies, which could be achieved not only through technical measures, but also by improving consumer behaviour (Ouyang & Hokao, 2009).

In transition economies, the residential sector accounted for 208,938 Ktoe in 2018, which represented almost 30% of its final energy consumption, this way being considerably higher than worldwide (IEA, 2020b). In addition, the residential sector in transition economies presents some differences with respect to other world regions which make them of special interest. The recent study by Pablo-Romero and Sánchez-Braza (2017) highlights that these countries present very high residential energy consumption per capita (RECpc), being similar to the EU15 region, although their per capita income is much less. Thus, their residential energy use related to their GDP is among the highest in the world. In addition, their renewable energy use in the sector is the lowest in the world, being 50% of the MENA countries, which is the group with the next lowest use of renewable energy. The gains that may be achieved from a more efficient energy use are expected to be high. Therefore, the analysis of the relationship between residential energy consumption and economic growth in transition economies is especially relevant to compliance with the environmental agreements.

Furthermore, it is important to focus on increasing the use of clean energy not associated with GHG emissions in the region. The total primary energy supply (TPES) of most transition economies is geared heavily towards fossil fuels, due to their sizeable deposits in the region. The International Energy Agency provides the data on TPES by source, excluding electricity and heat (IEA, 2020b). According to it, the largest amount of their TPES is provided by natural gas (50.6%), followed by oil (19.8%) and coal (18.6%); another 7% of primary energy is generated by nuclear plants. As a result, while there are some countries with a considerable share of renewable sources, the overall share of hydro, wind, solar, biofuels and waste in TPES of transition economies is only 4%. This is more than three times lower than in the EU-28 (15.3%) and worldwide (13.8%). Thus, in order to meet the INDC objectives, transition economies have to promote the use of renewable energy sources, thus diversifying the energy mix.

In addition, renewable energy deployment is also relevant in the context of meeting increasing power supply needs. Electricity is one of the main forms of energy used in the industrial and residential sectors, as well as in the commercial and public service sectors. In 2016, electricity accounted for 19% of world total energy final consumption and it is the fastest-growing source of final energy demand. In the New Policies Scenario, the worldwide share reaches 24% in 2040 (IEA, 2018). In line with this trend, the share of electricity in final energy consumption in transition economies is also increasing and had already reached 15% in 2016. In this sense, in order to meet increasing power supply needs while reducing CO2 emissions, renewable energy deployment becomes essential.

1.3. Objectives of the doctoral thesis.

To fulfil the commitments under the environmental agreements in the context of meeting increasing energy demand, national programs should be developed on the basis of efficient energy-use strategies. Withal, the development of adequate energy policies requires deep understanding of the relationship between the economic growth and energy consumption. In addition, any further policy recommendation requires a previous analysis of the existing legal framework of each country.

This doctoral thesis aims to increase the knowledge on transition economies that can be used in the process of developing the adequate energy-related strategies to reduce CO2 emissions in the region. For this end, the main aim of the thesis is divided into two objectives:

- The first objective of this doctoral thesis is to expand the knowledge on the relationship between economic growth and energy consumption in economies in transition, focusing specifically on residential energy.
- The second objective of this doctoral thesis is to increase and organise the knowledge on the measures that have been carrying out in these countries to promote a larger use of clean energy in transition economies, focusing specifically on the renewable energy use for electricity generation.

The first objective of this doctoral thesis is to respond with the research, conducted and presented in Chapter 2: **Relationship between economic growth and residential energy use in transition economies.** This paper was published in the journal *Climate and Development* in 2019 (Pablo-Romero et al., 2019). In this research, we analyse the relationship between economic growth and energy consumption of residential sector in transition economies by testing the expanded version of the Environmental Kuznets Curve (EKC) hypothesis in the period from 1995 to 2013.

The second objective of this doctoral thesis is to respond with the analysis, carried out and presented in Chapter 3: **Renewable energy use for electricity generation in transition economies: evolution, targets and promotion policies.** This paper was recently published in the journal *Renewable and Sustainable Energy Reviews* (Pablo-Romero et al., 2021). In this study, we provide a detailed analysis of the policies and measures adopted in these countries up to 2018 to promote the use of renewable energy sources to generate electricity.

This doctoral thesis is structured as follows: after this introduction, Chapter 2 analyses the relationship between economic growth and residential energy use in transition economies. Chapter 3 provides an in-depth overview of the measures and policies adopted to promote renewable energy for electricity generation in these countries. Finally, Chapter 4 summarizes the main conclusions of this thesis.

CHAPTER 2.

Relationship between economic growth and residential energy use in transition economies.

2.1. Introduction.

This Chapter aims to respond to the first objective of the doctoral thesis and corresponds to the research paper, **Relationship between economic growth and residential energy use in transition economies,** published in the journal *Climate and Development* (Pablo-Romero et al., 2019). In this Chapter, we analyse the relationship between economic growth and energy consumption in transition economies, focusing specifically on residential energy consumption.

This analysis has been conducted by testing the Environmental Kuznets Curve (EKC) hypothesis. According to this hypothesis, environmental degradation increases during the early stages of economic growth, but from a certain income level (turning point), higher economic growth would be accompanied by improvements in environmental quality. Therefore, economic growth could be a solution to the environmental problem, rather than its source (Rothman & De Bruyn, 1998).

The validity of the EKC hypothesis has been extensively tested by using time series and panel data techniques. In this regard, the studies by Kaika and Zervas (2013a, 2013b) and Stern (2014), among others, carried out a systematic review of these previous studies. More recently, these studies have expanded to test the EKC hypothesis in less developed economies, such as in Asian, African and Latin American countries (Al-Mulali et al., 2015, 2016; Apergis & Ozturk, 2015; Jebli & Youssef, 2015; Robalino-López et al., 2014; Saboori et al., 2016, among others). Similarly, Zortuk and Çeken (2016) have tested the EKC in the European Union transition economies. In most studies, CO2 emissions are used as the indicator of environmental degradation, but also energy consumption is used in numerous studies. Among the latter may be mentioned the studies by Cole et al. (1997), Luzzati and Orsini (2009) and Pablo-Romero and De Jesús (2016).

In addition to these regional economic studies, some others refer to emissions or energy consumption at sectoral levels. Some of them test the EKC referring to the industry sector (see Fu & Zhang, 2015; Wang et al., 2014), to the transport sector (such as Abdallah et al., 2013; Azlina et al., 2014; Shahbaz et al., 2015) and to the agricultural sector (recently, for example, (Liutao, 2016). In addition, the studies by Bohne et al. (2016) and Yin et al. (2015) estimate the EKC referring to the energy consumption of residential buildings. Furthermore, Liu et al. (2016) and Pablo-Romero and Sánchez-Braza, (2017) analyse the relationship between residential energy consumption and economic growth for 30 Chinese provinces and for the EU-28 countries, respectively.

However, to our knowledge, there are no studies on this relationship for transition countries. According to the review by Joo et al. (2015), there is currently only one study which has examined the relationship between energy consumption and economic growth in some transition economies. It is the study by Apergis and Payne (2009), referring to eleven countries of the Commonwealth of Independent States in the 1991–2005 period. However, this study is not specific for the residential sector. Other studies related to electricity consumption in the transition economies can also be found. Among them, the study by Bildirici and Kayıkçı (2012) refers to the countries of the former Soviet Union. The study by Acaravcı and Ozturk (2010) focuses on the causal relationship between electricity consumption and economic growth in 15 European transition countries, during the period 1990–2006. Finally, Wolde-Rufael (2014) analyses the same causal relationship, extending the study period from 1975 to 2010, obtaining different results. Nevertheless, none of them refer to the residential sector. In addition, none of them test the EKC hypothesis.

Following these previous studies, the aim of this research is to analyse the relationship between economic growth and per capita residential energy consumption in the transition economies. The EKC is tested by using a panel data of 12 economies in transition in the period 1995–2013, for which there are enough available data. In addition, RECpc, and residential energy consumption per capita less biofuel use (RECLBpc), were considered, as the use of biomass is generally assumed to be highly inefficient, in terms of final energy consumption, especially for space and water heating (IEA, 2013).

For a better model specification, urbanisation and population density have been taken into account as in Jafari et al. (2017) and (Steemers, 2003). Similarly, a transition index measuring the reform progress towards a market economy and the structural change of the economy is considered. These variables allow controlling for different productive structures as in Carvalho (2017). From the estimate results, the elasticities of the RECpc and RECLBpc with respect to GDP per capita (GDPpc), for each country and year, are calculated according to Pablo-Romero and Sánchez-Braza (2015). Therefore, this study contributes to enlarging the previous literature, as it is, to our knowledge, the first study to analyse the relationships between residential energy consumption and income in the transition economies, by testing an expanded EKC.

Thus, this research contributes to the state of the art in the following way. Firstly, it enlarges the previous literature on the relationships between energy consumption and income in the transition economies. Secondly, it is the first study to analyse this relationship for the residential sector in the transition economies. Thirdly, it is the first study to test the EKC hypothesis for the energy consumption and income for these countries. Fourthly, it is the first study to take into account urbanisation, population density, the reform progress towards a market economy and the structural change of the economy, when analysing the relationships between energy consumption and income in the transition economies. Finally, it is the first study to analyse not only the relationships between RECpc and income, but also between RECLBpc and income.

2.2. Methodology.

The general specification model for testing the EKC may be expressed by the following equation:

$$\mathrm{E}_{it} = \mathrm{A} + \beta_1 \mathrm{Y}_{it} + \beta_2 {\mathrm{Y}_{it}}^2 + \beta_3 {\mathrm{Y}_{it}}^3 + e_{it} \quad (1)$$

where E is a measure of environmental pressure, which in this study represents the RECpc or alternatively RECLBpc in natural logarithms. Y is the independent variable of GDPpc in natural logarithms, A is the constant term, β_1, β_2 and β_3 are the parameters of the function to be estimated, e is a random error term, i is equal to 1 to 12 countries of the sample, and finally, t is the time in years from 1995 to 2013. RECLBpc has been considered to also evaluate the effect of using biofuels and waste. This is relevant as the use of biomass is generally assumed to be highly inefficient in terms of final energy consumption, especially for space and water heating (IEA, 2013).

The values of the β coefficients inform about the form of relationship between the variables of RECpc (or RECLBpc) and GDPpc. According to Dinda (2004), the EKC hypothesis is verified and presents the classic inverted U shape if si $\beta_1 > 0, \beta_2 < 0$ and if applicable $\beta_3 \leq 0$. Similarly, if $\beta_1 > 0, \beta_2 > 0$ and $\beta_3 < 0$, the curve may present the U shape from a certain Y value which depends on the values of the β coefficient.

Equation (1) has been estimated in previous studies by including, or not, the cubic term of the variable Y. However, according to Luzzati and Orsini (2009), estimates including the cubic term give greater flexibility to the model. In this study, both specifications have been tested and compared.

Additionally, as in previous studies, other variables that may affect E have been included in the EKC specification, in order to best fit the available data and the overall objective of the study (Kaika & Zervas, 2013a). Firstly, a control variable representing the percentage of population living in rural areas has been included. This control variable measures the possible effect of living in rural or urban areas on residential energy consumption. Previous studies have considered that residential energy use may be affected by the rural-urban area dichotomy (Heinonen & Junnila, 2014; Wiedenhofer et al., 2013). In addition, recent studies consider that urbanisation expansion seems to have more effect on the EKC in least developed countries, where it shifts the curve upwards (Jafari et al., 2017). Therefore, it may be appropriate to control for the urbanisation factor in the transition economies.

The density of the total population has also been included. Various previous studies argue that compact urban forms would reduce energy consumption in buildings (Steemers, 2003), while other authors indicate that lower energy consumption would be achieved by decentralised concentration (Holden & Norland, 2005). Similarly, Dujardin et al. (2014) find that while dense urban settlements are more efficient, some rural settlements, characterised by a low density, also have good performances.

In addition to these control variables, two additional variables have been included to take into account the effects of the economic transition and structural changes on energy consumption. In order to measure the economic transition, an index from the six transition indicators produced by the European Bank for Reconstruction and Development (EBRD, 2017) have been calculated and used. There are two main reasons to include these control variables in the equation. Firstly, although it is widely agreed that economic liberalisation has positive effects on environmental effects, improving energy intensity by reducing resource misallocation problems and price distortions (Baek et al., 2009; Carvalho, 2016), some other authors highlight negative impacts (Cole, 2004; Tisdell, 1999). Secondly, including an index to measure the economic transition may reduce the heterogeneity among these countries. Carvalho (2017) states that there is large heterogeneity in the reform progress in transition countries. In addition, the structural change of the economy is considered by including the service sector participation in total GDP as a control variable. This variable represents the possible effect of the different productive structures of the countries on the energy use. It is worth noting that previous studies have adopted a similar procedure (Friedl & Getzner, 2003).

Furthermore, some other characteristics of the countries may influence the residential energy consumption, such as, for example, climate, heating type, household size, age of building etc. These characteristics are usually taken into account in studies when using microdata (for example, Jones & Lomas, 2015; Kialashaki & Reisel, 2013). However, it is difficult to consider these variables in macroeconomic studies, basically because of the lack of comparable data. Nevertheless, some studies, such as Alberini and Filippini (2011) and Blázquez et al. (2013), have considered climate effects by introducing ‘heating degree days’ (HDD) as an explanatory variable, as changes in temperature may affect energy consumption, especially for heating and cooling in the household sector (Shi et al., 2016). For the case of transition economies, the HDD can be calculated as the average HDD of the locations of each sample country provided by the database (Weatherbase, 2017). However, this database offers uniquely constant data for each location, so no differences through time can be obtained. Therefore, as an alternative to the inclusion of the climate variable, country dummies have been introduced in (1). These dummies measure the effects of omitted individual time invariant variables (Hsiao, 2007). Thus, they include the climate effect, but also other differences in constants that may exist. In addition, it is also possible to control for these specific characteristics by estimating the Equation (1) in differences, thereby eliminating the time-invariant variables.

Equation (2) shows an extended EKC where the control variables have been included.

$$\mathrm{E}_{it} = \delta t + \alpha_i + \beta_1 \mathrm{Y}_{it} + \beta_2 {\mathrm{Y}_{it}}^2 + \beta_3 {\mathrm{Y}_{it}}^3 + \phi_1 R_{it} + \phi_2 D_{it} + \phi_3 T + \phi_4 S + e_{it} \quad (2)$$

R, D, T and S are the control variables that have been added to the model. These variables represent the percentage of the population living in rural areas, the density of the total population, the transition index and the structural change measured as a percentage of service activities on GDP, respectively. Additionally, a common time trend and individual dummies have been included.

Finally, from the estimate results, the elasticity values of E with respect to Y have been calculated for each country and year, as follows:

$$Ela_{it} = \beta_1 + 2\beta_2 \bar{\mathrm{Y}}_{it} + 3\beta_3 \bar{\mathrm{Y}}_{it}^{\,2} \quad (3)$$

The elasticity in this case is the derivative of Equation (2), which allows the percentage change of per capita income in relation to per capita residential energy consumption to be defined.

2.3. Data.

2.3.1. Data sources.

This study uses a panel data of 12 transition countries over the period 1995–2013. The annual report published by the United Nations Economic and Social Commission for Asia and the Pacific (United Nations, 2016) classifies 17 countries as economies in transition. Nevertheless, this paper only considers 12 countries, given the unavailability of some data for Turkmenistan, the Republic of Macedonia, and Montenegro. In addition, Kazakhstan and

Kyrgyzstan have also been excluded due to lack of continuity in the energy data. These two countries do not have complete data for some energy consumption categories, which causes breaks in the energy series. The countries included in this study are Albania, Armenia, Azerbaijan, Belarus, Bosnia and Herzegovina, Georgia, the Republic of Moldova, Russian Federation, Serbia, Tajikistan, Ukraine and Uzbekistan.

Residential energy consumption data come from the International Energy Agency (IEA, 2016). The database offers information for total energy production and total energy consumption. In that regard, two options may be considered when referring to residential energy consumption. Firstly, it is possible to use the final energy used in the home, and secondly, the primary energy used to produce it. The latter indicator includes efficiency improvements, increased utility and fuel switching, all of which may be occurring as a result of economic development and clean energy policies. Nevertheless, this indicator is not directly offered by the IEA (2016a) and it is also complicated to calculate from the energy balances, because key statistics are missing, especially for the first years of the considered period, as stated in IEA (2004). Therefore, total final energy consumption by the residential sector is considered. These data include coal, oil products, natural gas, geothermal and solar energy, biofuels and waste, electricity and heat.

It is worth noting that the transition countries use different criteria when collecting the data, especially those related to heat statistics (IEA, 2004). Thus, some of them include heat energy data directly while others do not, but use other energy categories, for example, natural gas. Furthermore, some countries change the way they include these data over time. This hindered the comparison or analysis of the evolution of the residential energy use by type of energy. Therefore, total final energy consumption by the residential sector as a whole is used in this study. Data are expressed in natural logarithms of kilograms of oil equivalent consumption by the residential sector per capita. This variable is called total final energy consumption by the residential sector (RECpc).

In addition to RECpc, the total final energy consumption less biofuels (including solid biofuels) and waste energy consumption by the residential sector, has been also considered. This variable is expressed in natural logarithms of kilograms of oil equivalent consumption per capita, and is named as final energy consumption by the residential sector less biofuels (RECLBpc).

Data on *Y*, total population, rural population, density and structural change come from the World Bank Development Indicators (World Bank, 2016). Total population is used to convert residential energy consumption and income expressed in absolute terms in per capita terms. Y is expressed in natural logarithms of GDP in constant 2005 U.S. Dollars per capita. Population density is measured as the natural logarithm of persons per square kilometre. Rural population is expressed as a percentage of total population. Structural change is measured as a percentage of service activities in GDP.

Finally, the transition index is produced from the six indices used by the EBRD (2017) to evaluate the evolution of transition economies towards a market economy. The measurement scale for each indicator ranges from 1 to 4 +. Little or no change from a rigid, centrally planned economy is represented by 1, while 4+ represents the standards of an industrialised market economy. The six indicators refer to large and small scale privatisation, governance and enterprise restructuring, price liberalisation, trade and foreign exchange system and finally to competition policy. In order to represent the economic transition of the countries in one variable, a single index has been constructed from the above six by adding the value of each one. Therefore, the value 6 represents no change from a rigid, centrally planned economy and 24 represents the standards of an industrialised market economy. This variable has been converted into natural logs.

2.3.2. Descriptive analysis.

Table 3 presents the main descriptive statistics of the variables used. The between statistics refer to the average data values of each individual country, while the within statistics refer to intra group values over time, for each country, and to the variation from each individual country's average. Table 3 shows that the standard deviation of the data across countries is higher than across time for all variables during the considered period.

Table 3. Descriptive statistics (1995–2013).

