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ASSESSMENT OF GHG EMISSIONS IN EUROPE: FUTURE ESTIMATES AND POLICY IMPLICATIONS

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Abstract

Greenhouse gas (GHG) emissions represents a global challenge and a quantitative approach is a support for decision makers. The aim of this paper is to estimate future values of GHG emissions in Europe, considering different periods of reference and through two common mathematical parameters (average annual growth rate (AAGR) and compound annual growth rate (CAGR)).
Results analysis show that a reduction of GHG emissions can be reached. However, some Member States (MSs) as Ireland and Netherlands present a critical situation. In addition, it is defined the linear correlation of GHG emissions with both Gross Domestic Product (GDP) and population. An increase of 1000 GDP Purchasing Power Standards (PPS) means an additional 0.325 tons CO_2eq of GHG emissions and an increase of one citizen means an additional 9.6 tons CO_2eq of GHG emissions.
Finally, a comparison among European countries is defined for 2015 according to two indexes: i) GHG emissions intensity of the economy and ii) GHG emissions per capita. A new framework is proposed, in which the average of European Union (EU) 28 is used as reference level and the target value as benchmark. Regarding the first index, Sweden occupies the first position (160 gCO_2eq per GDP PPS) followed by Malta and France with 223 and 233 gCO_2eq per GDP PPS, respectively. Concerning the second index, Croatia has the best performance with 5646 kgCO_2eq per capita followed by Sweden and Latvia with 5733 and 5866 kgCO_2eq per capita, respectively. Some policy implications are provided for the European MSs.

Keywords: environmental sustainability, greenhouse gas emissions, policy implications, quantitative analysis

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1. Introduction

The great challenge of circular economy (CE) is to propose an alternative to the linear 'take, make and dispose' economic model (Santibanez-Gonzalez et al., 2016). CE is a solution for firms to increase the sustainability of their business (Melnjak et al., 2019) and an opportunity for citizens to tackle the climate change (Fava et al., 2018). The production of energy, products, and services with a sustainable level of GHG emissions is the final goal (Busu, 2019; Cozma et al., 2015). During the period 2014-2016, global CO_2 emissions from fossil fuels are always at same level. Instead, the estimations coming from the Global Carbon Project underlines an increase of around 2% in 2017. They are equal to 36.8 gigatons (Gt) per year in 2017 (while was 36.2 Gt CO_2 in 2016). The main actors responsible are: China (28%), the United States (14%), the EU 28 (9%) and India (7%) (Peters et al., 2017).

At the Conference of the Parties (COP 21) in December 2015, 195 countries have agreed legally

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binding target by limiting global warming to well below 2°C. The Paris Agreement is a great challenge for improving collective action and accelerating the global transformation to a low-carbon and climate resilient society. Each country defines its contribution according to the principle of progression. In fact, a country does not set a specific target within a specific date, but its goal should more be ambitious than the previously set targets. It is called "nationally determined contributions" (NDCs). This agreement has a great limit determined by the absence of normative character concerning NDCs and economic penalties are not provided (den Elzen et al., 2019). Some authors estimate that NDCs imply larger emissions reduction rates after 2030 than during the 2010–2030 period (Benveniste et al., 2018).

The EU committed to cut GHG emissions in 2020 by 20 % from 1990 levels (or 30% in the case of an international agreement) within its 2020 Strategy and a new 2030 target has defined a reduction of at least 40% in comparison to 1990 levels. This new framework includes EU-wide targets and policy objectives for the period between 2020 and 2030. The EU was the first major economy to submit its intended contribution to the Paris Agreement and the presentation of 2030 Strategy is a relevant step towards the goal of this international agreement (EC Directive, 2016).

The EU Emissions Trading System (EU ETS) is an international system for trading GHG emission allowances. It covers around 11,000 power stations and industrial plants in thirty-one countries (28 EU countries with the addition of Iceland, Liechtenstein and Norway) that are responsible of about 40-45% of the EU's GHG emissions. According to 2020 Strategy, emissions from sectors covered by the EU ETS will be 21% lower than in 2005. Instead, this value will be equal to 43% to achieve the target of 2030 Strategy (for this aim, non-ETS sectors would need to cut emissions by 30% compared to 2005) (EC Directive, 2016). The trend of GHG emissions is fluctuating. After a significant decrease of 4% in 2014 than the previous year, the EU recorded GHG emissions slightly increased by 0.6% in 2015. The amount of emissions is slightly increased and the report of European Commission identifies two causes: (i) an increase of heating degree-days and (ii) the decrease of price of fossil fuels. In 2016, EU emissions decreased by 0.7% in comparison to 2015. However, the European GHG emissions (excluding land use, land-use change and forestry (LULUCF)) were 23% below the 1990 level, while Gross Domestic Product (GDP) in real terms grew by 53% over the same period. Consequently, the EU's GHG emissions intensity of the economy (GHG intensity), defined as the ratio between emissions and GDP, was equal to 100 in 1990 and decreased by almost half in 2016. Low-carbon technologies, such as the use of renewable energy, and the raise of productivity, through more efficient power plants and cars, have determined this positive change (EC Directive, 2016). The variation of GDP results be more fluctuated than one registered for carbon emissions (Bianco et al., 2019).

