Renewable Energy 106 (2017) 298–309

Contents lists available at ScienceDirect

Renewable Energy

journal homepage: www.elsevier.com/locate/renene

The European Union possibilities to achieve targets of Europe 2020 and Paris agreement climate policy

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ARTICLE INFO

Article history:
Received 1 December 2015
Received in revised form
29 November 2016
Accepted 17 January 2017

Keywords:
Greenhouse gas emissions
Renewable energy resources
Energy consumption
Europe 2020 strategy
Paris agreement

ABSTRACT

The Europe 2020 strategy and recently ratified Paris agreement are the main documents in the European Union (EU) involving energy and climate policy. Therefore, the aim of this paper is to reveal the possibilities of EU countries to achieve the Europe 2020 strategy and Paris agreement targets. Referring to the regression analysis, the results showed that the growth of economy and primary energy consumption stimulate GHG emissions in EU-28; meanwhile, the increase of RES share decreased them. Moreover, the paper revealed that if the EU will achieve its targets committed in the Europe 2020 strategy, even assuming fast economic growth, the target to reduce GHG emission by 20% by 2020 compared to 1990 will be achieved. According to different tendencies of economic growth, energy consumption and share of RES changes, the results showed that only recent (2005–2012) tendencies are the most suitable for the implementation of GHG emissions targets of Europe 2020 strategy but not of the Paris agreement. Therefore, the EU countries should attempt more to reduce energy consumption and to increase the share of RES seeking to implement the target of GHG emissions committed in Paris agreement.

1. Introduction

The European Union (EU) as a whole is one of the biggest energy consumers and the one of the largest greenhouse gas (GHG) emitters in the world [23,25]. Thus, the energy and climate policy is one of the cornerstones of EU policy [63]. The EU energy and climate goals have been incorporated into the Europe 2020 Strategy for smart, sustainable and inclusive growth [16], and into its flagship initiative of Resource Efficient Europe [3,15,55]. Thereby, the EU has set overarching targets of GHG emissions reduction to be achieved by the year 2020 through a combination of energy efficiency and the use of renewable energy resources (RES). Further, in the Paris agreement formally ratified by the EU on 5thof October 2016, the EU and its Member States governments agreed on a long-term goal of keeping the increase in global average temperature to well below 2 °C compared to pre-industrial levels and binding target to decrease GHG emissions by 2030 at least by 40% compared to 1990.

A number of studies applying different forecast methods analysed how successfully the EU will achieve the Europe 2020 strategy targets concerning the climate and energy policy. The EEA [18], Picazo-Tadeo et al. [50], Roelfsema et al. [52], Saikku et al. [53], Gulbe [27], Simoes et al. [57], Streimekiene and Roos [61] analysed how successfully EU countries will achieve the GHG emissions targets, Smit et al. [59] and Thollander et al. [62] – primary energy consumption targets, Boie et al. [6], Nagy and Körmendi [47], Klessmann et al. [38], Giacomarra and Bono [26], EC [16], Śmiech and Papiež [58], and Scarlat et al. [55] – the targets of RES. Thus, our study enriches research in this field as we will analyse how EU-28 and separate EU countries will achieve their GHG emissions, primary energy and RES targets according to their past experience. Furthermore, in this study we will analyse the possibility to achieve the GHG emissions target which the EU committed in Paris agreement and to the best of our knowledge we are the first to analyse this possibility.

For implementation of climate policy it is very important to analyse the determinants of GHG emissions. Thus a number of studies (see Refs. [9,23,34,43,57] and etc.) analysed the factors affecting GHG emission in EU countries. However, there is the lack of analysis encompassing the impact of the Europe 2020 targets on GHG emissions. In our previous study [40], applying decomposition method, we analysed determinants of GHG emissions involving the

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http://dx.doi.org/10.1016/j.renene.2017.01.036
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Europe 2020 strategy components. Therefore, in this paper we expanded the research applying regression models (using first difference (FD), fixed effects (FE) and random effects (RE) estimations) to panel data to reveal how the primary energy consumption, the share of RES and economic growth influence changes in GHG emissions in EU-28 countries. Moreover, applying the results of regression analysis we will model how successfully EU-28 will achieve the targets of Europe 2020 and Paris agreement of GHG emissions according to the past trends of determining factors and according to EU-28 commitments of primary energy consumption and usage of RES.

Thus, the rest of the paper proceeds as follows: Section 2 presents the literature review of the determinants of GHG emissions, and the performed forecasts; the methods of paper are described in Section 3; Section 4 discusses the predicted results to achieve the energy and climate policy targets (primary energy, share of RES, and GHG emissions) in EU-28 and separate EU countries considering the strategy of Europe 2020, also, according to the regression analysis, the following results are presented: i) main determinants of GHG emissions in EU-28 countries and ii) modelling of EU-28 possibilities to achieve climate targets of the Europe 2020 and Paris agreement; Finally, Section 5 closes the paper with the main conclusions.

2. Literature review

2.1. Europe 2020 strategy, Paris agreement and the achievement forecast of climate and energy policy targets

The Europe 2020 is the umbrella strategy of the EU aiming at enhancing the economic growth of EU over the year 2010–2020 [35]. The Europe 2020 strategy is an economic ten-year strategy adopted by the European Council in 2010, "emphasises smart, sustainable and inclusive growth as a way to overcome the structural weaknesses in Europe's economy, improve its competitiveness and productivity and underpin a sustainable social market economy" [3,16]. This strategy involved energy and climate policy including the so called 20/20/20 targets, namely reduction of greenhouse gas emissions (by 20%), the increase of RES share (to 20%) and the increase of energy efficiency, thus, saving up to 20% in the energy consumption [15].

Further at the Paris climate conference in December 2015, 195 countries adopted the first-ever universal, legally binding global climate deal. The agreement sets out a global action plan to put the world on track to avoid dangerous climate change by limiting global warming to well below 2 °C. The Paris Agreement encompasses today's policies and climate-neutrality before the end of the century. The EU was the first major economy to submit its intended contribution to the new agreement and binding target of at least 40% of domestic reduction in GHG emissions by 2030 compared to 1990, when the EU formally ratified the Paris Agreement, thus enabling its entry into force on 4 November 2016.

2.1.1. Achievements of GHG emissions targets

A vast number of authors analysed how successfully EU countries will achieve the energy and climate policy targets of Europe 2020 strategy. Taking into account the GHG emissions, the EEA [18] and Picazo-Tadeo et al. [50] forecasted that in 2020 emissions (outside the EU Emissions Trading System) in most of EU members will be lower than their national targets set under the EU Climate and Energy Package. Moreover, Saikku et al. [53] testing the feasibility of meeting the targets of GHG emissions revealed that dematerialization and decarbonization did occur, but not enough to offset the slight growth of population plus rapidly increasing affluence in the period of 1993–2004. Therefore, they declared that if GHG emissions in EU27 are to be reduced by 20% below the 1990 level, this will happen in 2008–2020, because in 1990–2007 the emissions did not change much. Roelfsema et al. [52] also analysed whether the most effective policies of national climate and energy are sufficient to meet the proposals of emission reduction that countries made for 2020. Thus, they revealed that currently planned policies would not be sufficient to meet the conditional pledge of 30% reduction below the 1990 level in 2020. Therefore, to deliver the conditional target of 30%, the EU would need to develop and implement additional policies and measures beyond the policies currently planned by Member States. Meanwhile, Streimekiene and Roos [61] revealed that GHG emission projections, according to "with measures" scenario, the Baltic States will be able to implement their target when some circumstances of energy sector in the Baltic States are taken into account. Meanwhile, the medium-term targets of GHG emission which were presented in the Paris agreement to the best of our knowledge was not analysed. Therefore, in this paper we will fill this gap.