Variable		Mean	Std. Dev.	Min.	Max.	Observations
RECpc	overall	5.569	0.836	3.362	6.897	$N = 228$
(E)	between		0.852	3.601	6.755	$n = 12$
(in logs)	within		0.171	4.833	6.040	$T = 19$
RECLBpc	overall	5.395	0.899	3.362	6.879	$N = 228$
(ELB)	between		0.913	3.601	6.742	$n = 12$
(in logs)	within		0.198	4.659	6.047	$T = 19$
GDPpc	overall	7.333	0.835	5.325	8.842	$N = 228$
(Y)	between		0.787	5.742	8.491	$n = 12$
(in logs)	within		0.358	6.005	8.125	$T = 19$
% of rural population	overall	0.473	0.141	0.241	0.736	$N = 228$
(R)	between		0.146	0.265	0.731	$n = 12$
	within		0.017	0.381	0.546	$T = 19$
Density	overall	4.199	0.679	2.165	4.850	$N = 228$
(D)	between		0.706	2.180	4.832	$n = 12$
(in logs)	within		0.047	4.047	4.385	$T = 19$
Transition index	overall	1.038	0.208	0.155	1.254	$N = 228$
(T)	between		0.162	0.659	1.197	$n = 12$
(in logs)	within		0.138	0.286	1.328	$T = 19$
% of service activities	overall	0.499	0.679	2.165	4.850	$N = 228$
(S)	between		0.706	2.180	4.832	$n = 12$
	within		0.047	4.047	4.385	$T = 19$

Figure 5 shows the evolution of GDPpc in logs of the 12 analysed transition economies, over the period 1995 – 2013. The data for each country are represented individually by a coloured line. Additionally, the median spline of all countries for each year is represented by a black line. The evolution of GDPpc shows a positive trend over the analysed period. The countries with the highest GDPpc are the Russian Federation, Belarus, Serbia, Albania and Bosnia and Herzegovina. On the other hand, Ukraine, the Republic of Moldova, Uzbekistan and Tajikistan present a low average GDPpc level.

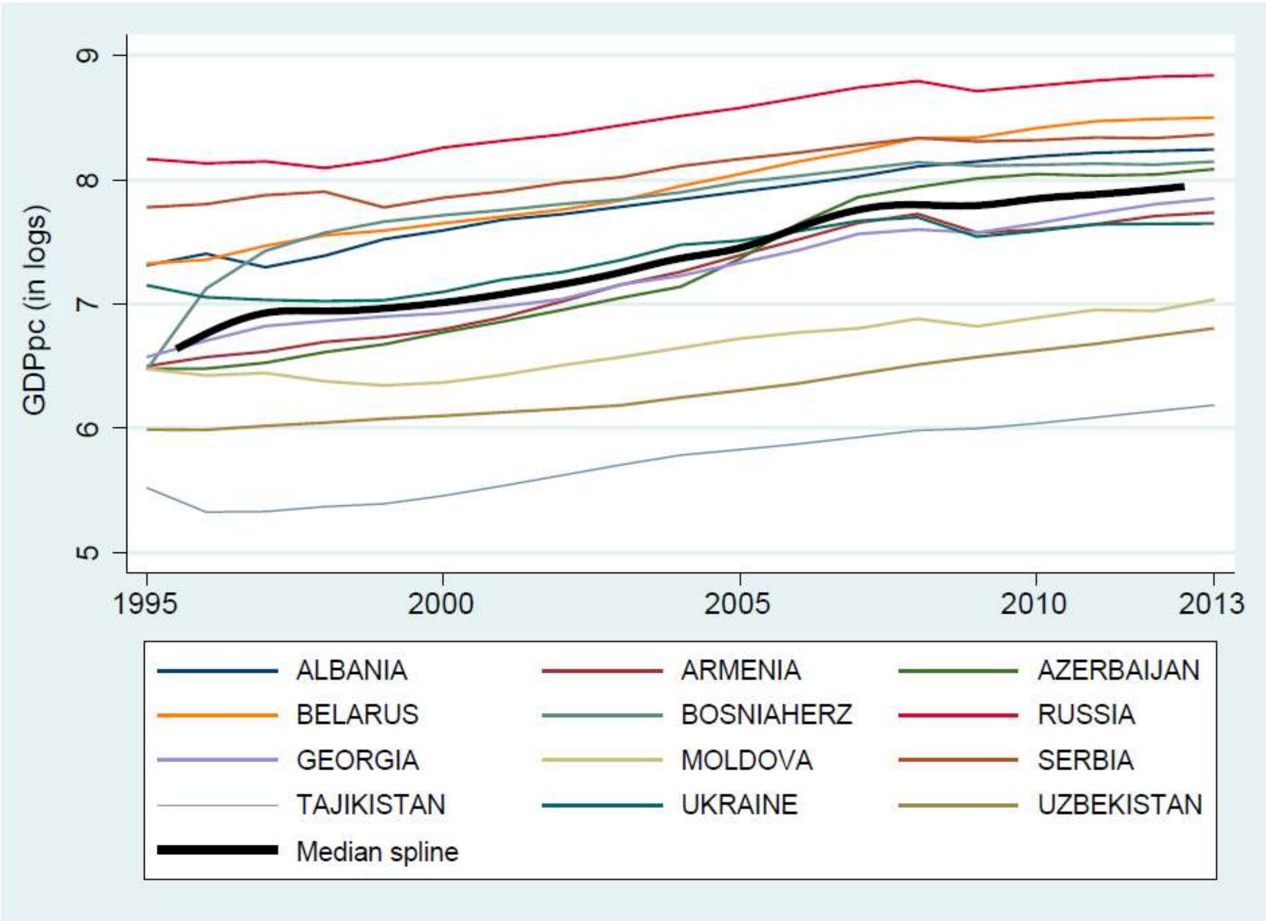


Figure 5. Evolution of GDPpc (1995–2013).
Source: Own production from IEA (2016a) and World Bank (2016).

Figure 6 shows the evolution of RECpc and RECLBpc in logs. They show a stable trend during the analysed period. Countries with the highest level of residential energy consumption (Ukraine, Belarus, Uzbekistan, Serbia and Azerbaijan) maintain slightly decreasing trends, while those with lower levels show increasing trends since 1999. The lowest energy consumption is observed for Tajikistan, also showing decreasing trends since 2000.

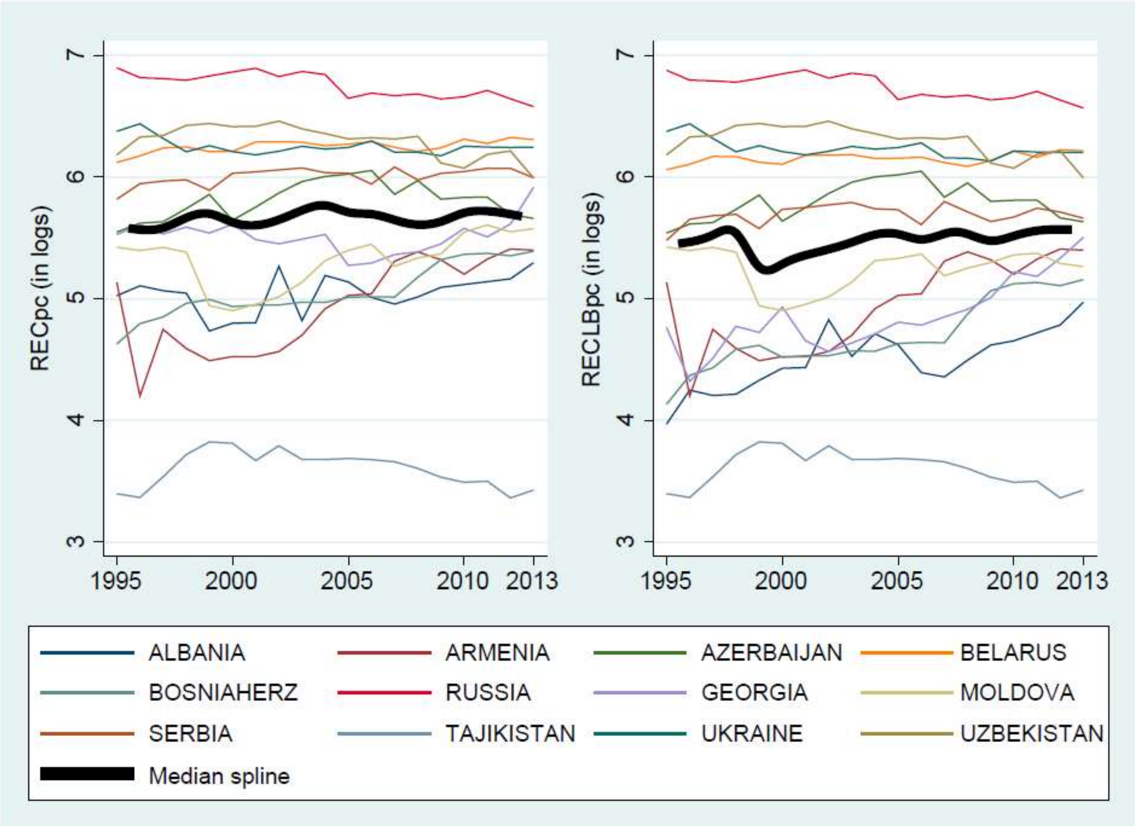


Figure 6. Evolution of RECpc and RECLBpc (1995-2013).
Source: Own production from IEA (2016a) and World Bank (2016).

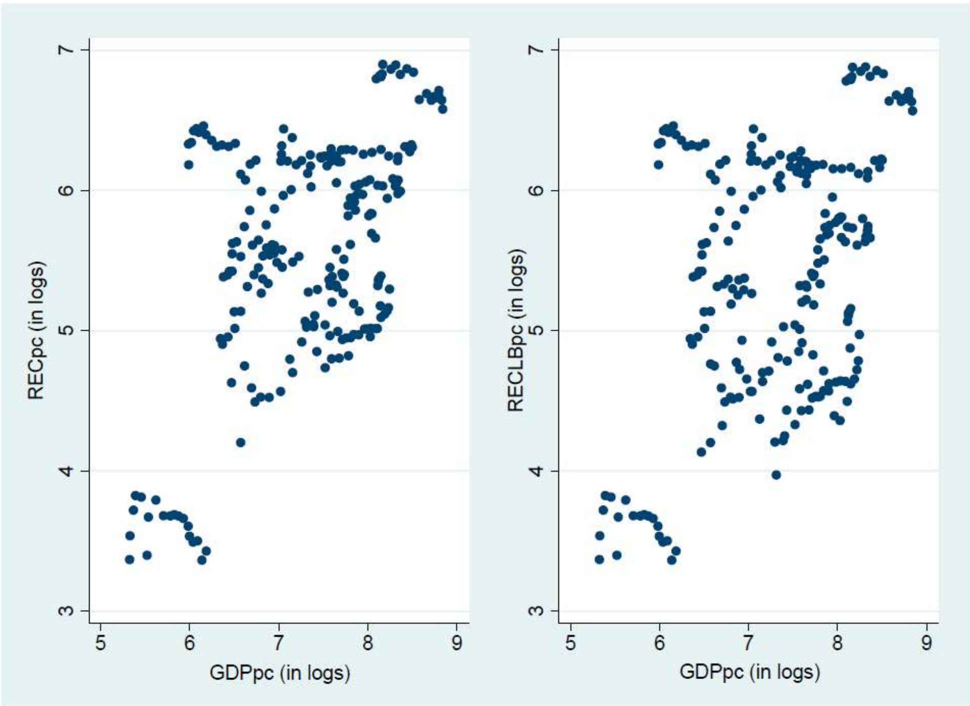


Figure 7. Scatter diagram of RECpc and RECLBpc related to GDPpc.

Source: Own production from IEA (2016a) and World Bank (2016).

Finally, Figure 7 shows the scatter diagrams between RECpc and RECLBpc related to GDPpc. In general, energy consumption grows with income, although some data dispersion is observed, which could be initially explained by country differences.

2.3.3. Econometric analysis of the data properties.

Before estimating Equation (2), it is necessary to perform the econometric analysis of the data properties. Firstly, multicollinearity among the squared and cubic variables has been analysed by using the variance inflation factor (VIF) statistic, as this problem has been noted in previous studies (Narayan & Narayan, 2010). The VIF statistic measures the extent to which the variance of the estimated regression coefficients has been inflated or overestimated, compared with a context in which the explanatory variables are not linearly related. The multicollinearity problem exists if any VIF statistic value is greater than 10, or 5, if a more stringent criterion is used (Kleinbaum et al., 1988; Pablo-Romero et al., 2015; Sánchez-Braza & Pablo-Romero, 2014).

Table 4 shows the VIF statistic values of the variables used in (2), when these are expressed through its values and when they have been transformed in terms of deviations from their geometric mean.

Table 4. Analysis of multicollinearity.

Variable	VIF variables	VIF deviations from the geometric mean
Y	33,516.28	3.94
Y^2	138,009.48	3.38
Y^3	36,251.88	4.68
R	3.11	3.11
D	2.79	2.79
T	1.13	1.13
S	1.76	1.76

As shown in Table 4, the transformation of variables significantly reduces the VIF statistic values, which made the multicollinearity problem between variables disappear.

Thus, it is possible to rewrite Equation (2) as follows:

$$\bar{E}_{it} = \delta t + \alpha_i + \beta_1 \bar{Y}_{it} + \beta_2 \bar{Y}_{it}^{2} + \beta_3 \bar{Y}_{it}^{3} + \phi_1 \bar{R}_{it} + \phi_2 \bar{D}_{it} + \phi_3 \bar{T} + \phi_4 \bar{S} + e_{it} \quad (4)$$

where the upper dash over variables shows that they are converted to deviations from the geometric mean of the sample. It is worth noting that, now, the β_1 coefficient is equal to the *E* elasticity with respect to *Y* in the central point of the sample.

Secondly, the stochastic nature and properties of the series have been analysed in order to determine the best method to estimate (4) and avoid spurious estimates (Stern, 2014). Initially, the test proposed by (Pesaran, 2004) is applied to contrast the null hypothesis of cross-sectional independence. Table 5 shows that at a 1% significance level, the null hypothesis of cross-sectional independence is rejected for *Y*, its squared and cubic term, and for the structural change the transitions index variables. Additionally, it is rejected for the density variable at a 5% significance level. Table 5 also shows that for all other variables, it is not possible to reject the null hypothesis.

Table 5. Cross-sectional dependence test.

Variable	CD-test
E	0.80
ELB	0.30
Y	33.26***
Y^2	33.36***
Y^3	33.46***
R	1.44
D	2.14**
T	29.45***
S	12.85***

Notes: ***denotes significance level at 1% and **at 5%.

Depending on the previous Pesaran test results, the IPS unit root test by Im et al. (2003) is performed if the series do not show cross-sectional dependence, while the CIPS unit root test (cross-sectionally augmented IPS) by Pesaran (2007) is used if the series present this dependence problem. In both tests, the null hypothesis considers that all units have panel unit root.

Tables 6 and 7 show the results of the unit root test applied to the variables, without and with cross-sectional dependence problems, respectively. In both cases, tests are applied to the variables in levels and first differences, with constant, and with constant and trend.

Table 6. IPS unit root test.

Variables	Levels		First differences	
	Constant	Constant and trend	Constant	Constant and trend
E	−1.116	−1.171	−2.068**	−2.542***
(Avg.lag)	(0.17)	(0.58)	(0.00)	(0.58)
ELB	−0.936	−1.321*	−1.824**	−2.500**
(Avg.lag)	(0.25)	(0.78)	(0.08)	(0.67)
R	−1.311*	−1.927**	−1.634**	−5.041***
(Avg.lag)	(1.67)	(1.42)	(1.67)	(1.17)

Notes: t-bar statistics ***denotes significance level at 1%, **at 5% and *at 10%. Avg. lag (in bracket) denotes the average lag length of the underlying ADF test regressions.

Table 7. CIPS unit root test in the presence of cross-sectional dependence.

Variables	Levels		First differences	
	Constant	Constant and trend	Constant	Constant and trend
Y	−2.095	−2.275	−3.367***	−3.217***
(Avg.lag)	(1.08)	(1.08)	(0.50)	(0.50)
Y^2	−1.802	−2.286	−3.144***	−3.052***
(Avg.lag)	(1.08)	(1.08)	(0.50)	(0.50)
Y^3	−2.133	−2.230	−2.855***	−3.012***
(Avg.lag)	(1.16)	(1.16)	(0.58)	(0.58)
D	−1.064	−2.057	−2.681***	−3.110***
(Avg.lag)	(1.50)	(1.50)	(0.58)	(0.58)
T	−2.347**	−2.668*	−4.827***	−4.163***
(Avg.lag)	(1.64)	(1.64)	(0.71)	(0.71)
S	−1.622	−1.775	−3.158***	−3.392***
(Avg.lag)	(1.50)	(1.50)	(0.57)	(0.57)

Notes: t-bar statistics ***denotes significance level at 1%, **at 5% and *at 10%. Avg. lag (in bracket) denotes the average lag length of the underlying ADF test regressions.

In order to determine the delay of the CADF regressions underlying the model, the ADF test was carried out for each individual of the sample. The optimal delay for each individual is determined according to the Bayesian Information Criterion (BIC). The results show that variables are I(1), as they are stationary in first differences and non-stationary in levels.

Finally, as variables are I(1), it is appropriate to test whether there is a long-run relationship between the variables. Panel cointegration tests are used to test the existence of a structural long-run relationship among the variables. The test proposed by Pedroni (1999) is used as no cross-section dependence is observed for the model, according to the parametric testing procedure proposed by (Pesaran, 2004). Table 8 shows that the hypothesis of cross-sectional independence cannot be rejected for the Equation (4) when the energy variable is measure as RECpc, or alternatively as RECLBpc.

Table 8. Cross sectional independence test.

Test	RECpc *(E)*	RECLBpc *(ELB)*
Friedman's test	16.958	14.353
Pesaran's test	−1.229	−1.029
Frees' test	1.292	1.805

Tables 9 and 10 show the results of the Pedroni cointegration tests, which include four panel cointegration test statistics and three group cointegration test statistics, the variables being cointegrated if the statistics reject the null hypothesis of no cointegration. Table 9 shows that, when RECpc is used, all indicators except one (ADF-panel), reject the null hypothesis of no cointegration of variables at a 1% significance level. Thus, it may be concluded that there is evidence for cointegration of variables, making it convenient to estimate (2) in levels. Table 10 shows that four test statistics reject the null hypothesis of no cointegration of variables at a 1% significance level, two of them cannot reject the hypothesis and the last only rejected at a 10% significance level, when RECLBpc is used. Hence, although there is some evidence of cointegration, there is also evidence against it. Therefore, estimates of level and first differences are performed and the results compared. In this regard, the estimates of first differences are also convenient in order to eliminate effects of constants which are not included in the function specification.

Table 9. Pedroni's cointegration test, considering RECpc *(E)* as a dependent variable.

Statistics	Panel statistics	Group statistics
Y	−2.449	–
Rho	3.068	4.488
T	−7.529	−9.13
ADF	1.286	4.131

Table 10. Pedroni's cointegration test, considering RECLBpc *(ELB)* as a dependent variable.

Statistics	Panel statistics	Group statistics
Y	−2.152	–
Rho	3.156	4.565
T	−5.575	−6.517
ADF	0.633	1.590

In order to estimate the equation in levels the dynamic ordinary least squares (DOLS) estimator is used. Although OLS estimators of the cointegrated vectors are super-convergent, it is a biased and inconsistent estimator when applied to a cointegrated panel. In the panel cointegration analysis, the fully modified OLS (FMOLS) developed by (Pedroni, 2001) and DOLS developed by Kao and Chiang (2000) are commonly used. Both techniques lead to normally distributed estimators and exhibit small sample bias. Nevertheless, Kao and Chiang (2000) show the DOLS estimators are higher than the FMOLS properties. Finally, in order to estimate (4) in first differences, the feasible generalised least squares (FGLS) method is used. This method has been recommended when there are doubts about whether or not the regression error is I(0) or I(1) (Choi et al., 2004).

2.4. Results and discussion.

2.4.1. Estimate results and elasticity values.

Table 11 shows the estimate results of Equation (4) for the 12 countries in transition during the period 1995–2013, when RECpc was used to measure the residential energy consumption. The estimates in levels were performed with and without the cubic term of the variable Y, by the DOLS method including 2 leads and lags. The estimates in first differences were also performed by including, or not, the cubic term of Y by the FGLS method in the presence of heteroscedasticity and autocorrelation, as the null hypothesis of homoscedasticity according to the modified Wald test, as well as the null hypothesis of no autocorrelation according to the Wooldridge (2002) test, are rejected in both cases.