European Commission underlined a critical situation of two MSs (Malta and Ireland) that will likely fail to reach their non-ETS targets. It was determined mainly by the not appropriate measures in the transport sector. However, also other MSs (Belgium, Germany, Luxembourg, Austria and Finland) had a critical situation (EC Directive, 2017). The Climate Action Tracker, that is an independent science-based assessment, provides an international comparison. Its projections towards 2020 and 2030 underline an increase of China and India and a decrease of USA and Europe (Fig. 1) (Climate Action Tracker, 2018).

A review of the existing GHG emission legislations highlights the positive performance of Europe than other major countries (Villoria-Sáez et al., 2016). In this direction, the trajectories towards national targets can be calculated proposing also a comparison among several countries (Štreimikiene and Balezentis, 2016). Different changes in levels of GHG emissions are observed considering separate reference periods.

In all scenarios examined, Netherlands and Malta do not reached their target (Liobikienė and Butkus, 2017). Gil-Alana and Trani (2019) define that United Kingdom is a country where the trend of CO_2 emissions show a significantly negative trend. Slovenia, Portugal, Sweden and Finland are characterized by low emissions intensities and high carbon removal rates (Su et al., 2016).

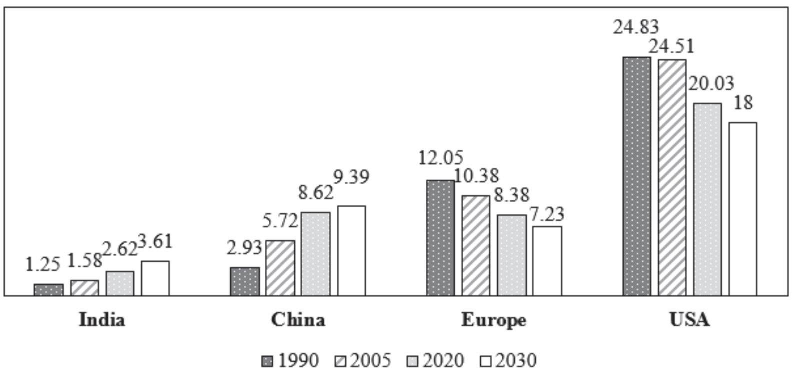

Fig. 1. Future trajectories of GHG emissions (tCO_2eq/cap) towards 2020 and 2030 (Climate Action Tracker, 2018)

The analysis of GHG emissions has a global perspective and each territory must monitored this parameter (Li et al., 2019; Perissi et al., 2018). This work follows this approach and three goals are proposed:

- The first evaluates the presence or less of a linear relationship among following macro-variables: GHG emissions and GDP PPS (Purchasing Power Standards), GHG emissions and population, GHG emissions per capita and GDP PPS per capita.
- The second concerns the estimates of GHG emissions towards 2020 in EU 28 MSs. Starting from historical values, two methodologies are proposed (AAGR and CAGR) considering three different reference periods.
- The third regards the comparison among EU 28 MSs based on two indexes, as (i) GHG intensity per GDP PPS and (ii) GHG emissions per capita.

2. Methods and data

The work is based on methodologies and data presented in the following subsections:

- A model of linear regression (section 2.1).
- A model used to define the future estimates (section 2.2).
- The definition of the reference level (section 2.3).
- Input data (section 2.4).

2.1. A model of linear regression

This work tests initially the presence or less of a linear regression between CO_2 emissions and economic development. Linear regression is a basic type of regression useful to conduct a predictive analysis. The most common form of linear regression is least squares fitting and the coefficient of determination (R^2) defines the goodness of fit of a model. It varies from 0 to 1 and the regression line perfectly fits the data when R^2 is equal to 1 (Umrao et al., 2018). In addition, the statistical significance of the data is evaluated. For this scope, the F-Test Two-Sample for Variances tool tests the null hypothesis that two samples come from two populations having the equal variances. The null hypothesis is verified when F value (F) is greater than F critical value. The probability to have F lower than Fcrit under the null hypothesis is quantified by a p-value (P) (Falcone, 2018).