The long-term targets of GHG emission were presented in 2011. The European Commission presented the 'Roadmap for moving to a low-carbon economy in 2050' [21]. This Roadmap aims at a reduction of greenhouse gas emissions in the EU-27 by at least 80% in 2050 comparing with1990. The forecasts and different scenarios of achievements of long-term targets were presented by other authors (see: [11,30–32,43].

2.1.2. Target achievements of primary energy consumption

Taking into account the targets of energy consumption, Fernández González et al. [24] revealed that in the EU-27 as a whole, the efforts through energy actions and programmes to increase energy efficiency were not sufficient in order to reduce aggregate energy consumption. They found that at the country level, aggregate energy consumption increased in most of them, particularly in Eastern and Central countries, Spain, Ireland and Greece, meanwhile only a few Western countries (Belgium, France, Germany, and the Netherlands) reported reductions in energy consumption. Smit et al. [59] found that the EU as a whole in 2020 will achieve primary energy saving by 16.4%, meanwhile only Slovakia, Latvia, Italy, Greece, Portugal, Spain, Ireland, Bulgaria, and Lithuania will exceed the targets of primary energy saving in 2020. Moreover, Thollander et al. [62] analysed the possibilities of achievement of Europe 2020 primary energy target in Sweden and found that if the Europe 2020 primary energy target is to be achieved, it will lead to significant changes in energy supply and energy end-use in Sweden. Furthermore, EEA [19] in report stated "considering the progress across EU Member States towards Europe 2020 strategy, the progress on energy efficiency remains slow".

2.1.3. Achievements of RES targets

The EU has implemented mandatory renewable energy targets [32]. Thereby, a number of authors (see [6,13,29,55]) declared that the RES has increased considerably in the EU and it is expected to keep growing in the future years. Thus, according to Klessmann et al. [38]; 15 Member States of EU are even planning to overachieve their national RES 2020 target. They also found that the majority of Member States are on track to achieve the RES targets of 2020. Moreover, Giacomarra and Bono [26] found that indeed, almost half of the Member States (Austria, Bulgaria, Czech Republic, Denmark, Germany, Greece, Spain, France, Lithuania, Malta, Netherlands, Slovenia and Sweden) planned to exceed their own targets and were able to provide surpluses for other Member States. Thus, if all these production forecasts are fulfilled, the overall share of RES in the EU could exceed the 20% target in 2020 COM [12]. The Ecofys [17], Śmiech and Papiež [58] and Scarlat et al. [55], also concluded that the future progress for 2020 would allow the EU Member

States to reach their 2020 targets.

2.2. The determinants of GHG emissions concerning the Europe 2020 strategy

A vast number of studies analysed the main determinant of GHG emissions. However, none of them have analysed the main factors of GHG emissions taking into account the Europe 2020 strategy, which has set overarching targets of GHG emissions reduction to be achieved by the year 2020 through a combination of energy consumption (or energy efficiency) and use of renewable energy resources.

2.2.1. The energy consumption impact on GHG emissions

Taking into account energy consumption, the authors (see [1,2,44]) stated that the climate change and fossil fuel markets are interrelated. Antanasijevic et al. [1] revealed that in 1990, the energy-related activities remain the major source of GHG emissions, reaching the share of almost 80% of all GHG emissions within the EU. Wu et al. [66] confirmed that in generally two thirds of greenhouse gas come from fossil energy-related GHG emissions and these emissions will increase with the increasing energy consumption. Therefore, the first step to reduce the GHG emissions is to reduce the energy consumption, or to increase the efficiency in energy use [11,20,28,41,46,48,53,56,60].

Picazo-Tadeo et al. [50] stated that it is easier to implement the improvement of energy efficiency than more drastic measures restricting the level of economic activity seeking for the targets of GHG emissions. Streimekiene et al. [60] confirmed that energy efficiency is the most cost effective way to reduce emissions, improve energy security and competitiveness, make energy consumption more affordable for consumers, as well as to create employment in export industries. Thus, the energy efficiency is essential to attenuate the impact from global warming [5,28,46,56,60]. However, Fernández González at al. (2014b) stated that improvement of energy efficiency is not enough to offset the joint influence of growing overall activities, whereas the actual impact of increased energy efficiency on total energy use and GHG emissions is uncertain due to the phenomenon of 'rebound' effects [4,54,64]. Therefore, it is more important to reduce the energy consumption rather than to increase the energy efficiency.

2.2.2. The RES impact on GHG emissions

The RES is another main determinant of GHG emissions [5,11,20,29,37,57]. Bölük and Mert [7] and López-Menéndez et al. [42] found that renewable energy consumption significantly lowers GHG emissions in the EU. Bölük and Mert [7] estimated that RES consumption lowers GHG emissions around ½ comparing with fossil energy consumption. Moreover, the increase of RES is mostly concerned with decarbonization process [49]. Therefore, the shift in the energy mix towards less polluting energies (renewable energy technologies) could be very important in achieving climate policy targets. Since the inputs of finite energy resources and the GHG emissions are considerably low compared to the conventional energy sources in renewable energy chain, intensified use of RES is the main task seeking for reduction of GHG emissions [7,60]. Thus, Tol [63] declared that promoting renewables is a second-best policy, and its costs are higher.

2.2.3. The impact of economic growth on GHG emissions

According to the Europe 2020 strategy, which aims at enhancing the EU economic growth, it is very important to consider GDP growth impact on GHG emissions. Kim and Kim [36] revealed that the change of economic activity is the dominant contributor to the growth of GHG emissions. The higher the development of the economy, the more energy is required and also more GHG emissions are expected [41]. It is particularly inherent in the developing countries [36,66,67]. Meanwhile, in mature EU countries, due to technologies and economic structural changes, Environmental Kuznets Curve occurs (EKC) [14,22,51,64]. However, taking into account the EU countries Bölük and Mert [7] during the period of 1990–2008 found no statistical evidence of the existence of the EKC for GHG emissions in 16 EU countries. Meanwhile, in the period of 1960–2011, Waslekar (2014) [65] covered that EKC occurred only in Sweden and Germany. López-Menéndez et al. [42] found the decreasing EKC pattern in Austria, Belgium, Finland, France, Germany, Italy, Netherlands, Sweden, and the United Kingdom in the period of 1996–2010.

In general, Bölük and Mert [7] stated that economic development itself ultimately would not lead to the reduction of emissions in the European Union. Fernández González et al. [25] and Saikku et al. [53] confirmed that in the whole EU the inertia of European economic growth affected GHG emissions. However, some studies (see [33,39]) declared that in the EU countries, particularly in the old EU members, the GDP growth is decreasing. Nevertheless, Markandya et al. [43] indicated that lower global growth in GDP does not make it particularly easier to achieve the GHG emissions targets.

3. Methods and data

3.1. The forecasts of GHG emissions, primary energy consumption, and share of RES considering past experience

In this paper we analysed the possibilities of the EU-28 as a whole and separate Member States to achieve energy and climate policy targets included in the Europe 2020 strategy and Paris agreement. How countries will achieve their targets of GHG emissions, primary energy consumption and the share of the RES we took into consideration three trends of past experience: 1990–2012 – which reveals the changes in variables during all period, and the initial level is concerned with the commitments of Europe 2020 strategy, to achieve the targets in 2020 compared to 1990 (*long period*); the period of 2000–2012 – covers the changes in variables during all economic cycle, when economic growth, decline and recovery are included (*inter-medium period*); the period of 2005–2012 is analysed because of the base level for comparison of GHG emission commitments for 2020 compared to 2005 (*short period*).