Table 11. Results of estimates by using RECpc *(E)* as a dependent variable.

Variables		Levels - DOLS		First differences - FGLS	
	Coef.	Squared	Cubic	Squared	Cubic
Y	β_1	0.192***	0.232***	0.218***	0.243***
		(0.065)	(0.103)	(0.068)	(0.068)
Y^2	β_2	0.129***	0.101*	0.119***	0.056
		(0.033)	(0.061)	(0.041)	(0.043)
Y^3	β_3	–	−0.070***	–	−0.076***
			(0.022)		(0.022)
R	ϕ_1	0.042***	0.048*	0.001***	0.001***
		(0.011)	(0.028)	(0.000)	(0.000)
D	ϕ_2	0.183	0.409	−1.350*	−0.999
		(0.505)	(0.641)	(0.812)	(0.805)
T	ϕ_3	−0.019***	−0.097***	−0.171**	−0.012**
		(0.006)	(0.014)	(0.086)	(0.006)
S	ϕ_4	−0.444**	−0.057***	−0.418**	−0.388**
		(0.177)	(0.017)	(0.172)	(0.175)

Notes: Standard errors are shown in parenthesis, ***denotes significance level at 1%, **at 5% and *at 10%.

Table 11 shows that both estimates, in levels and first differences, are quite similar. The β_1 coefficient is significant and positive in all specifications, being between 0.19 and 0.24. Therefore, the elasticity of the RECpc, with respect to GDPpc, is positive in the central point of the sample. The results also show that β_2 is positive and significant, except for the FGLS estimate, when the cubic term is included. In addition, β_3 is negative and significant. It should also be noted that the *R* coefficient (rural population percentage), is significant and positive, while the *D* coefficient (population density) is not significant. Nevertheless, excluding this variable from the estimates does not notably affect the values of the other coefficients. It is also worth noting that the coefficients for *T* (Transition index) and *S* (Structural change) are negative and significant. In that regard, the transition towards to a market economy tends to reduce the residential energy use, which may be related to more efficient technologies. This result is in line with Baek et al. (2009) who consider that liberalisation improves the sustainability. In addition, the structural change of the economy towards to a more tertiary economy also tends to reduce the energy use.

Table 12 shows the estimate results of Equation (4) when RECLBpc was used. Once again, the estimates in levels were performed by DOLS and the estimates in first differences by FGLS.

Table 12. Results of estimates by using RECLBpc *(ELB)* as a dependent variable.

Variables		Levels - DOLS		First differences - FGLS	
	Coef.	Squared	Cubic	Squared	Cubic
Y	β_1	0.419***	0.372***	0.370***	0.350***
		(0.048)	(0.070)	(0.076)	(0.086)
Y^2	β_2	0.150***	0.105**	0.158***	0.097*
		(0.030)	(0.044)	(0.050)	(0.055)
Y^3	β_3	–	−0.087***	–	−0.067**
			(0.023)		(0.026)
R	ϕ_1	0.007	0.007	0.001***	0.001**
		(0.012)	(0.014)	(0.000)	(0.000)
D	ϕ_2	0.858**	1.097**	−1.340*	−1.400
		(0.374)	(0.431)	(0.793)	(0.900)
T	ϕ_3	−0.014**	−0.019**	−0.277**	−0.018**
		(0.005)	(0.007)	(0.107)	(0.008)
S	ϕ_4	−0.040	−0.019	−0.014**	−0.372*
		(0.118)	(0.154)	(0.005)	(0.211)

Notes: Standard errors are shown in parenthesis, ***denotes significance level at 1%, **at 5% and *at 10%.

Table 12 shows similar results to Table 11 but with some differences. Firstly, β_1 now presents higher values in all estimates, between 0.35 and 0.41. Secondly, all estimate results show that the β_2 coefficient is positive and significant. Thirdly, some differences are observed in the significance of control variables, especially in the *R* and *S* coefficients, which become not significant in DOLS estimates. On the contrary, the *D* coefficient is significant in level estimates. Therefore, the major changes observed when excluding biofuels energy use from the residential energy consumption, is that it moves the estimated curve upwards.

These obtained results do not support the inverted U shape that confirms the EKC hypothesis for the residential sector in transition countries, within the period considered, when the GDPpc cubic term is not included, as the estimates show that $\beta_1 > 0$ and $\beta_2 > 0$, which means that an increase in GDPpc leads to an increase in RECpc or RECLBpc. Similarly, estimates including the cubic term have positive and significant values for both coefficients. Nevertheless, as $\beta_3 < 0$, the EKC may be supported from a certain GDPpc level. In order to calculate whether the EKC turning point has been reached, it is appropriate to calculate the elasticity values for each GDPpc level. The turning point is reached when the elasticity is equal to zero, and changes from positive to negative values.

From the β estimated values shown in Tables 11 and 12, and in accordance with (3), the elasticities of RECpc and RECLBpc, with respect to GDPpc *(Ela - REC* and *Ela - RECLB* respectively), were calculated for cubic specifications. The elasticities were calculated by using the coefficient values from both DOLS and FGLS estimates. Nevertheless, as no mayor differences are obtained, and the β_2 coefficient is not significant in the cubic specification of the FGLS estimate shown in Table 11, only the results from DOLS are shown. Therefore, these elasticity values are calculated as follows:

$$Ela - RECpc = 0.232 + 2 * 0.101\, \bar{Y}_{it} - 3 * 0.070 \bar{Y}_{it}^{2}$$

$$Ela - RECLBpc = 0.372 + 2 * 0.105\, \bar{Y}_{it} - 3 * 0.087 \bar{Y}_{it}^{2}$$

Figure 8 shows the estimated elasticity of RECpc and RECLBpc, with respect to GDPpc, in the case of the cubic specification. The elasticity shows an inverted-U shape in both cases. Initially, the elasticity is negative and increases with GDPpc, becoming positive from a GDPpc value range from 6.4 to 6.7 (in logs). This result indicates that the increases in GDPpc levels have reduced the per capita residential energy consumption, when GDPpc levels are low, thereby improving environmental quality. Similar results are found in Pablo-Romero and De Jesús (2016) when referring to energy consumption in the Latin American countries. Additionally, this conclusion is in line with Ozcan (2013) and Wang et al. (2011), who found that, in Middle East countries and in Chinese provinces, respectively, pollution levels decrease as a country develops when the development level is low.

However, from this GDPpc range value, the elasticity becomes positive. Therefore, GDPpc increases bring about a positive and growing trend in residential energy consumption. Eventually, for higher incomes, Figure 8 shows that the elasticity begins to decrease, although always positive. This is to say, the EKC turning point is not reached. Thus, the residential energy consumption continues increasing with GDPpc, but at a slower rate. Figure 8 also shows that the turning point is compatible for GDPpc values near to 9 (in logs), which is near to Russian highest GDPpc values.

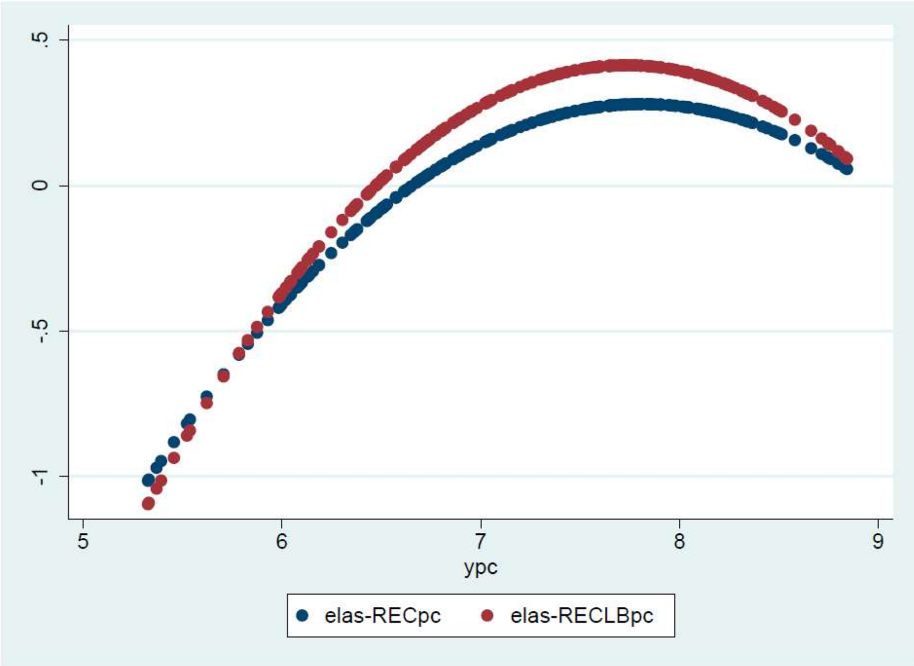


Figure 8. Estimated elasticity of RECpc and RECLBpc with respect to GDPpc.

Source: Own production.

Consequently, the economic growth of transition countries is not likely to solve the environmental problems caused by the residential energy consumption, at least for most countries. Previous studies show that the economic growth has been increasing the residential energy consumption, especially in developing countries where population and economic growth have been among the main driving factors (Nejat et al., 2015). It is also worth noting, that although economic growth could contribute to reducing energy consumption in the most developed transition countries, the residential energy use would remain high because, as stated in Pablo-Romero et al. (2017), these countries are currently among those with the highest residential energy use, in per capita and GDP terms.

Therefore, it is necessary to establish energy saving policies by setting out energy efficiency measures in households and buildings, and promote the use of renewable energy in order to reduce environmental problems. Nevertheless, applying these measures could be difficult for the less developed countries. Therefore, financial support from more development countries is needed if these countries have to undertake energy efficiency measures (Nejat et al., 2015).

It is worth noting that most of the transition countries have notable energy saving potential in district heating sectors. As stated in (IEA, 2015), a high share of the energy used in buildings comes from district heat. The Russian Federation is the country with the largest district heating system in the world, but this system also plays an important role in Belarus, the Republic of Moldova, Serbia, Ukraine, Uzbekistan and Tajikistan. However, this energy is produced, distributed and consumed very inefficiently. For example, in Russia, efficiency is around 73% compared to 90% in the countries of northern Europe. Thus, although some countries have begun to promote initiatives to improve the efficiency of district heating systems, as noted in Berardi (2017), much more is needed. In this regard, the IEA (2015) report highlights that the key to maximising the energy saving potential lies in sector reforms. Among them, requiring the system operator to perform system upgrades, increasing tariffs to full cost and removing subsidies which distort Price signals. It is worth noting that all estimate results show that the transition index coefficients are negative, so moving towards market economies tends to reduce the energy consumption. Nevertheless, although it may be appropriate to remove subsides, it may also be necessary, as stated in Bouznit and Pablo-Romero (2016), to apply some effective compensatory schemes, such as protecting low income groups by maintaining subsidy schemes for the most vulnerable.

In addition, some efforts should be made in population education, as previous studies have found that user behaviour is at least as important as the efficiency of technology, when explaining households' energy consumption (Gram-Hanssen, 2013). It is worth noting that a huge proportion of the residents of these countries were educated within the Soviet system, implying an exposure to supply systems characterised by low tariffs and extensive subsidising (Carvalho, 2017).

On the other hand, numerous studies, such as Nabiyeva (2015) and UNDP (2014a, 2014b) give evidence of the enormous potential for power generation from renewable energies in these transition economies. The use of these energies could reduce the residential energy dependence problems observed in some countries, while increasing less pollutant energy consumption in all of them. Additionally, some of these renewable energies could be especially relevant to distant rural areas of the region with limited access to the grid and conventional energy sources.

2.4.2. Evolution of RECLBpc elasticities by countries.

Figure 9 shows the evolution of the elasticity of RECLBpc with respect to GDPpc, by countries, when Elas-RECLBpc values are used to calculate them (no major differences are observed when using Elas-RECpc).

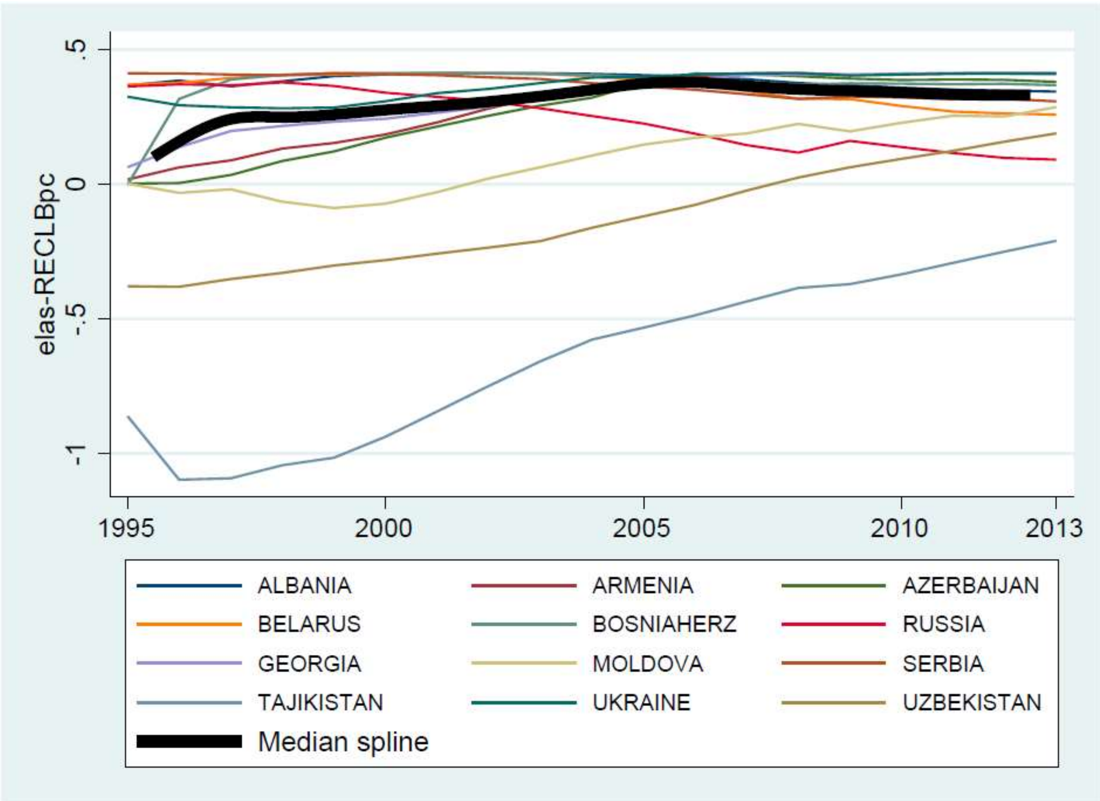


Figure 9. Elasticity of RECLBpc with respect to GDPpc for 12 transition countries (1995–2013).

Source: Own production.

As shown in Figure 9, the elasticity values are not constant over the analysed period. The black line represents the trend of the elasticity median spline. This trend was increasing throughout the analysed period until the beginning of the financial crisis in 2007. From that year, the trend was slightly decreasing.

Figure 9 shows notable differences among the transition countries elasticity values and trends. Belarus, Albania, Serbia and Bosnia and Herzegovina, have positive values, around 0.4, their trend being almost constant or slightly decreasing from 2005, therefore, positive elasticity values could be expected over the coming years. Russia also has positive and decreasing elasticity values through the period, its decreasing trend being much more evident and near to zero. Therefore, this country is close to decoupling growth and residential energy use. Meanwhile, the elasticity values of the Caucasus countries, such as Armenia, Azerbaijan and Georgia, are positive, with a growing trend. The Ukraine also shows positive values and a growing trend, but the former has lower elasticities (near zero) at the start of the period. Therefore, positive elasticities could also be expected for them. Finally, the Republic of Moldova, Tajikistan and Uzbekistan have very low or even negative elasticity values throughout the whole period. Nevertheless, these countries show noticeable positive trends. At the end of the period, the Republic of Moldova and Tajikistan ended up having positive elasticities. Therefore, although these countries have been reducing the residential energy use as they were growing, this could be expected to be at an end.

The notable elasticity differences among countries in trends and values, makes it interesting to discuss the situation of each of them. In the case of Belarus, it is worth noting its high energy dependence. Raslavičius (2012) concludes that a strategic task for the Belarusian economy is to reduce energy imports, with bioenergy being one of the most important renewable energy sources for the future energy supply in this country, especially for the residential sector. Also, Urge-Vorsatz et al. (2013) underline that the household sector should reduce its energy dependence.

The situation of Balkan countries, such as Serbia and Bosnia and Herzegovina, is quite similar. According to Tešić et al. (2011), Serbian energy imports are increasing over recent years and its main energy reserves are represented by various types of coal, dominated by low-quality lignite coal, to more than 92%, which is partly used for residential use (Karakosta et al., 2012). The shift from coal to cleaner and more efficient energies, without incurring increased energy imports, is a main challenge. Serbia and Bosnia and Herzegovina, as potential members of the

European Union, must meet the requirements regarding the proportions of renewable energy usage. The use of renewable energies could be a solution to reduce coal usage in the residential sector, either through the direct use of renewable energy sources, or through increasing electricity generated from clean energy consumption. To date, hydroelectric power is the only form of renewable energy that has been developed in these countries, although not all of its huge potential has been exploited.

Meanwhile, in the Caucasus countries (Armenia, Azerbaijan and Georgia), elasticity values are positive, with a growing trend. In this region, buildings represent about 50% of final energy consumption, which is a great opportunity to achieve energy savings of around 20–40% (REN21, 2015). In that regard, the IEA (2015) recommended strengthening local and regional initiatives for energy savings, in order to implement more efficient practices for electricity production and heating.

On the other hand, as has been noted previously, some countries have a low or negative elasticity. This decrease could be explained by the low level of economic development of these countries, as their per capita income is below the average value of the sample. These countries suffer from lack of investment, with their energy sector being characterised by old infrastructure and high losses (IEA, 2015). Therefore, while these countries are achieving higher income levels, they are investing in the energy sector, reducing the losses, and therefore becoming less polluting. Nevertheless, it could be expected that the residential energy use would start to grow when these countries become more developed. Therefore, some regulatory schemes related to buildings would be recommended when the countries' economies start growing.

Finally, it is worth noting the special case of the Russian Federation. The elasticity has shown a decreasing trend since 2000. Zhang (2011) notes that during 2001–2008, the Russian Federation has achieved a considerable reduction in energy intensity, due to two major factors. Firstly, owing to the oil and gas price hikes, Russia's fiscal revenue gained a tremendous increase, which provided a solid capital foundation for the advances in energy technology investments. Secondly, it may be associated with the market reforms and structural changes carried out (Cornillie & Fankhauser, 2004). Thus, this energy consumption decline may be considered as energy efficiency improvements that led to notable environmental benefits.

CHAPTER 3.

Renewable energy use for electricity generation in transition economies: evolution, targets and promotion policies.

3.1. Introduction.

This Chapter aims to respond to the second objective of the doctoral thesis and corresponds to the research paper, **Renewable energy use for electricity generation in transition economies: evolution, targets and promotion policies,** published in the journal *Renewable and Sustainable Energy Reviews* (Pablo-Romero et al., 2021). In this Chapter, we analyse the measures that have been carrying out to promote the use of clean energy in transition economies, focusing specifically on the use of renewable energy sources for electricity generation.

The aim of this analysis is to provide an overview of the status of RE use for electricity generation in 17 transition economies, and the targets and measures adopted in these countries, to promote their use. Firstly, electricity production and consumption data are considered, as well as the use of RE for electricity generation by sources in these countries. Secondly, RE policies and targets in transition economies are reviewed, including the measures established to promote the development of RE and its use in electricity generation. This procedure is relevant, as legal documents of the selected countries are not usually publicly available in the English language, which may be the reason why there are very few studies on these countries.