2.2. A mathematical model applied to the future estimates of GHG emissions

The aim of this work is represented by the definition of future trends of GHG emissions for EU 28. The expected future value is calculated considering the initial value and the number of periods. Six scenarios (Aagr Sp, Aagr Mp, AagrLp, CagrSp, Cagr Mp and CagrLp) are defined by the combinations of the following variables:

- Three reference periods as 1990-2015 (long period - Lp), 2005-2015 (medium period - Mp) and 2010-2015 (short period - Sp) are evaluated. In fact, 1990 is the initial year of reference for EU 28, while 2005 is one considered for each MSs. Furthermore, last data available for MSs are referred to 2015 and the 2010-2015 has the same length of 2015-2020 period.
- Two mathematical parameters are proposed within this work. AAGR is the arithmetic mean of a series of growth rates and it is a linear measure that does not take into account the effect of compounding. CAGR is the geometric progression ratio that defines a constant rate of return over the time period.

2.3. Definition of the reference level

The last step of this work is the definition of a ranking regarding European MSs. The percentage reduction of GHG emissions is not chosen as index, because the performance measurement can be ambiguous. In fact, 2020 targets are not defined only in terms of reduction of emissions, but also as maximum increase of emissions (regarding countries less developed). Consequently, two indexes are used as benchmarks:

- The first is GHG intensity per GDP PPS. GHG intensity is able to correlate economic growth and environmental assessment (Welfle et al., 2017). GDP-PPS is an artificial currency unit that analyses factors of each country to define a number on a person’s standard of living within that country. For this motive, GDP PPS is better than usual GDP (Kusch and Hills, 2017). In this work. GHG intensity is calculated as ratio between GHG emissions excluding LULUCF (Land use and Land Use Change and Forestry) and GDP PPS.
- The second is GHG emissions per capita. It provides only an environmental evaluation (Kawakubo et al., 2018). This index is obtained simply dividing the total emissions for the population number. In this way, there is no difference between great and little MSs and data become homogeneous (Cucchiella et al., 2018).

2.4. Input data

Input data can be characterised by uncertainty and consequently, output values may be unreliable due to the non-homogeneity of this information. The statistical office of the European Union (Eurostat) solves this issue. The proposed input values comes from this source (Eurostat, 2018).

A total number of data points equal to two hundred and twenty-four are obtained by the product between twenty-eight MSs and eight years of reference (referred to 2008-2015 interval). GHG emissions excluding LULUCF, GDP PPS and population are the variables examined. Statistical data concerning GHG emissions excluding LULUCF in Europe are proposed in Table 1. It is equal to 4452 million tons CO_2eq in 2015 and a low increase

(+0.6%) is verified in EU 28 in comparison to the previous year, when it was equal to 4424 million tons CO_2eq.

Twenty-three MSs have reached 2020 target. Fourteen MSs (Bulgaria, Croatia, Czechia, Estonia, Greece, Hungary, Latvia, Lithuania, Malta, Poland, Portugal, Romania, Slovakia and Slovenia) present an increase of emissions (in this case, 2020 target is characterized by a positive sign) and all MSs have reached this goal compared 2015 level than 2005 one. The same is verified also for Belgium, Cyprus, Finland, France, Hungary, Italy, Spain, Sweden and United Kingdom (2020 target is characterized by a negative sign). Five most populated MSs (France, Germany, Italy, Spain and United Kingdom) are responsible of about 60% of European value of emissions. In particular, data highlighted as Poland has a level of emissions greater than Spain (Fig. 2).

Table 1. GHG emissions excluding LULUCF - CO_2eq (Eurostat, 2018)

Countries	*million tons CO_2eq (2015)*	*Δ% (2015-2005)*	*2020 Target (%)*
Austria	81	-14	-16
Belgium	122	-18	-15
Bulgaria	62	-3	20
Croatia	24	-19	11
Cyprus	9	-10	-5
Czechia	129	-13	9
Denmark	51	-26	-20
Estonia	18	-6	11
Finland	58	-19	-16
France	475	-17	-14
Germany	926	-9	-14
Greece	99	-29	-4
Hungary	62	-20	10
Ireland	62	-14	-20
Italy	443	-25	-13
Latvia	12	1	17
Lithuania	20	-12	15
Luxembourg	12	-18	-20
Malta	3	-22	5
Netherlands	207	-8	-16
Poland	388	-3	14
Portugal	72	-19	1
Romania	118	-20	19
Slovakia	41	-20	13
Slovenia	17	-18	4
Spain	350	-22	-10
Sweden	56	-19	-17
United Kingdom	537	-26	-16
EU 28	4452	-22 (referred to 1990)	-20