Therefore, the analysis starts with naive approach by applying the statistical technique of trend estimation to aid interpretation of data. Variables of GHG emissions, primary energy consumption, and share of RES in separate EU28 countries are treated as a time series and trend estimation is used to make and justify statements about tendencies in the data, by relating the measurements to the times when they occurred. This model is used to describe the behaviour of the observed data and, in particular, useful to determine if GHG emissions, primary energy consumption, and share of RES exhibit an increasing or decreasing trend which is statistically distinguished from random behaviour. The linear model for trend estimation that has the general form was used:

$$y_{ti} = \beta_0 + \beta_1 t + u_t \quad (1)$$

where y_{ti} is observed GHG emissions (CO_2 equivalent in thousand of tones), primary energy consumption (million tonnes of oil equivalent) and share of RES (% of total final energy consumption) values in each year t (during whole analysed long, inter-medium and short periods) for a country i.For estimation of β_1 (it represents estimated average annual absolute change in y_{ti}) we used the most common procedure of least squares. Estimated trend model was used for extrapolating the observed values of GHG emissions, primary energy consumption and share of RES for each EU member state till 2020 (2030) in three scenarios: i) tendencies till 2020 (2030) will stay the same like those on average during long period (1990–2012); ii), tendencies till 2020 (2030) will stay the same like those on average during inter-medium period (2000–2012), and iii) tendencies till 2020 (2030)will stay the same like those on average during short period (2005–2012). Having these forecasted values for each country and EU-28 as a whole in three scenarios we compare them with target values and calculate the rate at which these targets are exceeded or failed to reach.

3.2. The evaluation of determinants of changes in GHG emissions

Our goal is to evaluate what impact on GHG emission have Europe 2020 targets – economic growth, efficiency of energy use while decreasing its consumption, and more intensive use of renewable energy resources. In order to do that, we will apply the first difference, fixed and random effect regression models to 28 EU Member States data from 1990 to 2012 (panel data 28 × 23). Different approaches of analysing panel data have their own advantages and disadvantages. One of the ways to use panel data is to view that unobserved factors (in our case unobserved heterogeneity of EU Member States) affecting the dependent variable (in our case GHG emissions) are constant over time (climate, endowment of natural energy resources). Many other factors may not be exactly constant, but they might be roughly constant over a 23 years period – society's attitude towards climate change, industry structure, and the rates of population growth. In order to produce a consistent estimator which represents the impact of factors on GHG emissions, we would have to assume that the unobserved effects of EU Member States are uncorrelated with these factors. But this is not the case, constant factors which influence GHG emissions at the same time correlate with economic growth, energy consumption level, and share of renewable energy resources in energy balance. The resulting bias can be eliminated differencing the data across time and as unobserved effects are constant over time they will be "differenced away." Equation (2), which we call the first-differenced equation, is:

$$\Delta\ln(CO_{2\ i,t}) = \alpha + \delta_3 1992_t + \ \dots\ + \delta_{23}2012_t + \beta_1\cdot\Delta\ln(GDPpc_{i,t}) + \beta_2\cdot\Delta\ln(PRIM\_EN_{i,t}) + \beta_3\cdot\Delta RENsh_{i,t} + \Delta u_{i,t} \tag{2}$$

where.

$CO_{2i,t}$ – is GHG emissions (CO_2 equivalent in thousands of tons) in a country i in year t. $\Delta\ln(CO_{2i,t})$ - approximates annual percentage change in GHG emissions.

$GDPpc_{i,t}$ – gross domestic product per capita in purchasing power parity (constant 2005 international $) in a country i in year t. $\Delta\ln(GDPpc_{i,t})$ – approximates annual rate of economic growth.

$RENsh_{i,t}$ – share of renewable energy resources (% of total final energy consumption) in a country i in year t.

$1992_t, \dots, 2012_t$ – year dummy variables. Allowing the intercept (α) to change over time is important in our analysis. Secular trends in the EU will cause GHG emission rates in all Member States to change ($\delta_3, \dots, \delta_{23}$) perhaps markedly, over a year.

β_1 and β_2 are interpreted as coefficients of elasticity and respectively represent the impact of economic and primary energy consumption growth on GHG emission growth.

β_3 after multiplying by 100% is interpreted as an impact of one percentage point increase of renewable resources in total energy balance share on GHG emissions growth.

$\Delta u_{i,t}$ – idiosyncratic error or time-varying error. We must assume that this error is uncorrelated over time for the usual standard errors and test statistics to be valid. This assumption will be tested in such way – if u_{it} follows a stable AR(1) model, then $\Delta u_{i,t}$ will be serially correlated. Only when u_{it} follows a random walk $\Delta u_{i,t}$ will be serially uncorrelated. If there is no serial correlation in the errors, the usual methods for dealing with heteroscedasticity are valid. We can use the Breusch-Pagan and White tests for heteroscedasticity, and we can also compute robust standard errors.

i – denotes cross-sectional observation number (28 EU Member States)

t – denotes time period (23 time periods prom 1992 to 2012).

Fixed effects (FE) estimator, which, like first differencing, uses a transformation to remove the unobserved effect prior to estimation. First differencing is just one way to eliminate fixed effects. An alternative method uses time-demeaned data. Within transformation removes any time constant effect along with time constant unobserved effects. In our analysis we will use a traditional view of the fixed effects model and assume that the unobserved EU member state effect is a parameter to be estimated for each member state. Thus, in Equation (3), $ms_i$is the intercept for member state i that is to be estimated for all except one country (benchmark country):

$$\ln(CO_{2\ i,t}) = \alpha + \delta_2 1991_t + \ \dots\ + \delta_{23}2012_t + \beta_1\cdot\ln(GDPpc_{i,t}) + \beta_2\cdot\ln(PRIM\_EN_{i,t}) + \beta_3\cdot\Delta RENsh_{i,t} + \sum_{i=2}^{28} ms_i v_{i,t} \tag{3}$$

We will use dummy variable regression method to estimate this equation. The way we estimate an intercept for each member state is to put in a dummy variable for each cross-sectional observation except one (in our case for all EU member states except one), along with the explanatory variables and dummy variables for each time period except the first one.

When T is large, and especially when n is not very large (as in our case, $n = 28$ and $T = 23$), we exercise caution in using the fixed effects estimators because they are extremely sensitive to violations of the classical fixed effects assumptions when n is small and T is large. In particular, we use unit root processes and this leads to spurious regression problem. In this case, using differences is favourable. On the other hand, FE turns out to be less sensitive to violation of the strict exogeneity assumption, especially with large T. When the processes are weakly dependent over time and T is large, the bias in the FE estimator can be small. It is more difficult to choose between FE and FD when they give substantively different results. It makes sense to report both sets of results.

The ideal random effects assumptions include all of the fixed effects assumptions plus the additional requirement that unobserved EU member state effects are independent of all explanatory variables (economic growth, energy consumption, and share of renewable energy resources) in all time periods (1990–2012). But such an assumption is very hard to ground in our case. We think that unobserved effects are correlated with explanatory variables and we will be using first differencing or fixed effects model in first place. Our model with random effects is as follows:

$$\ln(CO_{2\ i,t}) = \alpha + \delta_2 1991_t + \ \ldots\ + \delta_{23} 2012_t + \beta_1 \cdot \ln(GDPpc_{i,t}) + \beta_2 \cdot \ln(PRIM\_EN_{i,t}) + \beta_3 \cdot \Delta RENsh_{i,t} + e_{i,t} \quad (4)$$

Advantage of this model is that Generalized Least Squares (GLS) can be used to solve the serial correlation problem here. GLS transformation that eliminates serial correlation in the error involves quasi-demeaned data on each variable. When fixed effect estimator subtracts the time averages from the corresponding variable, random effects transformation subtracts a fraction of that time average. In order to have good properties in the procedure, it must have large *n* and relatively small *T*. And because that is not the case in our analysis we will use all three methods for estimating impact of economic growth, energy consumption, and share of renewable energy resources on GHG emissions and use them all for modelling EU28 GHG emissions for 2020and 2030 under various scenarios in order to get more accurate results.