A comparable analysis has been carried out by the United Nations Economic Commission for Europe (UNECE), in collaboration with the RE Policy Network for the 21st Century (REN21), on the status of RE in a global revision which considered 130 countries worldwide (REN21, 2017a). The REN21 (2017) report offers an overall view of the RE market, energy access and energy efficiency, and covers the policy landscape and investment flows in RE, mostly for 2015 and 2016. However, the Report, being of a general nature, does not offer in-depth details of the measures and the specific situation of the transition countries, which are the object of study in this paper.

Other studies have made in-depth, detailed analyses of the measures applied for the promotion of REs for electrical use in certain regions or groups of countries. For instance, Washburn and Pablo-Romero (2019) assess the RE measures adopted in the 18 Latin American countries signing the Paris Agreement to promote electricity generation. In the context of EU countries, Cansino et al. (2010) summarise the main fiscal incentives applied, in order to support green electricity and Pablo-Romero et al. (2017) provide a comprehensive review of feed-in tariffs (FITs), premiums and tender measures, to encourage the use of biogas for electricity.

In addition to the above, other studies have described the development of electricity generation of a country, based on scenario development. These include the studies by Hagberg et al. (2016), Indrawan et al. (2018) and Wierzbowski et al. (2017). Similarly, others have evaluated the influence of certain energy measures, through the use of several empirical models. Among these, Polzin et al. (2015) explore the influence of energy policies to promote investments in the use of RE for generating electricity, across OECD countries, by using panel data econometric techniques, while del Río et al. (2017) evaluate harmonised European renewable electricity policy pathways on a long-term horizon, by using the Green-X model.

Following the detailed review approach of the renewable electricity promotion measures of the first type of papers mentioned, that is to say (Cansino et al., 2010; Pablo-Romero et al., 2017; Washburn & Pablo-Romero, 2019), the current study provides a review of 17 transition countries in adopting RE policy for electricity development, based on previous reputable reports, not on a modelled or scenario development of a country. This study concentrates specifically on the electricity sector, including a comprehensive analysis of the evolution of electricity production and consumption in the 1995–2018 period. In addition, this paper contributes to expanding the previous research, focusing on the RE policies adopted for the sector in 17 transition economies reviewed up to 2018, by updating preceding reports and making a much more detailed analysis of the diverse measures adopted, in order to promote RE electricity generation in these countries. To do this, the information held by Climatescope (2018), IEA (2019), IRENA (2019), World Bank (2019) and legal documents from each country, have been reviewed and processed. This study is important as it takes into consideration the RE policies introduced under new laws that entered into force in recent years. Moreover, the study makes an in-depth analysis of some of the measures introduced, such as FITs, net metering, auction systems and tax incentives. To our knowledge, there is no previous study that provides a detailed, systematic and updated joint vision of the measures adopted in these countries.

3.2. Electricity consumption, production and the use of renewable energy in transition economies.

3.2.1. Electricity consumption and production trends worldwide.

Energy and electricity consumption and generation data were analysed, both globally and by regions. Table 13 shows the evolution of the total final energy consumption (TFC) per capita and worldwide, and by classifying the total values by regions, following the classification into the seven regions included in the International Energy Agency (IEA) energy database (IEA, 2020b).

Table 13. TFC per capita and share of electricity in TFC worldwide and by regions, 1995 and 2016.

	TFC per capita 1995, (toe/cap.)	TFC per capita 2016, (toe/cap.)	Growth rate, (%)	Share of electricity in TFC 1995, (%)	Share of electricity in TFC 2016, (%)	Growth rate, (%)
North America	4.19	3.81	- 9.04	18.89	21.38	13.14
Europa	2.11	2.03	- 3.70	17.28	21.50	24.41
Eurasia	2.54	2.45	- 3.55	11.71	13.97	19.33
Middle East	1.40	2.08	48.78	10.75	15.51	44.28
Central & South America	0.78	0.98	24.51	14.76	18.32	24.15
Asia Pacific	0.60	0.95	57.05	12.18	21.12	73.36
Africa	0.46	0.46	0.36	7.63	9.38	22.93
World	**1.14**	**1.28**	**12.13**	**14.31**	**18.79**	**31.31**

Source: Own elaboration from (IEA, 2020b).

The global TFC values increased from 6,537,338 Ktoe in 1995 to 9,533,585 Ktoe in 2016, which represents an increase of over 45% between those two years. Furthermore, it may be noted that the world TFC, per capita, clearly increased in 2016, compared to 1995, with a growth rate over 12%. However, this increasing trend is not manifested in all the regions considered. The Middle East, Central & South America, and Asia Pacific regions, starting with lower values in 1995, have significantly increased TFC values during this period. In contrast, North America, Europe, and Eurasia, which registered higher values in 1996, have moderately decreased their values during the period.

Table 13 also incorporates the evolution of the share of electricity in the TFC, between 1995 and 2016. This evolution is interesting in that the electrification of economies is considered a possible way of reducing CO2 emissions (IPCC, 2018), especially if its generation is combined with growth in the use of REs. In this case, as can be appreciated, the participation rate of electricity consumption in the TFC has increased in all cases, both globally and for each of the regions, registering variations of up to 44.28% and 73.36% for the Middle East and Asia Pacific regions, respectively.

The evolution of electricity consumption, generation and the use of RE in the electricity generation worldwide, and by regions, are shown in Table 14. The global electricity consumption per capita for all countries worldwide increased by 47.62%, from 2.1 MW to 3.1 MW, between 1995 and 2016. Also, all the regions increased electricity consumption per capita, with the Asia Pacific region registering the highest increase, followed by the Middle East, both above 100%.

It should be noted that the electricity production also shows a clear rising trend for all regions. The global electricity production values increase by 88.26% in the period, from 13,329,744 GW to 25,095,053 GW. The highest increase was registered in the Middle East and Asia Pacific regions, followed by Africa and Central & South America regions.

Finally, although the global share of RE in electricity generation increased with a growth rate over 19%, from 1995 to 2016, some regions show a clear decreasing trend. On the one hand, Europe is the region with the highest increase in the share of RE in electricity, close to

75% (74.94%), followed by Asia Pacific (34.93%), North America (16.90%), and Africa (3.65%).

Table 14. Electricity consumption, generation and the use of RE in the electricity generation worldwide and by regions, 1995 and 2016.

	Electricity consumption per capita 1995, (MWh/cap.)	Electricity consumption per capita 2016, (MWh/cap.)	Growth rate, (%)	Electricity generation 1995, (GWh)	Electricity generation 2016, (GWh)	Growth rate, (%)	RE participation 1995, (%)	RE participation 2016, (%)	Growth rate, (%)
North America	10.2	10.3	0.98	4,294,478	5,309,223	23.63	18.57	21.71	16.90
Europa	4.8	5.6	16.67	3,326,110	4,123,334	23.97	18.70	32.71	74.94
Eurasia	4.2	5.2	23.81	1,043,810	1,353,650	29.68	21.74	18.58	-14.55
Middle East	2.0	4.1	105.00	315,339	1,081,154	242.85	3.52	2.16	-38.68
Central & South America	1.4	2.2	57.14	640,220	1,297,119	102.61	74.23	62.87	-15.30
Asia Pacific	1.0	2.6	160.00	3,345,892	11,128,869	232.61	15.85	21.39	34.93
Africa	0.5	0.6	20.00	363,895	801,704	120.31	17.12	17.75	3.65
World	**2.1**	**3.1**	**47.62**	**13,329,744**	**25,095,053**	**88.26**	**20.45**	**24.36**	**19.17**

Source: Own elaboration from (IEA, 2020b).

On the other hand, the three remaining regions register a notable decrease in the share of RE in electricity. Despite this decreasing trend, Central & South America clearly continues to be the region with the highest share of RE in electricity in 2016, as it was in 1995.

3.2.2. Electricity consumption and production trends in transition economies.

The transition countries constitute a group that share common characteristics which make their study interesting. In this way, energy and electricity consumption, and generation data from this group of countries, were analysed. The TFC in transition economies accounted for 663,899 Ktoe in 2016, which is 6.96% of the world total consumption of energy, a significant share which makes an analysis of the TFC trend in the region relevant. Table 15 shows the evolution of the TFC per capita and the share of electricity in the TFC in transition economies.

Table 15. TFC per capita and share of electricity in TFC in transition economies, 1995 and 2016.

	TFC per capita 1995, (toe/cap.)	TFC per capita 2016, (toe/cap.)	Growth rate, (%)	Share of electricity in TFC 1995, (%)	Share of electricity in TFC 2016, (%)	Growth rate, (%)
Albania	0.31	0.69	126.43	17.79	23.67	33.06
Armenia	0.36	0.72	103.14	22.82	21.60	-5.34
Azerbaijan	1.24	0.92	-25.70	11.58	16.85	45.48
Belarus	1.79	1.94	8.22	11.86	13.70	15.49
Bosnia and Herzegovina	0.32	1.05	224.10	25.00	25.92	3.67
Georgia	0.47	1.17	145.55	25.29	20.82	-17.68
Kazakhstan	2.55	2.12	-17.03	11.00	15.05	36.76
Kyrgyz Republic	0.39	0.57	46.32	44.36	25.16	-43.28
Macedonia, FYR	0.75	0.95	27.01	28.83	27.00	-6.35
Moldova	0.85	0.79	-7.42	19.86	13.34	-32.84
Montenegro	1.25	1.16	-7.36	42.41	31.94	-24.67
Russia	3.09	3.25	5.35	11.60	13.63	17.51
Serbia	0.81	1.28	58.00	35.07	25.96	-25.99
Tajikistan	0.34	0.28	-15.31	61.51	45.15	-26.59
Turkmenistan	2.12	3.17	49.92	4.83	5.97	23.57
Ukraine	1.80	1.15	-36.26	13.30	19.55	46.97
Uzbekistan	1.44	0.84	-41.59	9.93	15.07	51.76
All 17 countries	**1.17**	**1.30**	**10.97**	**12.28**	**14.64**	**19.23**

Source: Own elaboration from (IEA, 2020b).

The last row presents the average values of the previously mentioned data across all 17 countries. It can be observed that the average TFC per capita had increased by 2016, compared to 1995, with the growth rate being almost 11%. Among the countries with the highest growth rates are Bosnia and Herzegovina, Georgia, Albania, Armenia, Serbia, Kyrgyzstan and Turkmenistan. Among those with negative growth rates are Ukraine, Uzbekistan, Azerbaijan, Kazakhstan, Tajikistan, Moldova and Montenegro, which can be explained by the significant gains in energy efficiency, derived from the transformations of their economies, which have caused them to achieve notable decreases in energy intensity since 2000 (CENEF, 2015). Finally, Russia did not have a significant increase in TFC per capita, its absolute value of 3.25 tonnes of oil equivalent remained the highest in the region, followed by Turkmenistan and Kazakhstan.

Due to the importance that its evolution and generation can have for the control of CO2 emissions, Table 15 also contains information related to the share of electricity within TFC. As can be observed, this electricity share in the region increased by 19%, during this period, (a growth rate lower than the world data, but more similar than those from Eurasia shown in Table 13), and accounted for 14.64% in 2016. Azerbaijan, Ukraine and Uzbekistan had the highest growth rates, while several countries, such as Armenia, Georgia, Kyrgyzstan, Moldova, Montenegro, Serbia and Tajikistan, had negative growth rates. Again, structural changes in the economies of these countries can explain these data. It is also worth highlighting that Tajikistan had the largest electricity share (45%), while Belarus, Russia and Moldova had an electricity share below the average value. Similarly, Turkmenistan had the lowest share, about 6%.

In the context of increasing energy demand as a whole in these countries, but with different individual evolutions between them, notable differences in the energy situation of transition economies must be taken into consideration. One difference to take into account is that there are energy importers, as well as energy exporters, in the region. Figure 10 shows net energy imports as a percentage of energy use in 2016. It is estimated as the primary energy before transformation to other endues fuels, less production, and a negative value indicates that the country is a net exporter. According to these data, there are five net exporters in the region: Azerbaijan, Kazakhstan, Russia, Turkmenistan and Uzbekistan, all of them with significant oil and gas deposits. The remaining countries are net energy importers to a greater or lesser degree. Thus, Albania has the lowest degree of energy import dependency at 13%, whereas the imports of Belarus and Moldova exceed 80%. In addition, net imports of three countries, Armenia, Kyrgyzstan and Macedonia, constitute more than 50% of their energy use, while in Bosnia and

Herzegovina, Montenegro, Serbia, Tajikistan and Ukraine, net imports account for about 30% of energy use, still constituting an energy challenge.

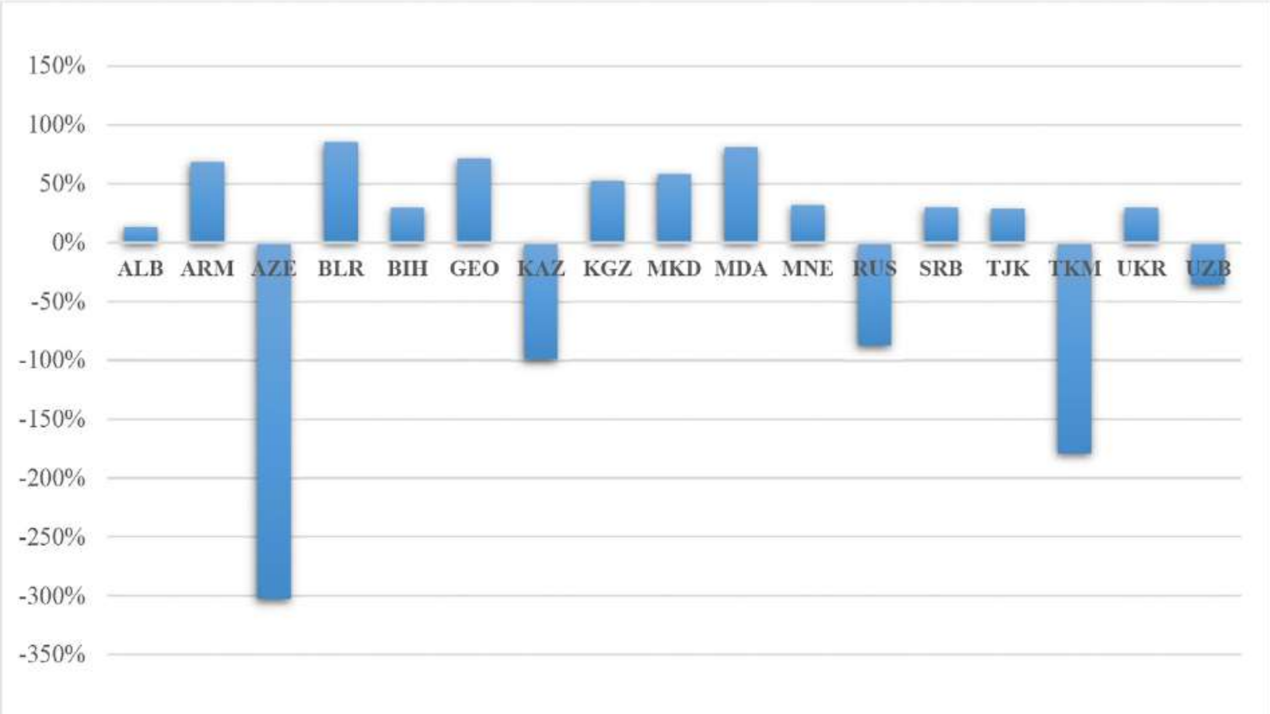


Figure 10. Energy imports, net (% of energy use), 2016.
Source: Own elaboration from (IEA, 2020b).

In this regard, energy security can be considered as a driver for RE deployment, as countries aim to reduce their energy import dependency by making greater use of local clean energy sources (REN21, 2017b).

Since the demand for electricity is expected to keep growing, an analysis of the electricity sector, and the RE share in electricity generation, is crucial. Table 16 shows the evolution of the electricity consumption, generation and the use of RE in the electricity generation, within each studied transition economy and globally.

Table 16 shows that the average electricity consumption per capita, across the countries, increased by 14.74% from 2.32 MW to 2.66 MW. Albania and Bosnia and Herzegovina showed the highest increases, followed by Georgia, Armenia and Turkmenistan. It is also worth highlighting that six countries of the region, Kyrgyzstan, Moldova, Montenegro, Tajikistan, Ukraine and Uzbekistan, had negative electricity consumption per capita growth rate. The available data for Montenegro commences in 2005. Although the country decreased its electricity consumption per capita, the absolute value was the second highest in the region, after the Russian Federation.

Table 16. Electricity consumption, generation and the use of RE in the electricity generation in transition economies, 1995 and 2016.

	Electricity consumption per capita 1995, (MWh/cap.)	Electricity consumption per capita 2016, (MWh/cap.)	Growth rate, (%)	Electricity generation 1995, (GWh)	Electricity generation 2016, (GWh)	Growth rate, (%)	RE participation 1995, (%)	RE participation 2016, (%)	Growth rate, (%)
Albania	0.64	1.91	200.98	4,473	7,782	73.98	93.99	100.00	6.40
Armenia	0.95	1.82	92.22	5,561	7,315	31.54	34.51	32.18	-6.75
Azerbaijan	1.67	1.81	8.06	17,044	24,953	46.40	9.13	8.78	-3.82
Belarus	2.48	3.09	24.51	24,918	33,566	34.71	0.08	1.25	1462.66
Bosnia and Herzegovina	0.94	3.15	236.16	4,401	17,767	303.70	82.78	31.88	-61.48
Georgia	1.40	2.82	101.94	8,154	11,574	41.94	63.81	80.68	26.44
Kazakhstan	3.26	3.70	13.47	66,661	106,627	59.95	12.50	11.24	-10.06
Kyrgyz Republic	2.01	1.67	-17.05	14,285	13,262	-7.16	77.83	86.67	11.36
Macedonia, FYR	2.51	2.98	18.77	6,132	5,629	-8.20	13.06	36.70	180.98
Moldova	1.96	1.22	-37.75	7,625	5,827	-23.58	4.25	4.22	-0.65
Montenegro	6.13	4.29	-29.98	2,864	3,141	9.67%	65.15	58.68	-9.94
Russia	4.17	5.16	23.80	860,027	1,090,973	26.85	20.70	17.43	-15.79
Serbia	3.31	3.87	16.97	34,476	39,342	14.11	35.37	29.47	-16.68
Tajikistan	2.41	1.50	-37.83	14,825	17,232	16.24	98.46	96.52	-1.97
Turkmenistan	1.19	2.20	85.45	9,800	22,534	129.94	0.04	0.00	-100.00
Ukraine	2.79	2.61	-6.32	194,018	164,573	-15.18	5.23	6.61	26.43
Uzbekistan	1.66	1.47	-11.35	47,453	58,319	22.90	13.04	20.28	55.56
All 17 countries	**2.32**	**2.66**	**14.74**	**77,807**	**95,907**	**23.26**	**19.67**	**18.18**	**-7.65**

Source: Own elaboration from (IEA, 2020b).

It may be observed that the average electricity production also increased by 23.26%, from 77,807 GW to 95,907 GW, in the region. In fact, electricity production increased in most of the countries, with the exception of Kyrgyzstan, Macedonia, Moldova and Ukraine. The highest increase was registered in Bosnia and Herzegovina, followed by Turkmenistan and Albania. Among the countries with below average growth rates were Montenegro, Serbia, Tajikistan and Uzbekistan. In addition, Russia, the largest country of the region, produced eleven times more electricity than the regional average, and reached a billion GW in 2016. It was followed by Ukraine and Kazakhstan which had above average electricity production values.

Finally, the ultimate three columns in Table 16 show the share of RE in electricity generation, in 1995 and 2016, and the growth rate of this share between those years. Firstly, it should be noted that, in 2016, there were greater differences in the share of RE in electricity production, as may also be observed in Figure 11, which have been included for an easier visualisation of these differences.