3.3. The modelling of EU-28 possibilities to achieve climate targets of the Europe 2020 and Paris agreement

The results of regression analysis will be applied in order to model how successfully EU-28 will achieve the target of GHG emissions: according to EU-28 commitments to reduce till 2020 primary energy consumptions by 20% compared to 1990 and increase share of RES to 20% of gross final energy consumption and making three assumptions regarding growth of the EU economy: (1) that the EU economy till 2020 (2030) will grow at an average rate such as that grew from 1990 to 2012; (2) as from 2000 to 2012; and (3) as from 2005 to 2012; if factors determining GHG emission will change during the period of 2012–2020 (2012–2030), the same like on average during three past periods: long, inter-medium and short. These extrapolated changes of factors affecting GHG emissions under different periods of estimated past tendencies is presented in Table 1.

The data of primary energy consumption, GHG emissions are taken from the Eurostat, the share of RES (% of total final energy consumption) – from World Bank database. In order to evaluate the impact of economic growth on GHG emissions, the GDP per capita PPP (constant 2005 international $) instead of market exchange rate was used. The data of GDP was used from World Bank database as well.

4. Results and discussion

4.1. Forecasts of GHG emissions, primary energy consumption and the share of the RES in the EU countries considering Europe 2020 strategy

Uneven efficiency of the climate policy of EU member states determined different changes of GHG emissions at country level. Moreover, in separate periods we observe different changes in levels of GHG emissions. During a long period (1990–2012), in Austria, Cyprus, Greece, Ireland, Malta, Portugal, Slovenia, and Spain, average annual growth of GHG emissions was observed. In the rest of EU countries, emissions decreased, however, the smallest average of annual decrease was in Belgium, Denmark, Finland, France, Italy, the Netherlands, Sweden, the United Kingdom, and in EU-28 as a whole. The highest annual decrease of GHG emissions during the same period was in Bulgaria, Romania, and three Baltic States (see Fig. 1). It was mostly related to the fact that post-Soviet countries due to the collapse of Soviet Union experienced shrink of economy in the transition period (1990–1995) and huge decline of GHG emissions as result of that [8,53].

In the period of 2000–2012, when economic growth was at its highest annual rates, increase (in terms of average annual rate) of GHG emissions was observed in Bulgaria, Estonia, Latvia, Lithuania, Luxemburg, Malta, and Poland. In other countries, GHG emissions decreased. In the short period (2005–2012), GHG emissions increased only in Estonia and Malta. Comparing all analysed periods, the highest annual decrease of GHG emissions in all EU countries (except Malta, Estonia, Bulgaria, Czech Republic, Germany, Lithuania, Latvia, Poland, and Romania) was during 2005–2012 (Fig. 1) and it reveals that in this period the implementation of climate policy and Kyoto protocol had a success in the EU.

Forecasts how a separate EU country will achieve its Europe 2020 strategy targets concerning GHG emissions shows (see Table 2) that if till 2020 tendencies of GHG emissions will be like these we had on average during the period of 1990–2012 just half of the EU countries will achieve their targets. If we take into account, while forecasting, more recent tendencies, like these in regard to 2000–2012, the commitment of GHG emissions will not be achievable for Estonia, Cyprus, Luxemburg, Malta, the Netherlands, Austria, and Finland. If the further changes of GHG emissions occur as on average in the period of 2005–2012, only Estonia, Malta and the Netherlands would not achieve their targets. Therefore, these countries should make more efforts seeking to achieve their targets in 2020. Particularly Estonia and Malta should attempt more in climate policy, whereas these countries will exceed the limits of GHG emission growth. Taking into account the EU as a whole, it will reach successfully its GHG targets according to all tendencies of GHG emissions change (Table 2). It is evaluated very positively that if the GHG emissions decrease at the same rate like during the period of 2005–2012, the reduction of GHG emissions in the EU will exceed its commitment and GHG emissions will be about 35% lower comparing to 1990.

Primary energy consumption during long period (1990–2012) grew in half of EU countries. The highest average growth rate (1.5–2.5% annually) in this period was observed in Malta, Cyprus, and Spain. In EU-28 as a whole primary energy consumption in the period of 1990–2012 was annually increasing negligibly. Meanwhile, the highest average annual decrease of primary energy consumption was observed in Lithuania, Latvia, and Romania.

In the inter-medium period, primary energy consumption increased in terms of average annual growth rates in all EU Member States except Belgium, Denmark, Germany, Greece, Hungary,

Table 1
Assumptions of tendencies of economic growth, energy consumption and share of RES changes for 2012–2020 and 2012–2030 periods used in modelling.

Period for estimating average tendencies	Predicted economic growth in per cent		Predicted change in energy consumption in per cent		Predicted change of share of RES in percentage point	
	From 2012 to 2020	From 2012 to 2030	From 2012 to 2020	From 2012 to 2030	From 2012 to 2020	From 2012 to 2030
1990–2012	20.4	38.6	8.29	11.4	0.30	1.76
2000–2012	14.9	28.6	0.45	−2.45	2.02	4.79
2005–2012	1.9	3.5	−10.33	−23.11	3.20	7.04

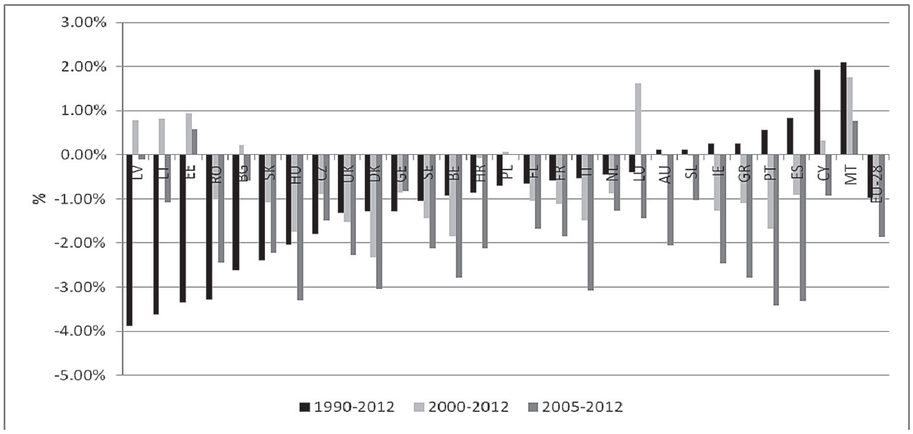

Fig. 1. Average annual changes in GHG emissions during different periods (%).

Table 2
The forecasts of GHG emissions according to different length of past tendencies.