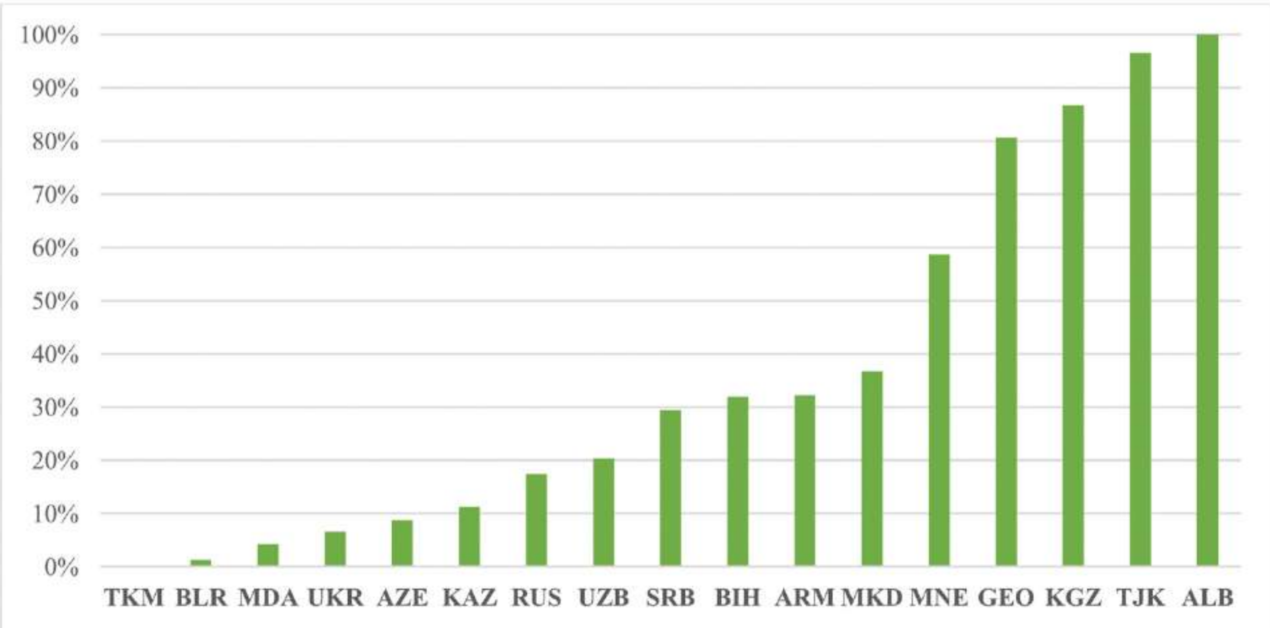


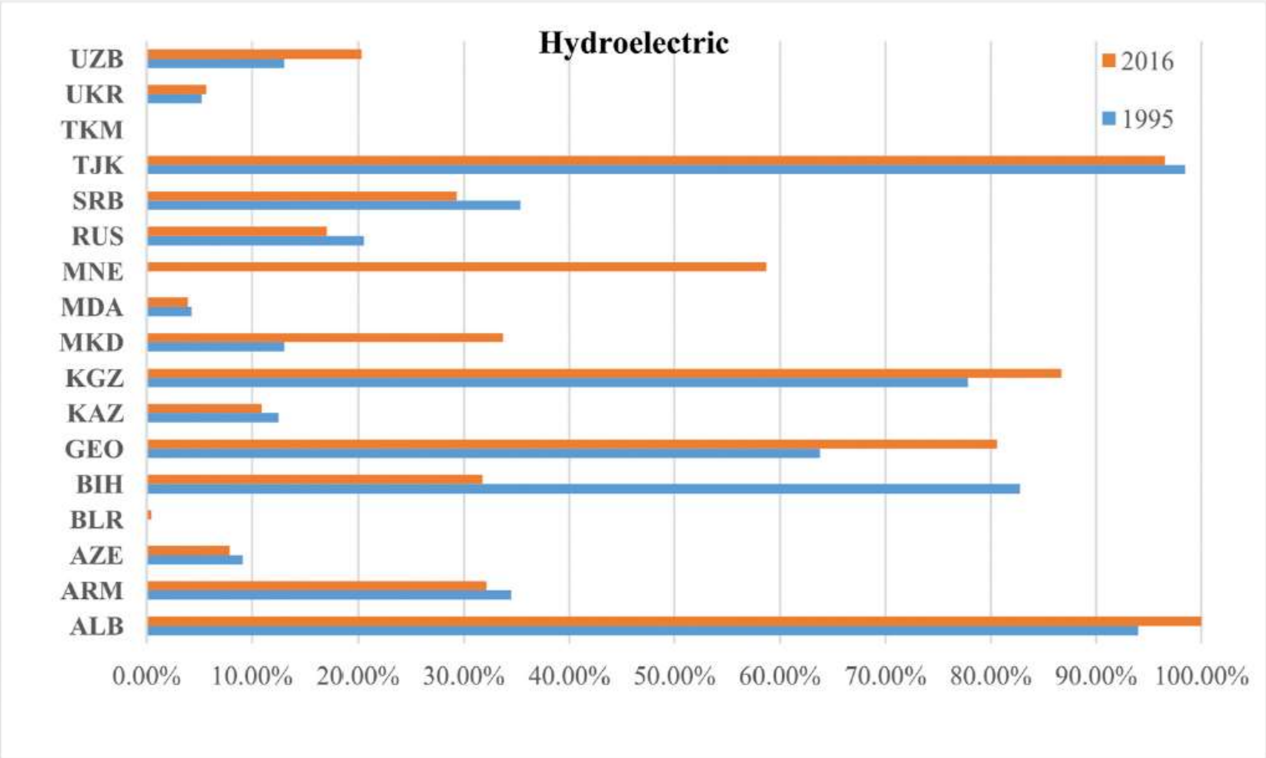
Figure 11. Total share of RE in electricity production, by country, 2016.
Source: Own elaboration from (IEA, 2020b).

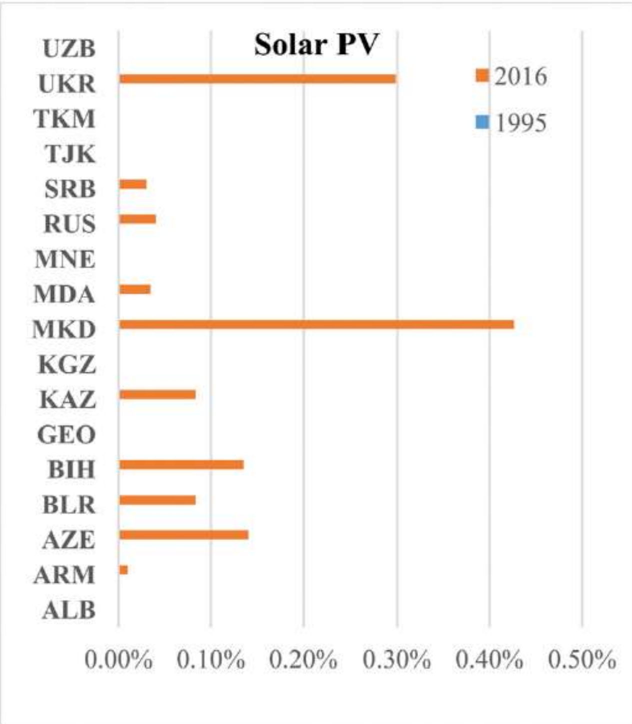
It may be observed that the individual values varied, literally, from zero to one hundred percent, across the selected countries, whereas the average share was 18.18%. The highest share of RE in electricity production can be observed in Albania and Tajikistan, while Turkmenistan had no share. It should also be noted that several countries, including Kyrgyzstan, Georgia and Montenegro, stand out for the higher share of above 50% of RE in electricity production. Additionally, the largest country of the region, Russia, produced 17.43% of its electricity from RE in 2016.

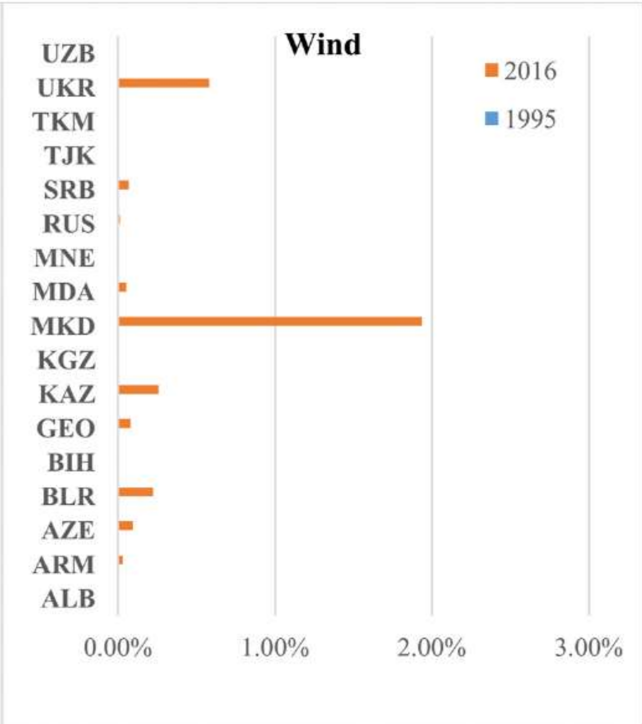
Secondly, it is worth pointing out that the share of RE in electricity generation in the region had a negative growth rate of 7.65%, with significant differences between the countries. Thus, 10 of the 17 countries, including four net exporters, decreased their share. Uzbekistan was the only energy exporter that increased its share of RE. Similarly, Macedonia, Georgia and Ukraine were the countries that had a significant increase in RE participation. In addition, although Belarus showed a giant increase in its RE share, the absolute value remained quite low. The decrease in the share of RE in electricity generation, in all the studied countries, and the differences observed between countries, may largely be explained, as detailed in the next section, by the evolution of the share of hydroelectric energy.

3.2.3. Renewable energy use for electricity generation in transition economies by sources.

Figure 12 compares the participation of the main renewable sources in electricity generation in transition economies in 1995, and in 2016. Firstly, it may be noted that a significant share of electricity is generated by hydropower. Uzbekistan, Ukraine, Macedonia, Kyrgyzstan, Georgia, Albania and Belarus are the countries with an increased share of hydroelectric energy, during the period. On the contrary, Tajikistan, Serbia, Russia, Kazakhstan, Azerbaijan, Armenia and Turkmenistan decreased the use of hydropower in electricity generation. Although the electricity production from hydropower in Bosnia and Herzegovina increased over the period of 1995–2016, in absolute terms, its share in total electricity generation decreased by more than 50% points, due to the rapidly growing contribution of indigenous production from coal, during the post conflict period (Energy Charter Secretariat, 2013).







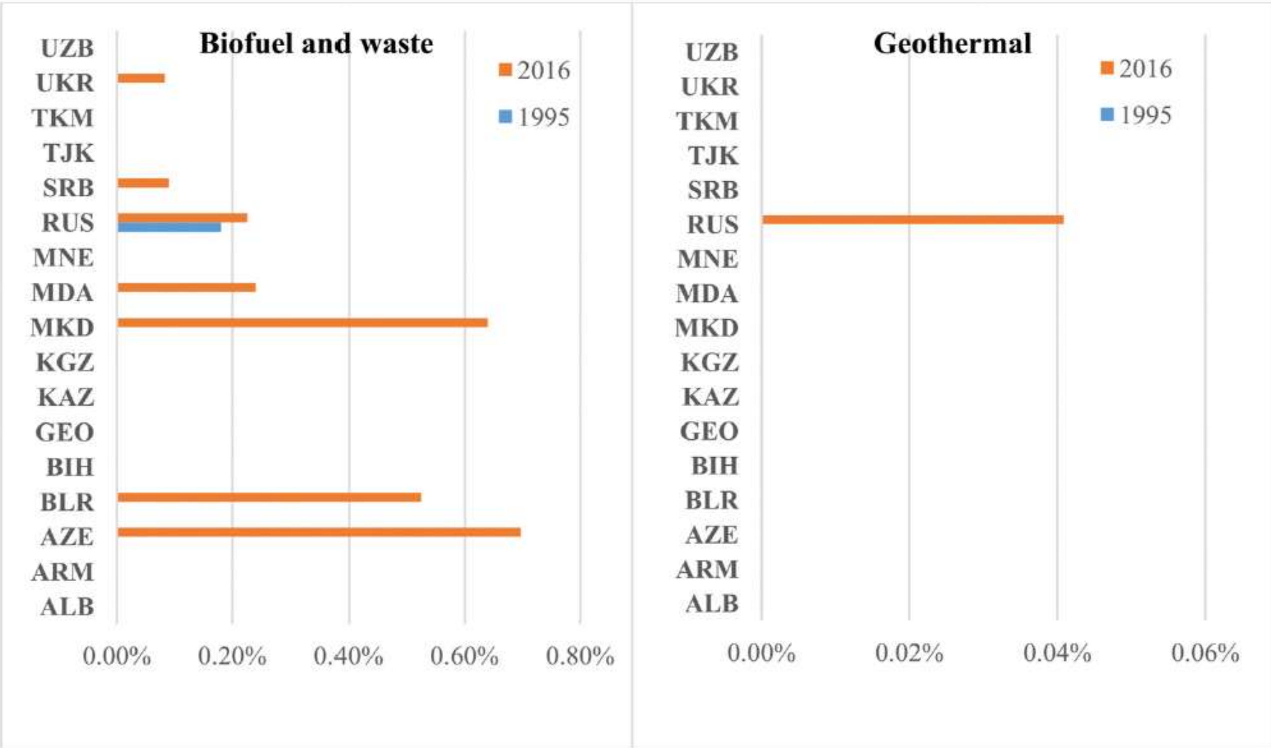


Figure 12. REs participation in electricity generation in transition economies in 1995 and 2016.
Source: Own elaboration from (IEA, 2020b).

Secondly, the participation level of wind and solar sources in electricity production in the region remains quite low, compared to their potential, as these energy sectors are still in the process of formation. Thus, Macedonia and Ukraine, two countries with the highest share of solar PV in the region, had a less than 0.50% share. Macedonia also has the largest wind share, about 1.94%, followed by Ukraine. In addition, there are countries, such as Albania, Kyrgyzstan, Montenegro, Tajikistan, Turkmenistan and Uzbekistan, that had no solar PV or wind share. Finally, limited use of biofuel and waste was registered in seven of the regions' countries. Azerbaijan, Macedonia and Belarus had the highest share, above 0.5%, followed by Moldova, Russia, Serbia and Ukraine. In addition, Russia is the only country with a share of geothermal energy in electricity generation.

Thirdly, it should be noted that the evolution of the share of hydraulic energy in electricity generation may be explained, at least in part, by the evolution of the share of RE in electricity generation. It can be observed that those countries which have increased the share of hydroelectricity, are the same as those that have increased their share of RE in electricity generation (shown in the last column of Table 16). Similarly, those countries that have experienced a decrease in the share of hydraulic energy, are the same as those that have decreased the share of RE. Thus, the small growth in the share of non-conventional RE in some countries has not been enough to offset the negative relative effect of hydropower. While in some cases, especially Ukraine, Macedonia and Belarus, the incipient growth of non-conventional RE has reinforced the positive effect of the evolution of the share of hydraulic energy. However, it is important to bear in mind that the decrease in the weight of hydroelectric energy in electrical generation is not due to a decrease in the use of this source, but rather to a percentage growth lower than the growth in electricity production (according to IEA (2019) data). In this sense, the use of polluting energy sources increased in these countries, during the period from 1995 to 2006. Only two exceptions should be noted, Moldova and Turkmenistan have reduced the use of hydraulic energy.

Therefore, these results show that the decrease in the share of RE in electricity generation, between 1995 and 2016, is generally due to a growth in electricity generation in these countries, which has been based on fossil energies. Thus, the increases in hydraulic energy and other nonconventional REs have not been enough to keep pace with electricity growth. It should be noted that the use of non-conventional RE was very low at the end of the period.

Although the average share of non-conventional REs (solar PV and wind), in selected countries, was 0.17% in 2016, the rapid growth of the share of renewable technologies can be observed during the later years. Table 17 presents a comparison of the values of RE electricity generation by source, in 2015 and 2018, and its growth rate in that period, in the countries in transition, and worldwide. Clearly, it can be seen from Table 17 that wind and solar PV installations in transition economies, presented higher than worldwide growth rates in 2018, compared to 2015. These data are in accordance with the increase in renewable capacities in transition economies during the 2016–2018 period. According to IRENA (2019), these countries added 5.3 GW of renewable capacities, of which 56.6% (3 GW) came from non-hydropower resources.

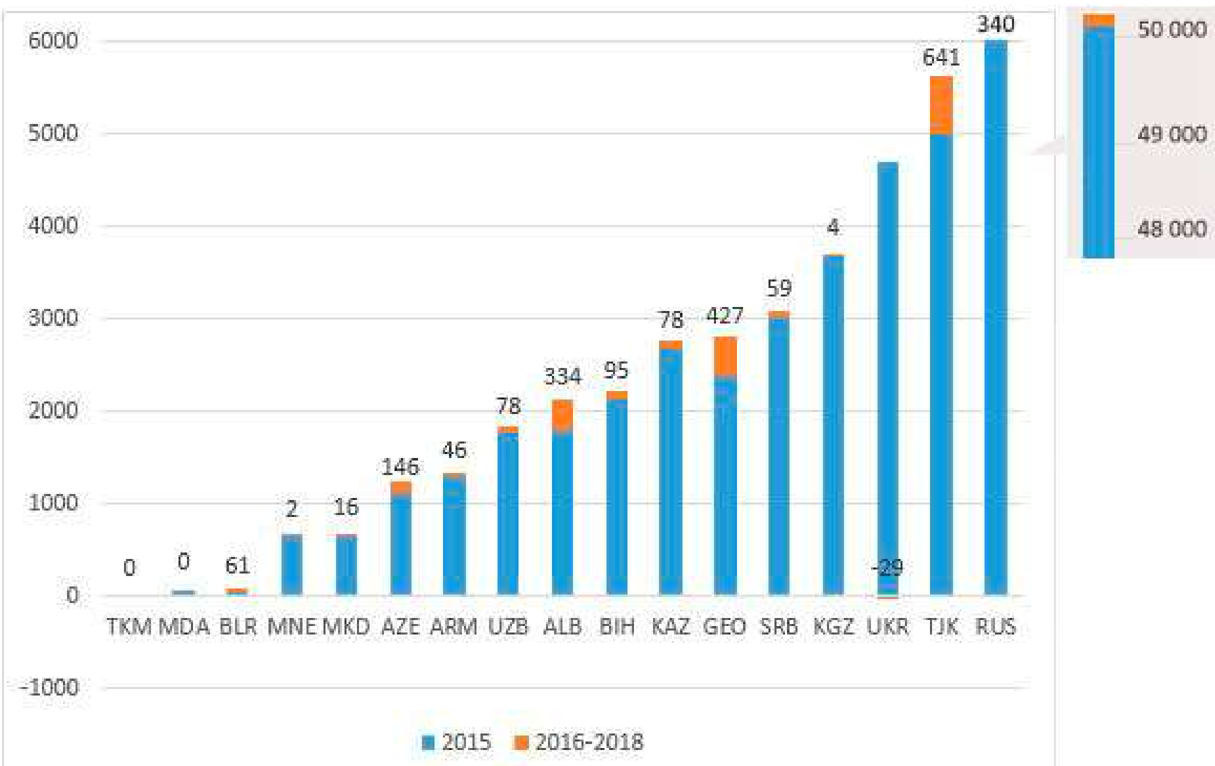
Figure 13 shows the hydropower, wind and solar PV installed capacities in 2015 and newly added renewable capacities in 2016–2018.