	Forecasts of GHG emissions for 2020 based on:			Observed GHG emissions in 2005	Forecasted level for 2020 of GHG emissions compared with observed emissions in 2005 decrease (−)/increase (+)			Reduction targets (2020 emissions compared to 2005 levels), %
	The tendencies of 1990–2012	The tendencies of 2000–2012	The tendencies of 2005–2012		Tendencies of 1990–2012	Tendencies of 2000–2012	Tendencies of 2005–2012	
Austria	90679.49	81073.44	66923.51	92580.94	−2.10%	−12.40%	−27.70%	−16
Belgium	119858.42	101068.85	90189.92	142069.8	−15.60%	−28.90%	−36.50%	−15
Bulgaria	45571.36	64700.1	57730.57	63860.53	−28.60%	1.30%	−9.60%	20
Croatia	32550.68	29837.58	22131.04	30725.58	5.90%	−2.90%	−28.00%	11
Cyprus	12129.19	10763.68	8957.43	9886.13	22.70%	8.90%	−9.40%	−5
Czech Republic	116598.11	125958.78	112816.34	145966.36	−20.10%	−13.70%	−22.70%	9
Denmark	52283.75	46297.77	36906.36	64083.19	−18.40%	−27.80%	−42.40%	−20
Estonia	11019.47	21253	20717.74	18422.3	−40.20%	15.40%	12.50%	11
Finland	72330.5	60580.69	52229.45	68624.26	5.40%	−11.70%	−23.90%	−16
France	495017.17	449187.85	406213.29	558780.68	−11.40%	−19.60%	−27.30%	−14
Germany	809388.88	831873.04	834864.04	994459.67	−18.60%	−16.30%	−16.00%	−14
Greece	137764.85	109619.78	82246.53	135319.57	1.80%	−19.00%	−39.20%	−4
Hungary	60162.61	55386.09	43222.12	78376.04	−23.20%	−29.30%	−44.90%	10
Ireland	70101.1	53297.47	42546.14	69655.66	0.60%	−23.50%	−38.90%	−20
Italy	525405.04	425074.81	331664.26	574258.09	−8.50%	−26.00%	−42.20%	−13
Latvia	4972.54	12319.82	10956.49	11056.46	−55.00%	11.40%	−0.90%	17
Lithuania	12806.68	23819.59	17183.41	23318.73	−45.10%	2.10%	−26.30%	15
Luxembourg	11805.24	13794.66	10429.92	13100.46	−9.90%	5.30%	−20.40%	−20
Malta	3573.79	3474.6	3173.01	2977.43	20.00%	16.70%	6.60%	5
Netherlands	191658.15	181976.39	179150.34	209448.24	−8.50%	−13.10%	−14.50%	−16
Poland	364005.45	415600.62	393212.34	398827.04	−8.70%	4.20%	−1.40%	14
Portugal	85688.8	58311.86	44922.8	87802.74	−2.40%	−33.60%	−48.80%	1
Romania	79789.19	107232.88	79263.27	141338.72	−43.50%	−24.10%	−43.90%	19
Slovakia	37099.62	39904.98	34476.89	50455.89	−26.50%	−20.90%	−31.70%	13
Slovenia	21373.12	19724.79	17141.39	20313.71	5.20%	−2.90%	−15.60%	4
Spain	444477.66	331095.71	204581.81	431392.66	3.00%	−23.20%	−52.60%	−10
Sweden	56094.96	51911.8	49419.57	66918.52	−16.20%	−22.40%	−26.10%	−17
United Kingdom	531577.17	491445.2	420909.65	684739.87	−22.40%	−28.20%	−38.50%	−16
EU 28	4495783.01	4216585.83	3674179.63	5632126.62 1990 level	−20.20%	−25.10%	−34.80%	−20 (compared to 1990 level)

Note: Grey colour means that the targets will not be achieved.

Ireland, Italy, Lithuania, Portugal, Romania, Slovakia, and the United Kingdom. This increase was due to the influence of fast economic growth, but it was also a consequence of changes in the production structures of those countries [24]. However, in EU-28 as a whole primary energy consumption reduced. Meanwhile, the period of 2005–2012 was the most successful in terms of energy consumption, whereas in this period only Estonia, Finland, and Poland increased primary energy consumption. Decrease was the highest in Lithuania − 4% annually on average (Fig. 2).

Forecast of primary energy consumption for 2020, taking into account the average tendencies of 1990–2012 period shows that only Bulgaria, Croatia, Estonia, Hungary, Lithuania, Latvia, Poland, Romania, and Slovakia will achieve their targets if these tendencies are relevant. According to more recent 2000–2012 primary energy consumption tendencies, again only Croatia, Cyprus, Denmark, Finland, Greece, Hungary, Italy, Lithuania, Latvia, Portugal, Romania, and Slovakia will achieve their commitments. Meanwhile, considering the newest 2005–2012 changes in primary energy

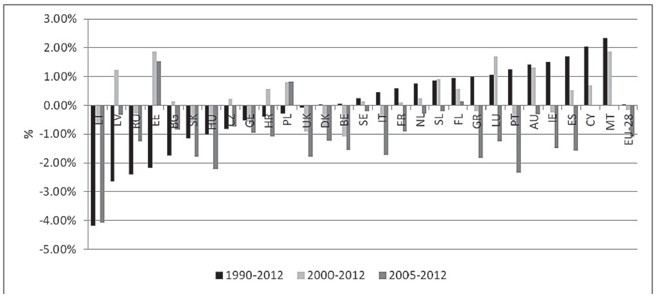

Fig. 2. Average annual changes in primary energy consumption during different periods (%).

consumption only Belgium, Estonia, the Netherlands, Poland, and Sweden will not be able to achieve 2020 targets (Table 3). Therefore, this proves that in these countries energy policy is not sufficient. Thollander et al. [62] also covered that the current energy policy instruments are not sufficient for the targets in Sweden. Thereby, the latter countries should take more efforts in saving energy through better energy management, energy-efficient technology, to encourage green consumption attitudes and to promote a structural change towards less energy-intensive goods and services.

Taking into account the whole EU-28, primary energy consumption targets will be achieved if the tendencies remain like these in the period of 2005–2012. Therefore, all EU should keep track of the latter period, when primary energy consumption on average decreased by 1% annually (Table 3). According to tendencies of more long-run period, achievement of target 1474 MTOE in EU in 2020 is not relevant.

The share of RES in total final energy consumption grew in all EU countries and in all periods, except in Portugal, in the period of 1990–2012 and Luxemburg – in 2000–2012. Comparing all periods, the share of RES in all EU Member States (except Estonia, Latvia, Lithuania, and Romania) mostly increased during the period of 2005–2012. In this period, the most rapid growth of share of RES was in Denmark, Austria, and Sweden (Fig. 3). Therefore, the latter period achieving the increase of RES was the most successful in the

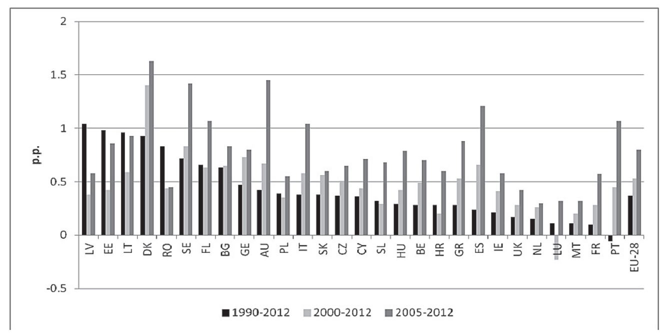

Fig. 3. Average annual changes in share of RES during different periods (percentage points).

Table 3
The forecasts of primary energy consumption according to different length of past tendencies.

	Primary energy consumption forecasts for 2020 based on:			Forecastedprimary energy consumption comparing with primary energy targets in 2020 (+) level at which target is not achieved/(−) level at which target is exceeded			Targets of primary energy consumption in 2020 MTOE
	The tendencies of 1990–2012	The tendencies of 2000–2012	The tendencies of 2005–2012	Tendencies of 1990–2012	Tendencies of 2000–2012	Tendencies of 2005–2012	
Austria	36.75	35	31.18	16.70%	11.10%	−1.00%	31.5
Belgium	51.53	46.25	44.68	17.90%	5.80%	2.20%	43.7
Bulgaria	15.31	17.2	14.76	−3.10%	8.90%	−6.60%	15.8
Croatia	8.85	8.12	6.67	−3.70%	−11.70%	−27.40%	9.19
Cyprus	3.06	2.67	2.26	9.30%	−4.60%	−19.30%	2.8
Czech Republic	39.99	41.08	36.56	1.00%	3.70%	−7.70%	39.6
Denmark	18.88	17.31	15.73	6.10%	−2.70%	−11.60%	17.8
Estonia	4.77	7.01	7.14	−26.70%	7.80%	9.80%	6.5
Finland	39.05	34.96	32.27	8.80%	−2.60%	−10.10%	35.9
France	268.9	245.57	230.36	13.80%	3.90%	−2.50%	236.3
Germany	296.47	284.05	273.37	7.20%	2.70%	−1.20%	276.6
Greece	32.17	25.78	19.47	18.70%	−4.90%	−28.10%	27.1
Hungary	22.13	21.1	17.79	−16.80%	−20.70%	−33.10%	26.6
Ireland	17.57	13.91	11.56	26.40%	0.10%	−16.80%	13.9
Italy	179.54	154.98	133.07	13.60%	−1.90%	−15.80%	158
Latvia	3.28	4.86	4.1	−39.00%	−9.50%	−23.60%	5.37
Lithuania	3.86	5.37	3.21	−40.50%	−17.10%	−50.50%	6.485
Luxembourg	5.08	4.97	3.97	13.40%	10.80%	−11.50%	4.482
Malta	1.08	0.95	0.79	31.20%	15.60%	−3.80%	0.825
Netherlands	72.41	67.79	65.48	19.30%	11.70%	7.90%	60.7
Poland	88.42	101.57	99.26	−8.30%	5.40%	3.00%	96.4
Portugal	26.84	20.76	17.82	19.30%	−7.70%	−20.80%	22.5
Romania	26.74	31.97	26.7	−37.80%	−25.60%	−37.90%	42.99
Slovakia	15.64	15.17	14.24	−3.50%	−6.40%	−12.10%	16.2
Slovenia	7.9	7.41	6.72	8.00%	1.40%	−8.10%	7.313
Spain	150.98	124.82	94.78	24.20%	2.60%	−22.10%	121.6
Sweden	47.44	46.19	47.09	9.30%	6.40%	8.50%	43.4
United Kingdom	204.56	178.35	162.9	15.20%	0.40%	−8.30%	177.6
EU 28	1689.21	1565.15	1423.92	14.60%	6.20%	−3.40%	1474

Note: Grey colour means that the targets will not be achieved.

EU countries. Boie et al. [6], Giacomarra and Bono [26], Jägemann et al., [32]; and deLlano-Paz et al. [13] also confirmed that in recent decade renewable energy generation has increased considerably and it is expected to keep growing in the future years. Klessmann et al. [38] also stated that European RES deployment and policy has progressed strongly in recent years, but the growth here has been mainly driven by effective policies in a small or medium number of top runner countries.

Forecast of RES for 2020, taking into account tendencies of the period of 1990–2012, suggests that only Bulgaria, Estonia, Finland, Latvia, Lithuania, Romania, and Sweden should achieve their commitments of RES. One of the reasons for this partial failure was that a number of EU Member States have not yet introduced active policies in line with the indicative targets they have set [26]. Taking into account more recent tendencies of 2000–2012 period and assuming that these tendencies will remain in future, almost half of EU countries will achieve their targets. Klessmann et al. [45], also stated that RES are currently insufficiently exploited in the European Union. Meanwhile, the extrapolation of the newest tendencies of 2005–2012 to 2020 shows that the majority of EU countries will achieve their targets. Giacomarra and Bono [38] also indicated that the majority of Member States are on the right way and their RES will successfully grow until 2020. However, according to our study and considering the latest tendencies of 2005–2012, Belgium, France, Ireland, Luxemburg, Malta, the Netherlands, and the United Kingdom will not implement targeted share of RES in 2020 (Table 4). Giacomarra and Bono [26] also found the difficulties to reach the RES targets in Italy and Luxembourg. Scarlat et al. [55] stated that renewable energy technologies have made significant progress so far and have a large potential and could contribute to this goal, but still face technical and cost challenges. Therefore, the last mentioned countries particularly should implement effective and efficient policies.

Taking into account EU-28 as a whole, the EU will achieve its targets if only the tendency of share of RES growth will remain as in 2005–2012 (when the average growth of share of RES was 0.8% points annually) (Table 4). Scarlat et al. [55] also declared that considering the progress made since 2005 on the deployment of renewable energy, the EU could achieve its 2020 renewable energy targets.

4.2. *The determinants of GHG emissions according to the results of regression analysis*

In this part of research, we present results of regression analysis emphasizing more on estimated impact of economic growth, primary energy consumption and share of RES on GHG emissions. In the next part, we will apply these results to model GHG emissions for 2020 and 2030 taking into account various different possible changes of impact factors. In Table 5, we present estimated analysis results using three different methods of panel data regression analysis.

As we see all estimations are statistically significant, but not without drawbacks. Fixed effects estimation suffered from error

Table 4
The share of RES forecasts according to different length of past tendencies.

	Forecasts of share of RES for 2020 based on:			Difference between forecasted share of the RES and targets for 2020 in percentage points (−) level at which target is not achieved/(+) level at which target is exceeded			The share of RES target in 2020
	The tendencies of1990–2012	The tendencies of 2000–2012	The tendencies of 2005–2012	Tendencies of 1990 –2012	Tendencies of 2000 –2012	Tendencies of 2005 –2012	
Austria	32.33%	39.14%	44.00%	−1.7	5.1	10.0	34%
Belgium	6.62%	9.64%	11.85%	−6.4	−3.4	−1.1	13%
Bulgaria	18.75%	18.67%	22.06%	2.7	2.7	6.1	16%
Croatia	16.31%	19.69%	24.87%	−3.7	−0.3	4.9	20%
Cyprus	9.03%	10.80%	13.95%	−4.0	−2.2	1.0	13%
Czech Republic	11.88%	14.31%	16.06%	−1.1	1.3	3.1	13%
Denmark	28.88%	34.85%	38.44%	−1.1	4.9	8.4	30%
Estonia	33.26%	28.33%	36.11%	8.3	3.3	11.1	25%
Finland	39.70%	40.73%	43.79%	1.7	2.7	5.8	38%
France	10.49%	14.45%	17.37%	−12.5	−8.6	−5.6	23%
Germany	14.56%	18.22%	18.24%	−3.4	0.2	0.2	18%
Greece	10.79%	15.06%	18.98%	−7.2	−2.9	1.0	18%
Hungary	9.62%	13.03%	17.15%	−5.0	−1.6	2.5	14.65%
Ireland	6.55%	10.01%	12.21%	−9.4	−6.0	−3.8	16%
Italy	10.55%	14.95%	21.22%	−6.5	−2.1	4.2	17%
Latvia	45.54%	38.35%	42.32%	5.5	−1.7	2.3	40%
Lithuania	30.95%	26.31%	32.10%	7.9	3.3	9.1	23%
Luxembourg	3.95%	3.85%	6.61%	−7.1	−7.2	−4.4	11%
Malta	1.32%	2.21%	3.45%	−8.7	−7.8	−6.5	10%
Netherlands	5.18%	6.88%	6.76%	−8.8	−7.1	−7.2	14%
Poland	12.48%	12.47%	15.77%	−2.5	−2.5	0.8	15%
Portugal	23.00%	32.00%	36.66%	−8.0	1.0	5.7	31%
Romania	30.40%	28.87%	28.69%	6.4	4.9	4.7	24%
Slovak Republic	12.72%	15.14%	16.49%	−1.3	1.1	2.5	14%
Slovenia	19.37%	20.19%	25.24%	−5.6	−4.8	0.2	25%
Spain	13.08%	19.39%	26.41%	−6.9	−0.6	6.4	20%
Sweden	52.21%	57.20%	59.58%	3.2	8.2	10.6	49%
United Kingdom	4.14%	6.33%	7.93%	−10.9	−8.7	−7.1	15%
EU 28	14.41%	17.68%	20.53%	−5.6	−2.3	0.5	20%

Note: Grey colour means that the targets will not be achieved.