Table 17. Renewable energy electricity generation by source and its growth rate.

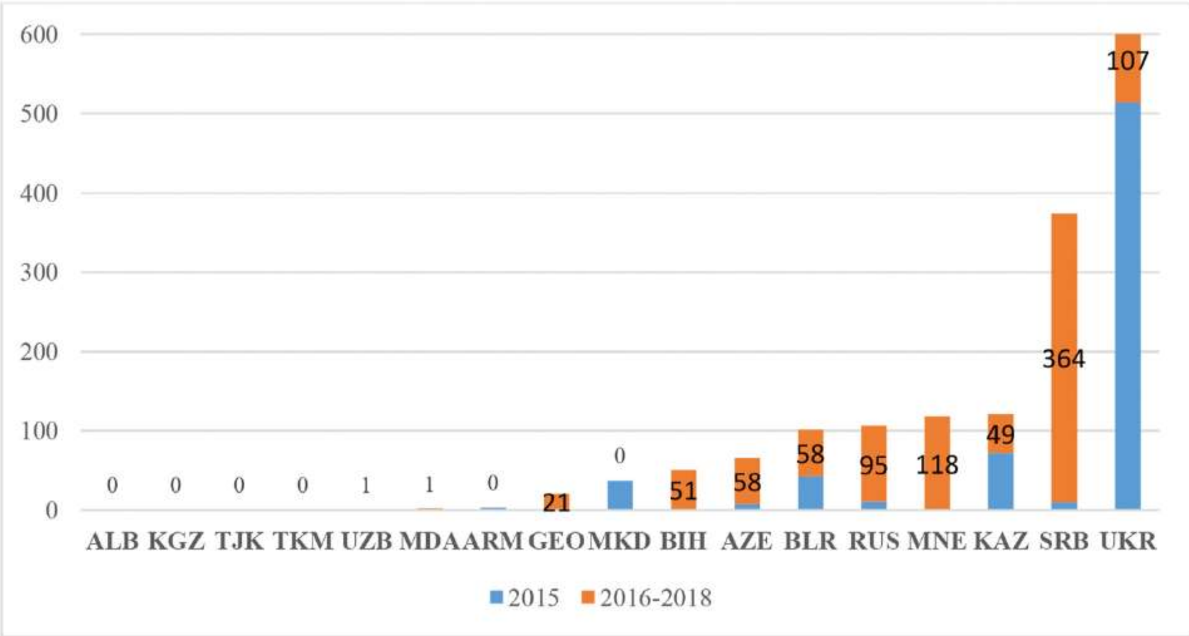
	Transition economies			World		
	2015 (GWh)	2018 (GWh)	Growth rate (%)	2015 (GWh)	2018 (GWh)	Growth rate (%)
Hydropower	80,717	83,015	2.85	1,097,189	1,171,612	6.78
Wind	699	1,622	132.05	416,225	563,726	35.44
Solar PV	1,018	3,025	197.15	221,067	480,357	117.29
Bioenergy	1,577	1,649	4.57	94,131	113,379	20.45
Geothermal	78	78	0.00	11,856	13,329	12.42
Total	**83,055**	**88,355**	**6.38**	**1,840,468**	**2,342,403**	**27.27**

Source: Own elaboration from (IRENA, 2019).

Hydropower



Wind



Solar PV

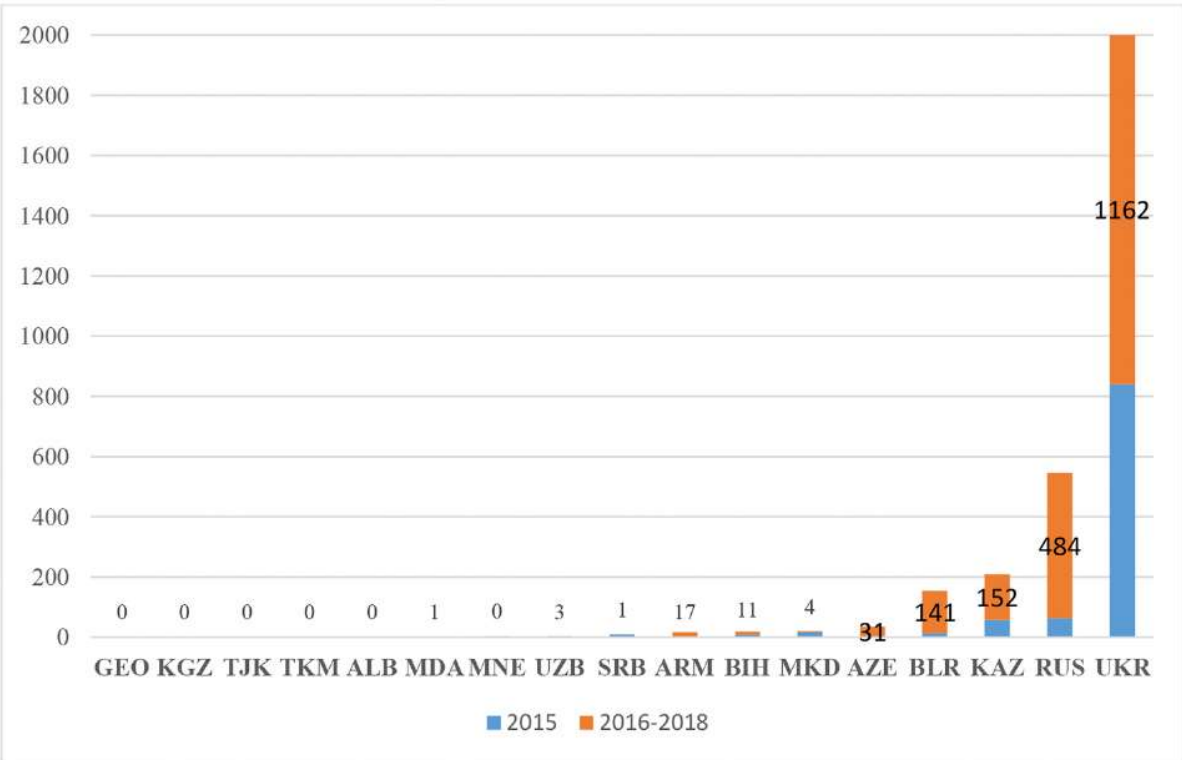


Figure 13. Installed Renewable energy capacities in 2015 and 2016–2018 additions.
Source: Own elaboration from (IRENA, 2019).

Tajikistan, Georgia, Albania and Russia added the most hydropower capacity, approximately 1.7 GW or 75% of total hydro capacity additions. On the contrary, Turkmenistan and Moldova had no hydro installed capacity. According to the United Nations Economic Commission for Europe Report (UNECE, 2011) in the case of Turkmenistan, this may be explained by the extremely high importance of the oil and gas sector, which determines that almost all electric power is generated at gas plants. In the case of Moldova, although most of the electricity is also generated at gas plants, the country does not have natural reserves of coal or natural gas. Thus, the lack of hydraulic plants, as stated in the report mentioned (UNECE, 2011), can only be explained by their low hydropower potential, which in turn is located in an area that has an uncertain administrative status.

Regarding the increases in installed wind capacity, it is worth highlighting that Serbia added 364 MW (or about 40% of total added wind capacity) in 2016–2018, mainly due to the Green for Growth Fund (GGF) support. According to its Annual Impact Report (GGF, 2017), the GGF played a vital role in construction of several wind farms, such as the Malibunar (8 MW), the Alibunar (42 MW) and the Cibuk (157 MW), the country's largest wind farm. Thus, Serbia became the second country in the region with the largest wind installed capacity, after Ukraine, which has high climatic potential for wind power and is to continue to gradually expand in capacity. In addition, the wind power cost-competitive potential of Ukraine amounts to 119.2 GW, which is the largest wind power potential of South East Europe (IRENA, 2017b). Montenegro and Russia also added sizable wind capacity in 2016–2018, followed by Belarus, Azerbaijan, Bosnia and Herzegovina and Kazakhstan.

The Solar PV graph in Figure 13 also shows that Ukraine became the absolute leader in terms of solar energy in the region, by adding 1.2 GW, or approximately 58% of total added solar PV capacity, followed by Russia, Kazakhstan and Belarus. Some factors may explain this significant growth in solar installations in Ukraine. Among them, the Ukrainian energy market report (Investment Flanders & Trade, 2018) highlights the following: legislation favourable to the promotion of REs that accelerate the independence of Russian gas, good indicators of solar radiation, the capacity of energy networks, the policy of local authorities, and the emergence of contractor operators which offer integrated solutions to investors.

Finally, it is worth noting that Ukraine, the Russian Federation and Serbia are the countries that added more than 70% (approximately 2.2 GW) of their RE capacities from non-hydropower resources.

3.3. Targets and measures to promote RE for electricity generation in transition economies.

3.3.1. Targets on RE related to electricity in transition economies.

RE policies and targets are crucial, not only to promote the use of RE, but also to increase energy efficiency, as was previously agreed at the COP21 in Paris. Transition economies are still in the process of introducing policies and adopting measures for RE, in order to remove barriers for its further development, and to increase the flexibility of power systems (REN21, 2017b). Table 18 presents the overview of the RE legal framework in the selected countries, including targets, laws on RE, national strategies and action plans.

It may be observed that all selected countries, apart from Georgia and Turkmenistan, have strategic documents, such as a national strategy or law on RE, outlining their RE target. In Turkmenistan, clean energy remains a low priority, due to cheap and heavily subsidised natural gas which accounts for nearly all of the country's electricity mix, signifying that there has been no regulation or policy enacted to support these technologies (Climatescope, 2018). In the case of Georgia, the adoption of the RE law by its government, as well as the implementation of a National RE Action Plan (NREAP), is still pending. This country does not have an RE target to 2020, due to its late accession to the Energy Community, an international organisation founded to extend the EU internal energy market rules to its neighbours, and beyond. To date, eight countries of the region, Albania, Bosnia and Herzegovina, Georgia (day of accession: July 1, 2017), Macedonia, Moldova, Montenegro, Serbia and Ukraine, are Contracting Parties of the Energy Community Treaty. Armenia is an Observer and Belarus applied for Observer status in October 2016.

Table 18. Overview of renewable energy policies in transition economies.

	RE Target	National strategy / Law on RE	National RE Action Plan
Albania	✓	✓	✓
Armenia	✓	✓	
Azerbaijan	✓	✓	
Belarus	✓	✓	
Bosnia and Herzegovina	✓	✓	✓
Georgia			
Kazakhstan	✓	✓	
Kyrgyz Republic	✓	✓	
Macedonia, FYR	✓	✓	✓
Republic of Moldova	✓	✓	✓
Montenegro	✓	✓	✓
Russia	✓	✓	
Serbia	✓	✓	✓
Tajikistan	✓	✓	
Turkmenistan			
Ukraine	✓	✓	✓
Uzbekistan	✓	✓	

Source: Own elaboration from IEA (2019) and Climatescope (2018).

Generally, in South-Eastern Europe, NREAPs and commitments within the Energy Community tend to accelerate legislative changes in RE, whereas in Eastern Europe, the Caucasus and Central Asia, the adoption of such legislation is happening at a slower pace (REN21, 2017b). In addition, there are four EU candidate countries (Albania, Serbia, Macedonia and Montenegro), which are in the process of incorporating EU legislation into national law. Their RE national objectives are generally set higher than in other countries, since the EU Directive for RE (Directive 2009/28) stipulates a general objective of 20% for the EU, and individual objectives for the Member States, based on their current RE and economic development levels.

Table 19 details the RE targets in transition economies by sector.

Table 19. Overview of RE targets in transition economies by sector.

Country	Sector	RE Target
Albania	Energy	38% of GFC by 2020.
Armenia	Electricity	21% of REs in total power generation by 2020; 26% of REs in total power generation by 2025.
Azerbaijan	Energy	Energy consumption from REs: 9,7% by 2020; 2 GW of cumulative power capacity by 2020.
	Electricity	Electricity consumption from REs: 20% by 2020.
Belarus	Energy	6% of REs in the total energy supply by 2020; 7% by 2025; 8% by 2030 and 9% by 2035.
Bosnia and Herzegovina	Energy	40% of REs in GFC by 2020.
Georgia		No target yet.
Kazakhstan	Electricity	Solar and wind: not less than 3% by 2020; 30% of alternative sources (solar, wind, hydro, nuclear) by 2030 and 50% by 2050.
Kyrgyz Republic	Electricity	10% of REs in electricity generation by 2021 161 MW of small hydro.
Macedonia, FYR	Energy	21% REs in GFC by 2020.
Republic of Moldova	Energy	20% of GFC by 2020.
	Electricity	10% of final gross electricity consumption by 2020.
Montenegro	Energy	RES in GFC: 33% by 2020.
	Electricity	RES in GFC: 51.4% by 2020.
Russia	Electricity	4.5% of power generation by 2024, excluding large hydro, 5.9 GW by 2024.
Serbia	Energy	27% of GFC by 2020.
	Electricity	36,6% of GFC by 2020.
Tajikistan	Electricity	10% share of REs in total electricity balance by 2030. 103.6 MW of small hydro.
Turkmenistan		No target yet.
Ukraine	Energy	11% of REs in GFC by 2020.
	Electricity	11% of REs in GFC by 2020.
Uzbekistan	Electricity	19.7% of share of REs, including 15.8% of hydro, 2.3% of solar and 1.6% of wind energy in the generation by 2025.

Source: Own elaboration from IEA (2019) and Climatescope (2018).

Significant differences between the national targets of the countries may be observed in various aspects. Table 20 summarises the main RE target differences related to the affected sector by type, maximum value and term of target. The RE targets are set mostly for the total RE share in electricity (11 countries). However, the overall share of energy from RE sources in total energy is also commonly used (9 countries). Similarly, there is the same number of countries fixing their targets on energy (or electricity) consumption or generation.

Table 20. Main RE target differences between the 17 transition economies.

	Sector		Target on		Maximum target	Target term	
	Energy	Electricity	Consumption	Generation		Short 2020-25	Long 2030-50
Albania	✓		✓		38%	✓	
Armenia		✓		✓	26%	✓	
Azerbaijan	✓	✓	✓	✓	20%	✓	
Belarus	✓			✓	9%	✓	✓
Bosnia and Herzegovina	✓		✓		40%	✓	
Georgia							
Kazakhstan		✓		✓	50%	✓	✓
Kyrgyz Republic		✓		✓	10%		
Macedonia, FYR	✓		✓		21%	✓	
Republic of Moldova	✓	✓	✓		20%	✓	
Montenegro	✓	✓	✓		51.4%	✓	
Russia		✓		✓	4.5%	✓	
Serbia	✓	✓	✓		36.6%	✓	
Tajikistan		✓		✓	10%		✓
Turkmenistan							
Ukraine	✓	✓	✓		11%	✓	
Uzbekistan		✓		✓	19.7%	✓	
Total number	**9**	**11**	**8**	**8**		**13**	**3**

Source: Own elaboration from IEA (2019) and Climatescope (2018).

Among the countries with the highest national RE objectives are Montenegro (51%), Kazakhstan (50%), Bosnia and Herzegovina (40%), Albania (38%), and Serbia (36%). It is worth noting that the maximum RE targets shown for Montenegro, Kazakhstan and Serbia are set as percentages of electricity, and that Kazakhstan's target is very long term, at 2050. On the other hand, Russia set the lowest RE target in the region (4.5% of power generation by 2024), followed by Belarus, which committed to a gradual objective, starting from 6% of RE share, by 2020, to 9% by 2035.

It is worth highlighting that Kazakhstan is the only country that sets an ambitious RE target to reach, in the very long term, by 2050, with intermediate targets of 3% by 2020, and 10% by 2030. Similarly, also in the long term, Belarus and Tajikistan set targets for 2030. The rest of the countries established short-term targets for 2020 or 2025, which need to be updated.

3.3.2. Policies to promote RE use for electricity generation in transition economies.

3.3.2.1. Feed-in tariff.

Feed-in tariffs (FITs) are a type of price-based policy instrument whereby a fixed, guaranteed level of electricity prices are paid to eligible RE generators, for each unit of energy produced and fed into the electricity grid. These prices are usually established depending on each generation technology, and the payment is guaranteed for a certain period of time, usually related to the economic lifetime of the RE project. This increases the stability and allows for long-term planning, which encourages investment in RE projects. Some policies also provide fixed premium payments that are added to wholesale market or cost related tariffs, as a variant called a feed-in premium system.

The FIT is the most widely spread policy to promote RE in transition economies, however, it has recently been replaced with an auction system. Thus, in Kazakhstan, the FIT system, introduced in 2014, was used for wind, solar, hydropower and biogas. A fixed tariff and 15-year contracts allowed the RE market to be boosted at its initial stage of development. Later, the country decided to replace this scheme with a competitive auction system (Republic of Kazakhstan, 2017)

To date, 12 countries had adopted FIT policies: Albania, Armenia, Azerbaijan, Belarus, Bosnia and Herzegovina, Georgia, Kyrgyzstan, Macedonia, Republic of Moldova, Montenegro, Serbia and Ukraine. Table 21 shows the main elements of the implemented FIT policies in transition economies. Numerous options exist for defining the levels of incentives, basically depending on the REs technology and total installed capacity. Table 21 includes FIT coefficients per kWh produced, and the payment guaranteed period by technologies and installations capacity.

Table 21. FIT legislation and rates in transition economies.