Table 5
Panel data regression analysis results.

Parameter	VIF	Parameter estimator and its significance		
		First difference estimation using robust standard errors [95% confidence interval]	Fixed effects [95% confidence interval]	Random effects [95% confidence interval]
Constant		−0.0047	7.4215***	7.5814***
δ_2			−0.0073	−0.0075
δ_3		−0.0127	−0.0174	−0.0166
…				
δ_{23}		−0.0033	−0.1914***	−0.1925***
Gross domestic product per capita	1.919	0.2446** [0.0045; 0.4846]	0.1067*** [0.0697; 0.1436]	0.0938*** [0.0574; 0.1303]
Primary energy consumption	1.560	0.6225*** [0.3556; 0.8894]	0.8847*** [0.8411; 0.9282]	0.9171*** [0.8843; 0.9499]
Share of renewable energy	1.253	−0.0097*** [-0.0139;-0.0054]	−0.0060*** [-0.0080;-0.0040]	−0.0053*** [-0.0071;-0.0036]
ms_2			0.296113***	
…				
ms_{28}			0.316681***	
N		611	639	639
F(df1,df2) (p-value)		F(24, 586) = 64.9 (<0,0001)	F(52, 586) = 69.5 (<0,0001)	
White's test				B-P test
LM (p-value)		464.005 <0,0001)	32.904 (0.0837)	χ^2 = 11.19 (0.0665)
AR(1)		−0.1270***	−0.031*	
$R^2_{adj.}$		0,7155	0.8749	
Schwarz criterion		−2382.681	−1887.886	147.227
Akaike criterion		−2493.059	−2124.261	31.270
Hausman test				
χ^2 (p-value)				24.277 (0.5034)

heteroscedasticity, thus we re-estimated it using robust standard errors and that led to a quite wide parameter confidence interval. Model also follows a stable AR(1) process, so there is evidence of minimal negative serial correlation in the first-differenced errors. Unlike the positive serial correlation, the usual OLS standard errors may not greatly understate, thus, the significance of the independent variables probably will not be affected and we can also compute robust standard errors. Fixed effect estimation error follows a random walk and is constant according to White's test results. But Hausman test with high p-value does not count against the null hypothesis that the random effects model is consistent, in favour of the fixed effects model. Furthermore, we should exercise caution in using the fixed effects estimators because in our sample *n* is small and *T* is large. However, information criterions suggest that random effect estimation does not fit observation as well as two previous methods.

In such case, for interpretation of analysis results and later for modelling we will use all three estimations, because: their results do not conflict with each other, estimated direction of impact is logical (Variance Inflation Factors do not indicate a collinearity problem, that is a bit of surprise in case of no correlation between economic growth and primary energy consumption), in almost all cases estimated parameters using one method fall in confidence intervals of parameters estimated using other methods.

Therefore, the general results of regression analysis show that the economic growth stimulates GHG emission. Growth of GDP per capita by 1%, induces the increase of GHG emissions on average from 0.1 to 0.24% depending on what estimation we have referred (Table 5). This result reveals that EKC in the EU did not occur and higher economic development rates influence increase in energy consumption and also more GHG emissions are expected [41]. The same results, that in the EU as a whole the inertia of economic growth affected GHG emissions, are confirmed by other authors as well (see: [7,25,53]).

Moreover, the results of regression analysis cover that in EU28 Member States increased consumption of primary energy affects the increase of GHG emissions. Growth in energy consumption by 1%, increases GHG emissions on average from 0.62% to 0.92% depending on what estimation we have referred (Table 5). Therefore, our analysis confirmed that energy consumption and GHG emissions are very closely interrelated [1,2,44,58,59,64]. Thereby, the first step to reduce GHG emissions is to reduce energy consumption and to increase the efficiency in energy use [11,20,28,41,46,48,53,56,60].

Meanwhile, according to the results of regression analysis, the increase of share of RES in final energy consumption by one percentage point determines the decrease of GHG emissions on average from 0.53 to 0.96% depending on what estimation we have referred (Table 5). Bölük and Mert [7] and López-Menéndez et al. [42] also found that renewable energy consumption significantly lowers GHG emission in the EU. Thereby, promoting growth of RES in energy consumption balance could be very important in achieving climate policy targets. Moreover, promotion of RES contributes to the future of more resilient energy by reducing the dependence on finite and imported fuels [10,37].

4.3. GHG emissions modelling for 2020 and 2030 according to the results of the regression analysis

In the beginning we will start with a question: is it possible to achieve the objective to reduce GHG emissions up to 20% in 2020 in comparison to 1990, if at the EU level the objectives will be achieved to increase the share of RES to 20%, and consume no more than 1474 MTOE of energy; and will try to answer to it applying modelling technique. In order to achieve these two goals, share of RES must increase by 5.86% points (as in 2012 it was 14.14%.), while energy consumption should fall by 6.94% (as in 2012 consumption was 1583,9MTOE). We have also made three assumptions regarding growth of the EU economy: in the first scenario the EU economy from 2012 to 2020 is expected to grow by about 20.4%., in the second and the third, 14.9 and 1.9%, respectively. Under these circumstances modelling results applying all three estimations are presented in Table 6.

Modelling results using all three estimations show that if at the EU level the objectives will be achieved to increase the share of RES to 20%, and consume no more than 1474 MTOE of energy even at

Table 6
Modelling results of GHG emission for 2020 under assumption of full implementations of energy consumption and share of RES targets under fast, moderate and slow economic growth scenarios.

Indicator	Economic growth scenario (growth rate from 2012 till 2020)	Estimation method		
		First difference	Fixed effects	Random effects
Results of GHG emission modelling (rate (in per cent) at which GHG emissions will decrease in 2020 compared to 2012)	20.4%	−4.99	−7.48	−7.58
	14.9%	−6.33	−8.06	−8.09
	1.9%	−9.52	−9.45	−9.32
Estimated GHG emissions in 2020 (in thousand TOE)	20.4%	4321366	4208240	4203613
	14.9%	4260397	4181653	4180221
	1.9%	4115548	4118486	4124646
Decrease of GHG emissions in 2020 compared to 1990 (in per cent.)	20.4%	−23.27	−25.28	−25.36
	14.9%	−24.36	−25.75	−25.78
	1.9%	−26.93	−26.88	−26.77

fast economic growth assumption, the target to reduce GHG emissions by 20% in 2020 compared with 1990 will be achieved.

We will continue modelling of GHG emissions by trying to answer to slightly different questions – is it possible to achieve the objective to reduce GHG emissions up to 20% in 2020 in comparison to 1990 if tendencies of economic growth, energy consumption and share of RES changes for 2012–2020 period will be the same like these on average during: (i) 1990–2012, (ii) 2000–2012 and (iii) 2005–2012. Under the assumptions listed in Table 1, we have modelled GHG emissions for 2020 using all three regression estimation methods. Modelling results are presented in Table 7.

The results clearly show that if tendencies in terms of economic growth, energy consumption and share of RES for the period 2012–2020 would stay the same like these we had from 1990 till 2012, probability to achieve reduction of GHG emission by 20% by 2020 compared to 1990 will be negligible. Past tendencies of inter-medium period are more positive and predict moderate probability to achieve GHG emission goal. Recent (2005–2012) tendencies of economic growth, energy consumption and share of RES are the most promising to implement GHG emissions target (Table 7). Therefore, these results revealed that during current period the EU is on the right way to successfully implement the Europe 2020 targets and should support tendencies of the latter (2005–2012) period in terms of economic growth, primary energy consumption and the increase of share of RES.

Further we will end modelling of GHG emissions by trying to answer to questions – is it possible to achieve the Paris agreement objective to reduce GHG emissions up to 40% in 2030 in comparison to 1990 if tendencies of economic growth, energy consumption and share of RES changes for 2012–2030 period will be the same like these on average during: (i) 1990–2012, (ii) 2000–2012 and (iii) 2005–2012. Under the assumptions listed in Table 1, we have modelled GHG emissions for 2030 using all three regression estimation methods. Modelling results are presented in Table 8.

Contrary to the results of possibilities to achieve the GHG emissions targets committed in Europe 2020 strategy, the target to reduce the GHG emission by 40% in 2030 will not be achieved in referring to all tendencies and estimation techniques (Table 8). Therefore, despite that recent (2005–2012) promising tendencies in economic growth, energy consumption and share of RES are suitable for implementing GHG emissions targets of Europe 2020 strategy, they are not suitable for implementing targets of Paris agreement. Thus, the EU countries should attempt more to reduce energy consumption and to increase the share of RES seeking to implement GHG emissions target committed in Paris agreement.

5. Conclusion and policy implications

Uneven efficiency of EU Member States energy and climate policy determined different changes in GHG emissions, primary energy consumption, and the share of RES at country level. Moreover, comparing the different periods (1990–2012, 2000–2012 and 2005–2012), changes in GHG emissions and factors affecting them varied as well. The period of 2005–2012 was the most successful in terms of GHG emissions, reduction of primary energy consumption and the growth of the share of RES. During this period, GHG emissions increased only in Estonia and Malta, the primary energy consumption - in Estonia, Finland and Poland. Meanwhile, the share of RES increased in all EU countries, however, the lowest growth was observed in Luxemburg, Malta and Netherlands.

Forecasts of Europe 2020 strategy targets show that EU-28 as a whole and just half of Member States will achieve their targets in terms of GHG emissions, if the tendencies of GHG emissions till 2020 will be like these we had on average during period 1990–2012. Extrapolation of trends from the same period showed that only Bulgaria, Croatia, Estonia, Hungary, Lithuania, Latvia,

Table 7
Modelling results of GHG emission for 2020 under extrapolating long, inter-medium and short period tendencies.

Indicator	Period for extrapolating tendencies used for modelling	Estimation method		
		First difference	Fixed effects	Random effects
Results of GHG emission modelling (rate (in per cent) at which GHG emissions will change in 2020 compared to 2012)	1990–2012	9.86	9.33	9.36
	2000–2012	1.97	0.78	0.73
	2005–2012	−9.05	−10.85	−11.00
Estimated GHG emissions in 2020 (in thousand TOE)	1990–2012	4996843	4972705	4973930
	2000–2012	4638181	4583674	4581677
	2005–2012	4136547	4054685	4047893
Decrease of GHG emissions in 2020 compared to 1990 (in per cent.)	1990–2012	−11.28	−11.71	−11.69
	2000–2012	−17.65	−18.62	−18.65
	2005–2012	−26.55	−28.01	−28.13

Note: Grey colour means that the targets will not be achieved.

Table 8
Modelling results of GHG emission for 2030 under extrapolating of long, inter-medium and short period tendencies.

Indicator	Period for extrapolating tendencies used for modelling	Estimation method		
		First difference	Fixed effects	Random effects
Results of GHG emission modelling (rate (in per cent) at which GHG emissions will change in 2030 compared to 2012)	1990–2012	14.84	13.15	13.14
	2000–2012	0.85	−1.99	−2.12
	2005–2012	−20.32	−24.29	−24.62
Estimated GHG emissions in 2030 (in thousand TOE)	1990–2012	5223275	5146330	5145886
	2000–2012	4586885	4457932	4451935
	2005–2012	3623941	3443532	3428418
Decrease of GHG emissions in 2030 compared to 1990 (in per cent.)	1990–2012	−7.26	−8.63	−8.63
	2000–2012	−18.56	−20.85	−20.95
	2005–2012	−35.66	−38.86	−39.13

Note: Grey colour means that the targets will not be achieved.

Poland, Romania, and Slovakia will achieve their targets of energy consumption and only Bulgaria, Estonia, Finland, Latvia, Lithuania, Romania, and Sweden should achieve their commitments of RES. Meanwhile, considering the trends of the newest 2005–2012 period and assuming that these tendencies will remain in future, almost all EU countries will achieve their targets of Europe 2020 strategy. However, according to this tendency Estonia, Malta, and the Netherlands would not achieve their GHG emissions targets; Belgium, Estonia, the Netherlands, Poland, and Sweden will not be able to achieve the targets of primary energy consumption; Belgium, France, Ireland, Luxemburg, Malta, the Netherlands, and the United Kingdom will not implement targeted share of RES in 2020. Therefore, it reveals that in these countries energy and climate policy is not sufficient. Thereby, these countries should attempt more in climate policy, take more efforts in saving energy and promotion of RES.

Referring to the regression analysis, the research showed that the economic and primary energy consumption growth in EU-28 stimulates GHG emission. Particularly, energy consumption has the biggest impact on GHG emissions, the increase in energy consumption by 1% increases GHG emissions on average from 0.62% to 0.92% depending on what estimation we have referred. Meanwhile, the increase of share of RES in final energy consumption by one percentage point determines decrease of GHG emissions on average from 0.53 to 0.96%.

According to these results and modelling how successfully EU-28 will achieve the target of GHG emissions of Europe 2020 strategy and Paris agreement, the paper revealed that if the EU achieve the objectives to increase the share of RES to 20%, and consume no more than 1474 MTOE of energy even at fast economic growth assumption, the target to reduce GHG emissions by 20% in 2020 compared with 1990 will be reached. Analysing how successfully EU-28 will achieve the targets of GHG emissions of Europe 2020 strategy, according to the past trends of determining factors, the results clearly showed only recent (2005–2012) tendencies of economic growth, energy consumption, and share of RES are the most suitable for the implementation of GHG emissions target. Therefore, in recent period the EU is on right way seeking to implement the GHG emissions targets committed in Europe 2020 strategy. Meanwhile, analysing the possibilities to achieve the targets of GHG emissions reduction which EU committed in Paris agreement, referring to all tendencies ((i) 1990–2012, (ii) 2000–2012 and (iii) 2005–2012), the targets to reduce the GHG emission by 40% in 2030 will not be achieved. Therefore, despite that recent (2005–2012) tendency of economic growth, energy consumption and share of RES are the most suitable for the implementation of GHG emissions target of Europe 2020 strategy, the EU countries should more attempt to reduce energy consumption and to increase the share of RES seeking to implement the target of GHG emissions which is committed in Paris agreement.

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