Country	REs technology	FIT excl. VAT (per kWh)	coefficient	Period
Albania	Law No. 07/2017 on REs, 2017			
	Solar PV < 2 MW	€ct 10		15 years
	Wind < 3 MW	€ct 7.6		
Armenia	Law on Energy Efficiency and RE, 2004 (amended in 2011)			
	SHPP on natural water streams	23.864 AMD (approx. €ct 4.17)		15 years
	SHPP on irrigation systems	15.906 AMD (approx. €ct 2.78)		
	SHPP on natural drinking sources	10.605 AMD (approx. €ct 1.85)		
	Solar, wind, biomass <1 MW	42.845 AMD (approx. €ct 7.49)		20 years
Azerbaijan	Law on Electrical and Heating Power Stations, 1999			
	Wind	approx. €ct 4.15		
	Small and mini hydro	approx. €ct 2.32		
Belarus	Law on RE Sources No 204-W, 2010			20 years
	Solar PV (< 300kW, 301kW-2MW, >2MW)		2 or 1.7 or 1.5	
	Wind		1.1 or 1.01	
	Hydro (< 300kW, 301kW-2MW, >2MW)		1.3 or 1.25 or 1.2	
	Wood and biomass <750kW(< 300kW, 301kW-2MW, >2MW)		1.3 or 1. or 1.2	
	Biogas < 750kW		1.2 or 1.15 or 1.1	

Bosnia and Herzegovina- The Federation of Bosnia and Herzegovin	Law on the Use of REs, 2013 (amended in 2014), Decree and Rulebook on REs, 2014, Decision on guaranteed price, 2017			
	Wind	Micro 2 kW – 23 kW	KM 0.37124 (approx. €ct 17.86)	12 years
		Mini 23 kW – 150 kW	KM 0.22140 (approx. €ct 10.65)	
		Small 150 kW – 1 MW	KM 0.18917 (approx. €ct 9.10)	
		Medium 1 MW – 10 MW	KM 0.16033 (approx. €ct 7.71)	
		Large over 10 MW	KM 0.14766 (approx. €ct 7.10)	
	Solar	Micro	KM 0.49075 (approx. €ct 27.70)	
		Mini	KM 0.30696 (approx. €ct 18.31)	
		Small	KM 0.25971 (approx. €ct 15.78)	
	Hydro	Micro 2 kW – 23 kW	KM 0.29036 (approx. €ct 14.84)	
		Mini 23 kW – 150 kW	KM 0.18192 (approx. €ct 9.30)	
		Small 150 kW – 1 MW	KM 0.13751 (approx. €ct 7.03)	
		Medium 1 MW – 10 MW	KM 0.12373 (approx. €ct 6.33)	
	Biogas	Micro 2 kW – 23 kW	KM 0.71160 (approx. €ct 36.37)	
		Mini 23 kW – 150 kW	KM 0.66637 (approx. €ct 34.07)	
		Small 150 kW – 1 MW	KM 0.27891 (approx. €ct 14.26)	
	Biomass	Micro 2 kW – 23 kW	KM 0.31292 (approx. €ct 16.10)	
		Mini 23 kW – 150 kW	KM 0.24987 (approx. €ct 12.77)	
		Small 150 kW – 1 MW	KM 0.24067 (approx. €ct 12.30)	
		Medium 1 MW – 10 MW	KM 0.22706 (approx. €ct 11.61)	
Bosnia and Herzegovina- Republic Srpska	Law on REs, 2013 (amended in 2015), Rulebook on REs promotion, 2014, Decision on the amount of the guaranteed price, 2017			
	Wind	Up to 10 MW	BAM 0.1466 (approx. €ct 7.52)	15 years

	Solar Residential	Up to 50 kW	BAM 0.2734 (approx. €ct 14.02)		
		50 - 250 kW	BAM 0.2341 (approx. €ct 12.00)		
		250 kW - 1 MW	BAM 0.1856 (approx. €ct 9.51)		
	Ground mounted	up to 250 kW	BAM 0.2169 (approx. €ct 11.12)		
	Hydro	Up to 1 MW	BAM 0.1396 (approx. €ct 7.16)		
		1 - 5 MW	BAM 0.1227 (approx. €ct 6.29)		
		5 - 10 MW	BAM 0.1186 (approx. €ct 6.10)		
	Biogas	Up to 1 MW	BAM 0.2402 (approx. €ct 12.28)		
	Biomass	Up to 1 MW	BAM 0.2413 (approx. €ct 21.53)		
		1 - 10 MW	BAM 0.2261 (approx. €ct 11.55)		
Georgia	Decree No. 214, 2013				
	Solar, wind and hydro		Up to 0.144 GEL(approx. €ct 3.94) for eight months of the year (September through April).		15 years
Kyrgyz Republic	Law on RE, 2008 (amended in 2012)				
	Solar		13.4 KGS (approx. €ct 14.70)	6	8 years
	Wind		5.60 KGS (approx. €ct 6.14)	2.5	
	Biomass		6.10 KGS (approx. €ct 6.69)	2.75	
	Geothermal		7.50 KGS (approx. €ct 8.23)	3.35	
	Small hydro (<30 MW)		4.70 KGS (approx. €ct 5.16)	2.1	
Macedonia, FYR	Decree on Electricity Feed-in Tariffs, 2011 (amended in 2013), Decision for total installed capacity, 2013				
	Wind (50 MW) ≤ 0.050 MW		8.90 €ct		20 years
	Hydro up to 10 MW	≤ 85,000 kWh	12.00 €ct		
		> 85,000 and ≤ 170,000	8.00 €ct		
		> 170,000 and ≤ 350,000	6.00 €ct		

		> 350,000 and ≤ 700,000	5.00 €ct	
		> 700,000 kWh	4.50 €ct	
	Solar up to 1 MW	≤ 0.050 MW	€ct 16	15 years
		> 0.050 MW	€ct 12	
	Biomass up to 3 MW		€ct 15.00	
	Biogas		€ct 18.00	
Republic of Moldova	Law No. 10 on Use of Energy from Renewable Sources, 2016 (entered into force 2018), Decision No. 375, 2017, Decision No. 689, 2018			
	Solar and other technologies (< 1 MW)		1.90 lei (approx. €ct 9.58)	15 years
	Wind (< 4 MW)		1.40 lei (approx. €ct 7.06)	
Montenegro	Energy Law, 2010 (amended in 2015), Tariff System Decree, 2011 (amended in 2014 and 2015)			
	Wind		9.61 ct€	
	Solar up to 1 MW		12.00 ct€	
	Hydro	up to 3 MW	10.44 ct€	
		from 3 up to 5 MW	8.87 ct€	
		from 5 up to 8 MW	8.35 ct€	
		from 8 up to 10 MW	6.80 ct€	12 years
	Biogas up to 10 MW	Biogas	15.00 ct€	
		Waste gas	8.00 ct€	
		Solid waste	9.00 ct€	
	Biomass up to 10 MW	From forestry and agriculture	13.71 ct€	
		From wood-processing industry	12.31 ct€	
Serbia	Energy Law, 2014, Regulation on Incentive Measures, 2010 (amended in 2018)			
	Wind		€ct 9.20	
	Solar	Roof-mounted power plants up to 0.03 MW	€ct 14.60-80*P	
		Roof-mounted power plants 0.03 - 0.5 MW	€ct 12.404 - 6.809*P	12 years
		Ground-mounted power plants	€ct 9	
		Up to 0.2 MW	€ct 12.60	

	Hydro up to 30 MW	0.2 - 0.5 MW		€ct 13.933-6.667* P			
		0.5 - 1 MW		€ct 10.60			
		1 - 10 MW		€ct 10.944-0.344			
		10 - 30 MW		€ct 7.50			
	Geothermal			€ct 8.2			
	Biogas	0-2 MW		€ct 18.333-1.111*P			
		2-5 MW		€ct 16.85 - 0.370*P			
		Over 5 MW		€ct 15			
		landfill and sewage gas		€ct 8.44			
		waste-based		€ct 8.57			
	Biomass	Up to 1 MW		€ct 13.26			
		1 - 10 MW		€ct 13.82-0.56*P			
		Over 10 MW		€ct 8.22			
Ukraine	Electricity Law No. 10183, amended by Law No. 1220-VI in 2009, No. 5485-VI in 2013, No. 514-VIII in 2015 and No. 1804-VIII in 2016						
		Start date		2017	2020	2025	
	Households	Solar (< 30 kW)		3.36	3.02	2.69	
		Wind (< 30 kW)		2.16	1.94	1.73	
	Business entities	Solar		2.79	2.51	2.23	
		Wind	< 600kW	1.08	0.96	0.84	Until 2030
			600kW-2000kW	1.26	1.12	0.98	
			> 2000 kW	1.89	1.68	1.47	
		Hydro	Micro	3.24	2.92	2.59	
			Mini	2.59	2.33	2.07	
			small	1.94	1.75	1.55	
		Biomass and biogas		2.7	1.84	1.61	
		Geothermal		2.79	2.51	2.33	

Source: Own elaboration from IEA (2019), Climatescope (2018) and legal documents of each country.

As can be observed from Table 21, the tariffs are usually awarded for 15 years (Albania, the Republic of Srpska, Georgia and Moldova), and for 12 years (Montenegro, The Federation of Bosnia and Herzegovina, and Serbia). Armenia and Macedonia award FITs for 15 or 20 years, depending on the REs technology. Thus, in Armenia a 20-year FIT applies to wind, solar and biomass plants up to 1 MW, whereas in Macedonia, it applies to wind and hydro power plants of different capacities. Similarly, in Belarus the producers of electricity from all RE sources have the right to use FITs for 20 years, in Kyrgyzstan, the FIT period is only for eight years.

In addition, in Belarus, Kyrgyzstan and Ukraine, the tariff levels are defined by applying a technology specific coefficient to the retail power price, with the highest coefficient being applied to solar energy plants. In the case of Kyrgyzstan, the coefficients apply to the highest price which is set for non-household consumers (industry, agriculture and others). Furthermore, the green tariff rate in Ukraine has an established "minimum floor", which is set each quarter by the National Energy and Utility Regulatory Commission (NEURC) through exchanging the green tariff calculated, as of January 1, 2009, into Euros. It should also be noted that Ukraine establishes different FITs for renewable electricity produced by households and business entities.

The only country that does not have a FIT for solar energy is Azerbaijan. Although there are FITs for wind and small hydro power plants (SHPP), recent years have seen only a small amount of private investment, with the exception of some pilot wind power plants. Furthermore, this mechanism is not extended to other RE technologies (Energy Charter Secretariat, 2013). It should also be highlighted that, although a negotiated 15-year Power Purchase Agreement (PPA) is a major incentive for the development of new renewable power generation in Georgia, the country could possibly move on to another form of incentive by the end of the decade, due to its membership of the EU Energy Community (Climatescope, 2018).

In Albania, the current legal framework for REs support is Law No. 07/2017 on "The Promotion of the Use of Energy from Renewable Sources". This Law also introduced a specific form of FIT called Contracts for Difference (CfD). It is a feed-in premium system that enables RE producers to sell the electricity and receive the difference between the auction and the market price (reference price). According to the Law, the CfD are concluded for a maximum period of 15 years and apply to installations with an installed capacity of more than 2 MW, while smaller RE facilities are entitled to claim a regulated FIT.

Moldova has the most recent FIT policy introduced by the Law on the Promotion of the Use of Energy from Renewable Sources (Law No. 10 of February 26, 2016) which entered into force in 2018. The feed-in tariffs are determined by the National Energy Regulatory Authority (NERA), depending on the power plant type and its capacity, so that the Net Present Value (NPV) of the project, calculated for a period of 15 years, is zero (15 years payback time). A methodology to determine the tariffs was approved by Decision No. 375 of September 28, 2017. The tariffs for small wind installations (up to 4 MW) and small solar and other technologies (up to 1 MW) are awarded on the basis of the "first come, first served" principle. Similarly, in Belarus, the amount of capacity that can qualify in each year is limited by quotas.

Finally, in Bosnia and Herzegovina, in both of the country's two political entities, the guaranteed tariffs are calculated by adding technology-specific premiums to a reference price. The Republic of Srpska also offers a premium for electricity produced from REs, which is either sold directly to the market, or is used for its own consumption. Ukraine also offers a premium to the FIT of 5%, if at least 30% of the equipment is from local sources, and of 10%, if at least 50% is from local sources (Verkhovna Rada of Ukraine, 2015).

3.3.2.2. Net metering.

Net metering is also another of the price-based RE support instruments, referring to a regulated arrangement in which consumers who have installed their own electricity generation systems, pay only for the net electricity delivered from the utility. Generating customers feed excess electricity into the general utility grid consume it later when they need to, and pay only for the net difference.

Therefore, net metering is a system available to encourage consumers of electricity to invest in alternative methods of RE generation, allowing these consumers to inject surplus electricity into the general grid, using it to balance out the deficit, and encouraging them to meet their electricity demand with their own production.

Net metering mechanisms have been implemented by the following counties: Albania, Armenia, Bosnia and Herzegovina, Georgia, Moldova, Montenegro and Ukraine.

In 2017, Albania adopted the new law on RE Sources (RES Law, Art. 15), introducing a net metering scheme for solar and wind installations of less than 500 kW, for private households and small and medium-sized companies. According to the Law, the net balance is calculated on a monthly basis, and excess electricity is remunerated, according to prices approved by the Albanian Energy Regulator Authority (ERE). On the contrary, in Bosnia and Herzegovina, net metering exists, but surplus production is not subject to remuneration.

The Armenian government also supports the residential and commercial solar and other renewables installations, up to 150 kW, through a net metering scheme, which was introduced by amendment to the Armenia Energy Law in 2015, and came into force in June 2016. This allows participants to supply electricity to the network, without any license or additional tax obligations, and reduces their power electricity bills by the amount of electricity they inject, valued at 50% of the retail electricity price.

The Parliament of Georgia approved the regulation for net metering in early 2016, and the scheme is open to solar, wind, biomass, and hydropower generation installations, with a capacity of up to 100 kW. A similar scheme was introduced in Moldova, by Law No. 10 of February 26, 2016, for small systems up to 200 kW, aimed at covering their own electricity consumption.

Finally, a net metering mechanism came into force in Ukraine in April 2015 (Law N◦ 514-VIII). This mechanism can be applied to solar PV installations below a 30 kW capacity. As of the end of September 2018, the total capacity of rooftop PV systems, installed in the country under net metering, has reached 121 MW, as reported by The State Agency on Energy Efficiency and Energy Saving of Ukraine (SAEE). In Montenegro, net metering was also in place for systems up to 50 kW, which promotes small-scale residential solar PV (IRENA, 2017a).

3.3.2.3. Tendering.

Tender mechanisms are quantity-based systems because the legislator fixes a quantity that has to be provided by certain market actors. Tendering systems, also called auctions, are procurement mechanisms by which RE capacity or supply is solicited from electricity producers under a competitive bidding process, offering bids at the lowest price that they would be willing to accept (REN21, 2017a).

Tenders are organized by public authorities for a certain quota of RE capacity or supply, and the winning bids are remunerated at prices usually above standard market levels. Bids may be evaluated on both price and non-price factors, including additional criteria. Thus, tenders are competitive schemes for allocating financial support to REs projects. Depending on the REs tender design, the bids can refer to electricity production or, more usually, to installed capacity. Tenders to promote REs electricity generation can be technology neutral, although these mostly focus on a specific REs technology.

According to the report (IRENA, 2016), the number of countries that adopted tendering (public competitive bidding or auctions) for RE increased from six, in 2005, to more than 67, by early 2017. In line with this trend, RE auctions became an emerging trend in the region. Several Balkan countries, such as Albania, Bosnia and Herzegovina and Montenegro, as well as Armenia and Kazakhstan, issued their first tenders in 2018. Figure 14 shows the RE capacities, by source, awarded through those auctions.

Firstly, of these countries, it may be noted that Kazakhstan issued the largest number of tenders, in terms of the RE installed capacity, aimed at reaching the significant amount of 1 GW. The successful multiple auctions carried out in the country awarded 858 MW capacity, including 270 MW solar, 501 MW wind, 82 MW hydropower, and 5 MW biomass fired generation. Secondly, Montenegro also held its first auction for the construction of a PV project with an installed generation capacity of 250 MW. In addition, Albania, Bosnia and Herzegovina and Armenia awarded contracts to build their first large-scale PV projects, with a total capacity of 100 MW, 65 MW and 55 MW, respectively.

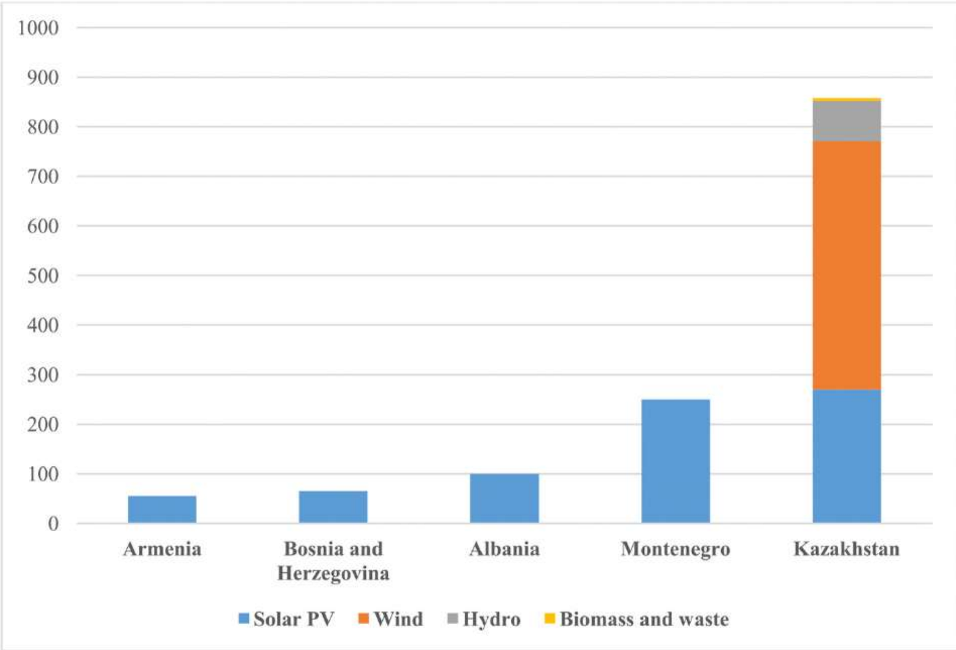


Figure 14. Results of the first auctions in transition economies, 2018.
Source: Own elaboration from IEA (2019), Climatescope (2018), and World Bank (2019).

It is also worth highlighting that, to support the launch of auction mechanisms for large-scale RE projects in South-Eastern Europe, the Energy Community Secretariat and the European Bank for Reconstruction and Development (EBRD) recently released guidelines for transparent, open and predictable RE auctions (EBRD, 2018). Moreover, in recent years, the EBRD, together with the World Bank, have been financing a considerable number of RE projects in all 17 transition economies (REN21, 2017b).

In addition, several countries in the region are on the way to introducing an auction mechanism for large-scale solar and other renewables, to drive down costs. Thus, in 2020, Azerbaijan (EBRD, 2019a) and Uzbekistan (EBRD, 2019c) are to initiate the development and implementation of a competitive (auction) scheme. In 2019, and, potentially, in 2020, the Moldovan government was already in the process of launching RE auctions for on-shore wind and solar PV projects. The auctions are poised to contract 80 MW of wind, 25 MW of PV and 8 MW of biogas. Within this context, the EBRD is providing technical assistance on drafting all the required tendering documentation (EBRD, 2019b). In addition, Serbia plans to draft an auction-based model for RE development by mid-2019, and is preparing to announce its first project tenders in 2020. Similarly, the Ukrainian parliament is in the process of approving amendments to draft Law No. 8449-d, contemplating the introduction of RE auctions within the country.

Finally, in Russia, the auction system, introduced in 2013 by Decree No. 449, is the main support mechanism to promote REs electricity, on the basis of the installed capacity (MW or MW per month) of RE installations (Russian Federation, 2013). This capacity-based approach is significantly different from the schemes established in most countries around the world, where support for renewable electricity is usually linked to the electricity output (MWh) (International Finance Corporation, 2013). The aim of the programme is to secure 5.9 GW of additional renewables capacity by 2024, comprising some 3.6 GW of wind, 1.5 GW of PV and 0.8 GW of small hydro. Those RE projects with a total installed capacity of greater than 5 MW are eligible to tender annually. In addition, the local content requirements (LCRs) are established to enhance local economic development. Table 22 shows the LCRs and the auction results in Russia during 2013–2018.

Table 22. LCRs and auction results in Russia, MW, 2013–2018.

		Wind	Solar	Small hydro	Total	Cumulative total
2013	MW awarded	105	0	399.2	504.2	504.2
2014	LCRs, %	35	50	20		
	MW awarded	51	20.6	505	576.6	1,080.8
2015	LCRs, %	55	50	20		
	MW awarded	35	49.8	280	364.8	1,445.6
2016	LCRs, %	25	70	45		
	MW awarded	610	0	0	610	2,055.6
2017	LCRs, %	40	70	45		
	MW awarded	1,651.1	520	49.8	2,220.9	4,276.5
2018	LCRs, %	55	70	65		
	MW awarded	853.3	148.5	39.7	1,041.5	5,318.0
2019-2024	LCRs, %	65	70	65		

Source: Own elaboration from Energo ATS (2018) and Russian Federation (2013, 2015).

Thus, the lack of interest from project developers in auctions, during 2013–2015, can be explained by the high LCRs. It may be observed that just 1.4 GW (1445 MW) of RE capacity was awarded in three rounds of auctions, held between 2013 and 2015. It is worth noting that, in 2016, the government reduced the wind LCR to 25%, rising to 40% in 2017, 55% for 2018, and 65% for 2019–24 (Decree No 1472-R (Russian Federation, 2015)). In addition, the LCRs for wind projects can now be met through equipment produced by Vestas Manufacturing Rus (Nizhny Novgorod region). Consequently, awarding a total of 2.2 GW and 1.04 GW of wind, solar and small hydro capacities in 2017 and 2018, respectively, auctions showed much better results.

3.3.2.4. Tax incentives.

Tax incentives are economic stimuli providing actors (households, electricity producers) with a reduction in their contribution to the public treasury, in the form of rebates or grants, via income or other taxes. Fiscal rebates may be granted on the amount of electricity produced by RE, or on investment in RE capacity. These mechanisms include excise and property tax exemptions, tax credits, and/or many other similar alternatives.

Tax incentives for RE promotion are used in the following transition economies: Ukraine, Moldova, Belarus and Tajikistan. All of these countries apply exemptions from Value Added Tax (VAT) on the imports of certain RE equipment. Thus, in Moldova, hydro turbines with a capacity up to 1 MW, and electric generators with a capacity from 75 kW to 275 kW, are exempt from VAT. Similarly, in Belarus, equipment and spare parts used for the generation, storage or transmission of electricity from renewables, are exempt from VAT, if the national standards committee approves the equipment. Property bought to develop renewables projects are also exempt from VAT in Belarus. In Tajikistan, hydropower equipment and other projects, classified as "high-priority projects", are VAT exempt. In addition to VAT exemptions, Ukraine and Tajikistan also apply exemptions from customs duties.

Further, Ukraine and Belarus apply a full exemption from income tax. In the case of Ukraine, profits obtained from companies which generate electricity from REs are exempt from corporate income tax (CIT) payments. In addition, there is also a partial CIT exemption (80%

of the profits) for profits obtained from the sale of certain self-produced goods, including equipment powered from REs, materials used in RE production, and energy-saving equipment. In Belarus, RE investors are eligible to deduct the full amount of VAT and income tax, for the seller, paid on the purchase of property rights. In Tajikistan, based on the investment amount, investors are entitled to two to five years of tax holidays on profits that they make from investments made directly in the RE sector.

Ukraine also established a partial exemption of 75% from land tax, while in Belarus, the renewable projects are fully exempt of land tax, or from rent payments, in the case that they are situated on public land. Finally, it should be noted that Ukraine is the only country in the region that has established a carbon tax. Although it entered into force in 2011, the impact on the economy and the environment was negligible, due to its low rate (Frey, 2017). However, in 2018, the environmental tax rate was significantly increased from UAH 0.41 up to UAH 10 per ton, for CO2 emissions of more than 500 tons per year (Tax EY, 2018).

3.4. Overview of the energy measures implemented, and renewables participation in electricity generation, in transition economies.

Table 23 shows a summary of the support policies established in transition economies to promote the use of RE in electricity generation, as well as the main indicators related to the recent use of these REs in these economies.

Firstly, the last row in Table 23 shows the global values for the 17 considered countries. As can be observed, 12 countries apply FITs, seven use net metering to support small-scale renewable projects, six have launched tenders, and four apply tax incentives. Thus, the most used measure is FITs. Nevertheless, a positive trend towards the use of tenders is observed, as this measure was planned in 2018 in five more countries. These measures seem to be beginning to have some positive effects over the latter years studied. Thus, Column 9 in Table 23 shows that the RE capacity increase (without considering hydro), from 2016 to the end of 2018, was 2997 MW. This represents 43% of all installed renewable capacity in 2018.

Table 23. RE support policies and share of REs in electricity generation.

	Feed in tariffs	Net metering	Tendering	Tax incentives	RE participation in generation 2016, (%)	RE participation without hydro in generation 2016, (%)	RE capacity without hydro 2018, (MWh)	RE capacity increase without hydro 2016-18, (MWh)	RE capacity without hydro 2018, (% on total electricity capacity)
Albania	✓	✓	✓		100.00	0.00	2	0	0
Armenia	✓	✓	✓		32.18	0.04	20	17	0.04
Azerbaijan	✓		planning		8.78	1.27	146	91	1.8
Belarus	✓			✓	1.25	0.83	362	205	3.5
Bosnia and Herzegovina	✓	✓	✓		31.88	0.13	78	62	1.7
Georgia	✓	✓			80.68	0.07	21	21	0.3
Kazakhstan			✓		11.24	0.34	331	201	1.5
Kyrgyz Republic	✓				86.67	0	0	0	0
Macedonia, FYR	✓				36.70	2.12	66	5	3.5
Republic of Moldova	✓	✓	planning	✓	4.22	0.32	39	22	1.2
Montenegro	✓	✓	✓		58.68	0	118	118	12.0
Russia			✓		17.43	0.32	2631	579	1.0
Serbia	✓		planning		29.47	0.19	390	375	0.6
Tajikistan				✓	96.52	0	0	0	0
Turkmenistan					0.00	0	0	0	0
Ukraine	✓	✓	planning	✓	6.61	0.96	2722	1294	5.2
Uzbekistan			planning		20.28	0	5	4	0
All 17 countries	**12**	**7**	**6**	**4**	**18.18**	**0.39**	**6934**	**2997**	**1.77**

Source: Own elaboration from IEA (2019), IRENA (2019), Climatescope (2018) and legal documents of each country.

Despite this, electricity generation from renewables remains low. If hydropower is taken into account, in 2016, the percentage of electricity generation by renewables was 18%. If this energy is not taken into account, this percentage drops considerably to 0.39%. Similarly, the percentage is also low when considering the installed capacity of electricity generation by means of RE. Its value at the end of 2018 was only 1.77% of total electricity capacity. This low level can be explained by the lack of investment in the use of RE, before 2015. In fact, as shown in Table 16, in the period from 1995 to 2016, the RE participation in electricity generation decreased by more than one percentage point, which may be associated with the decrease in electricity generated by hydraulic energy.

Secondly, important differences are observed in the data by country. Focusing on the measures taken, Table 23 shows that all countries, except Turkmenistan and Uzbekistan, have adopted at least one policy to promote RE. Both countries are net energy exporters. However, their energy mix and energy policies are different. In Turkmenistan, RE is not used for electricity generation and its promotion remains a low priority in this country, which has quite a closed economy. Consequently, in 2016 the energy intensity of Turkmenistan, coupled with the CO2 emissions in GDP (PPP) terms, were the highest in the region, with the latest being equal to 0.79 kg CO2/2010 USD. On the other hand, Uzbekistan generates electricity mainly by using natural gas power. Thus, the country's energy intensity, as well as the CO2 emissions level, is above the region's average values. Nevertheless, unlike Turkmenistan, the government of Uzbekistan published RE targets in 2017, aiming to reach 1.2 GW of hydro, 450 MW of PV and 300 MW of wind, by 2025, in order to diversify the country's energy mix. In that regard, it has recently launched two 200 MW solar tenders.

Focusing on the installed capacity of electricity, in Column 9 in Table 23, it can be seen that there are seven countries with values very close to zero. Two of them are again Turkmenistan and Uzbekistan. Four of them (Albania, Tajikistan, Kyrgyzstan and Georgia) are countries with a large share of hydropower generation, above 80%, in 2016. Thus, despite the fact that they have adopted some type of measure to promote the use of RE, it has had little impact, as they are sufficiently supported by non-polluting hydraulic energy. Finally, Armenia has not yet achieved relevant levels of RE installed capacity. However, in 2018, it had already increased its solar capacity through the use of the tender of 17 MW. Similarly, it currently continues to launch solar tenders within the plan, announced by the government in 2017, to increase the installed solar capacity by 110 MW in six years.

On the other hand, Table 23 also shows that the countries that have most increased their RE installed capacity are: Ukraine, the Russian Federation and Serbia. In fact, in 2016–2018, these countries added more than 2.2 GW in their RE capacities from non-hydropower resources, representing more than 75% of the 17 countries RE capacity increase (without hydro) during the period. In 2018, Ukraine became the absolute leader, in terms of solar energy in the region, with 2.7 GW of total installed capacity. This fact can be explained by the successful FIT implementation in the case of solar PV plants, where the country guarantees the minimum tariff rates fixed in Euros. Despite the success obtained, Ukraine planned to replace its FITs with an auction system (like many other countries), because it was burdensome for the state budget. Thus, the Auction Law of May 22, 2019 introduced the new support mechanism, which would become operational in 2020. Similarly, the auction system has been the main support mechanism for RE in Russia since 2013. However, until 2017, it had not started to show improved results, when the LCRs for wind energy were reduced. Finally, Serbia had also applied FITs to increase the RE installed capacity. However, as with Ukraine, it is moving to tenders to reduce prices.

It is also worth noting the relevant effort made by Montenegro during the 2016–18 period, with a new RE installed capacity of 118 MW which represents 12.0% of total electricity installed capacity. This important RE installed capacity has been reached through the launch of auctions. It is worth noting the invaluable support of the EBRD.

CHAPTER 4. CONCLUSIONS

4.1. General conclusions.

This doctoral thesis is driven by the need to develop energy policies in transition economies, known for their high energy consumption along with high energy intensity levels. The adequate energy-related strategies are essential to fulfil the commitments under the Paris Agreement in the context of meeting increasing energy demand.

This doctoral thesis contributes to the knowledge on transition economies that can be used in the process of developing the adequate energy-related strategies to reduce CO2 emissions in the region. Firstly, the research project focused specifically on the relationship between CO2 emission, economic growth and residential energy consumption in transition economies. Secondly, the research project is enriched with the analysis of the current state of the renewable energy use for electricity generation in the selected countries.

This last chapter of the doctoral thesis aims to synthesize the most relevant conclusions of the conducted research, based on the previously proposed objectives. These conclusions, grouped into two sections in accordance with the structure of the thesis, are presented below.

In Chapter 2, based on published paper, **Relationship between economic growth and residential energy use in transition economies,** we analyse the relationship between economic growth and energy consumption in the residential sector, in 12 transition economies, by testing the EKC hypothesis. A panel data referring to 12 transition countries during the period from 1995 to 2013 is used. In addition, the estimate results are compared to those obtained when the biofuels and waste consumption is omitted from the total residential energy consumption. DOLS and FGLS, in first differences models, are used in the econometric estimation. Furthermore, from the results of the estimates, the elasticities of both energy consumption measures, with respect to per capita income, are calculated for each country and each year.

The estimate results show that the elasticity of the residential energy consumption, with respect to GDPpc, is positive in the central point of the sample. The estimated results also show that the inverted U shape that confirms the EKC hypothesis for the residential sector in transition countries is not supported, when the GDPpc cubic term is not included. Nevertheless, as the cubic GDPpc coefficient is negative in the cubic function specification, the results are compatible with the EKC. However, the calculated elasticity values of RECpc and RECLBpc, with respect to GDPpc, show that the turning point has not been reached, although the GDPpc value in 2013 for Russia is close to it. The results also show that the calculated elasticity values, with respect to GDPpc, are negative for low GDPpc values, meaning that for countries with low-income levels the economic growth has been allowing residential energy consumption reductions, which may be associated with efficiency gains. Nevertheless, for countries with higher GDPpc values, the economic growth has been increasing the residential energy consumption. Finally, the results show that the elasticity values are not constant over time and there are significant differences among countries. However, positive elasticities could be expected for all studied countries, except for Russia which is close to decoupling residential energy use and growth.

Therefore, in the light of the results obtained, two types of recommendations can be made to reduce environmental problems. In the first place, it may be appropriate to establish energy efficiency measures in households and buildings. As most of the transition countries have notable energy saving potential in district heating sectors, it may be recommendable to promote initiatives to improve the efficiency of district heating systems, such as requiring the system operator to perform system upgrades, increase tariffs and remove subsidies. Despite this, it could be appropriate to apply some effective compensatory schemes for the most vulnerable. In the second place, it may be appropriate to promote the use of renewable energies which could reduce the residential energy dependence problems observed in some countries while increasing less pollutant energy consumption. This could be especially relevant for distant rural areas with limited access to the grid.

Nevertheless, the significant differences make it recommendable to adapt the energy policy to each country. In the case of Belarus, the most important task is to reduce the energy dependence, with bioenergies being the most important renewable energy sources for future energy supply. In the case of the Balkan countries, the shift from coal to cleaner and more efficient energies is a main challenge. In this regard, the use of renewable energies could be a solution in the residential sector, either through the direct use of renewable energy sources, or through increasing electricity generated from hydroelectric power. In the case of the Caucasus countries, it could be recommendable to promote measures to implement more efficient practices for electricity production and heating. In addition, for those countries with lower GDPpc, it could be appropriate to promote growth and implement some regulatory schemes related to new buildings. Finally, the Russian Federation represents a special case, with its elasticity trend markedly decreasing in recent years, which may be related to investments in energy saving technology and the implementation of some initiatives to improve efficiency of district heating systems. However, much remains to be done, as this efficiency is still relatively low, compared with other European countries.

In Chapter 3, based on published paper, **Renewable energy use for electricity generation in transition economies: evolution, targets and promotion policies,** we analyse the RE use for electricity generation, from 1995 to 2016, the newly added RE installed capacities, from 2015 to the end of 2018, and the RE policies and measures established for RE deployment in 17 transition economies.

The conducted research has revealed a number of important insights that can be used to improve and/ or adjust the current RE policies and measures in transition economies in the future. Firstly, there are several main findings regarding the evolution of the RE use for electricity generation and the RE installed capacities in these countries, during the period. While the average electricity consumption per capita, as well as the average electricity production, increased over the analysed period, the average share of RE in electricity generation decreased across all countries. In addition, at the end of 2016, the RE share accounted for 18.18% in electricity generation and significant differences between the countries are observed. In terms of RE sources, hydropower generated the largest share of electricity in the region, while the participation of solar, wind, geothermal, biofuel and waste energy, remained quite low, accounting for only 0.39% of electricity generation at the end of 2016. In this sense, it is important to notice that, since 2015, the 17 transition countries have been increasing their RE installed capacity to generate electricity. As a result, from 2016 to the end of 2018, the RE capacity increase (without considering hydro) represented 43% of all installed renewable capacity in 2018.

Secondly, several main findings, related to the RE regulation in the studied transition economies, are obtained. Thus, all transition economies, except Georgia and Turkmenistan, have national strategies which outline RE targets. FITs are the mechanism most used to promote RE for electricity generation and are currently in force in twelve countries: Albania, Armenia, Azerbaijan, Belarus, Bosnia and Herzegovina, Georgia, Kyrgyzstan, Macedonia, Republic of Moldova, Montenegro, Serbia and Ukraine. The second most used mechanism is net metering, which had been introduced in seven countries: Albania, Armenia, Bosnia and Herzegovina, Georgia, Moldova, Montenegro and Ukraine. Tendering is spreading rapidly within the region, often replacing FITs, with the aim of driving down renewable electricity costs. Six countries had already held their first auctions in 2018 (Albania, Armenia, Bosnia and Herzegovina, Kazakhstan, Montenegro and the Russian Federation), and another five (Azerbaijan, Uzbekistan, Moldova, Serbia and Ukraine) have worked on the introduction of an auction system during 2019–20. Finally, tax incentives are also in place in Ukraine, Moldova, Belarus and Tajikistan.

Thirdly, in terms of the differences observed between the countries within the measures applied and installed capacity improvements, the findings of the research are the following. All countries, except Turkmenistan and Uzbekistan, have adopted at least one policy to promote RE. In Turkmenistan, RE promotion remains a low priority, while in Uzbekistan, solar tenders have recently been launched. Seven countries present RE installed capacity values close to zero: Turkmenistan and Uzbekistan (as before), Albania, Tajikistan, Kyrgyzstan and Georgia (with a large share of hydropower generation), and Armenia (which has recently worked on tenders). The countries which have achieved the highest increases in their RE installed capacity are Ukraine, the Russian Federation and Serbia, representing more than 75% of the RE capacity increase (without hydro) of the 17 countries, during the period. Ukraine and Serbia have achieved these records, by means of FITs, and the Russian Federation, by means of tendering systems. However, both Ukraine and Serbia are moving to tenders to reduce the budgetary expenses that the FIT measure involves. Montenegro has made an important effort in RE installed capacity, reaching 12.0% of total electricity installed capacity, by means of the tendering system.

To summarize, the recent measures adopted to promote RE use for electricity generation in these countries, seems to be having a positive impact on the use of nonconventional REs, although the rise in levels remains low.

Based on the previous conclusions derived from the research conducted in Chapter 2 and Chapter 3, we can consider the following insights on the current situation of energy consumption in economies in transition.

To achieve significant reductions in CO2 emissions, further energy transition to a low-carbon alternatives is required in most countries of the region. In this sense, transition economies should pay special attention to the main pillars of deep decarbonization: energy efficiency and renewable energy. On the one hand, the countries must continue working on improving energy efficiency, especially in households and buildings. For that, it is essential to design and build new buildings that would be of the highest efficiency. In addition, since buildings tend to have quite long lifespans, it is also important to accelerate energy efficiency improvements of the existing ones through the renovation and upgrades. On the other hand, further reduction of carbon intensity by shifting towards a larger use of clean energy is necessary. The latter can be accomplished not only by the direct use of renewable energy, but also through increasing electricity generated from it. This is especially relevant taking into account the untapped potential of non-conventional renewable energy sources in the region.

However, a comprehensive transition to low-carbon energy would require substantial structural changes in most transition economies, which are challenging at different levels. First of all, the political aspect has to be mentioned. Such a complex process as decarbonization of the economies will only be feasible when it becomes a priority in the region. However, it is evident that economies dependent on fossil fuel will be negatively impacted from the green transition, at least in a short-term perspective. Therefore, it is essential to find a way to adapt the existing fossil fuel infrastructure through new business models and innovation. Secondly, the transformation should be compatible with ensuring economic growth and raising living standards. In other words, a balance in the process of achieving these objectives must be found. In order to do that, the countries have to develop appropriate economic and energy strategies that would take into account different scenario possibilities. Thirdly, to be able to move towards a diversified energy and electricity mix, economies in transition need to have access to a combination of things: investment and clean technologies. In this sense, international cooperation in terms of technical and financial support is fundamental in order to facilitate this transition in the region.

Moreover, while the countries of the region share some common challenges, significant differences in their economic level and energy use have been identified. Therefore, the energy policies and renewable energy related strategies should be adapted in accordance with the special characteristics and circumstances of each country.

Nevertheless, despite all the difficulties mentioned above, the energy transition can be beneficial for the selected countries. It can not only provide additional development opportunities for their economies, but also improve energy security and reduce local air pollution. Thus, all the efforts to change the existing energy system will be rewarded in a long-term perspective.

4.2. Further research studies.

In Chapter 1 of this doctoral thesis, we have mentioned that the economies in transition have not been extensively studied in the field of energy economics, as some other regions. In order to increase the knowledge on transition economies, we want to propose the following future research suggestions in terms of CO2 emission, energy consumption and renewable energy:

Firstly, it could be of a special interest to analyse and identify common drivers of CO2 emissions in transition economies in the last decades, especially in the context of achieving the goals under the Paris Agreement.

In addition, future studies could examine the relationship between economic growth and residential energy consumption in the Republic of Macedonia, Montenegro, Kazakhstan, Kyrgyzstan and Turkmenistan. An additional country-specific analysis is relevant since these countries were excluded from the study in Chapter 2 due to the unavailability of some data at the time of research.

It is also recommended for future research studies to focus on the analysis of energy consumption in transition economies by other sectors, such as transportation and industry. In addition, the measures to promote the use of renewable energy sources should be reviewed.

Finally, another interesting approach could be conducting an in-depth analysis of the region, focusing individually on each renewable energy source, and providing a detailed review of its potential, evolution and deployment. In this sense, future studies could carry out a country-specific or multi-country analysis of the development of non-conventional renewable sources, such as solar, wind, biomass and small hydropower, taking into consideration socio-political and technical aspects of it.

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INDEX OF FIGURES

INDEX OF TABLES