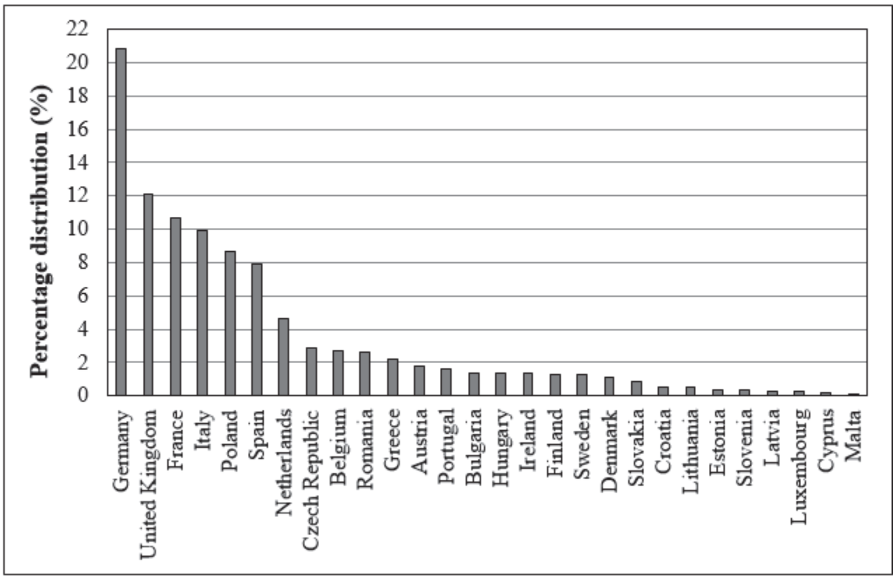

Fig. 2. Percentage distribution of GHG emissions among MSs in EU 28 in 2015 (Eurostat, 2018)

3. Results

3.1. Correlation model between GHG emissions and GDP PPS

Starting by section 2.1. and using input data proposed by Eurostat during 2008-2015, a regression model regarding two variables is proposed as follows:

- GHG emissions excluding LULUCF and GDP PPS (Fig. 3).
- GHG emissions excluding LULUCF and population (Fig. 4).
- GHG emissions excluding LULUCF per capita and GDP PPS per capita (Fig. 5).

The analysis of data highlights that GHG emissions has a linear relationship with both GDP PPS and population. In fact, the value of R^2 is equal to 0.94. The difference of this value from 1 is very low and consequently, the regression line almost perfectly fits the data. Considering the equations, it is possible to define that:

- an increase of 1000 GDP PPS means an additional 0.325 tons CO_2eq of GHG emissions.
- an increase of one citizen means an additional 9.6 tons CO_2eq of GHG emissions.

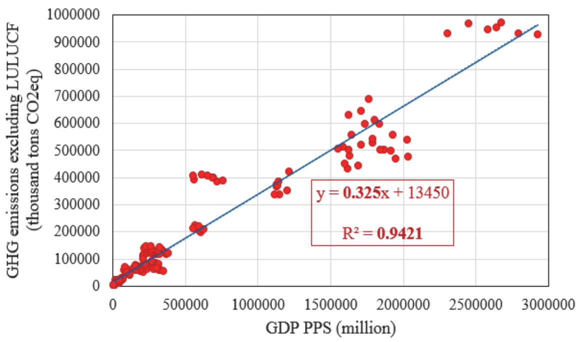

Fig. 3. The correlation between GHG emissions and GDP PPS

These equations could be used for estimating future values of GHG emissions. The relationship defined in this work not depends by the time as variable because several periods are analysed. While the analysis regarding variables per capita presents a low value of R^2 (0.5343) and consequently, it is not present a linear correlation. According to section 2.1., F-test analysis is conducted for three combinations of variables (Table 2). The statistical significance of the model is confirmed because F value is always greater than Fcrit value. It is chosen a level of significance equal to 0.05 and p-values are always very low.

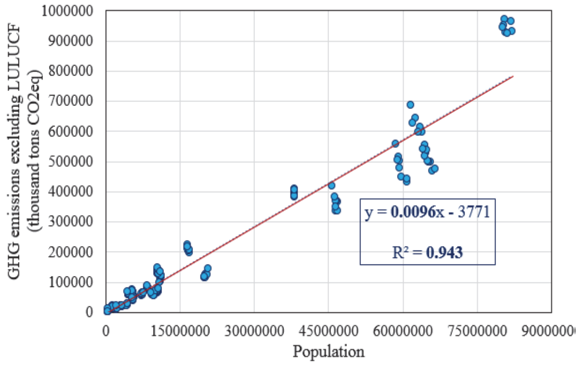

Fig. 4. The correlation between GHG emissions and population

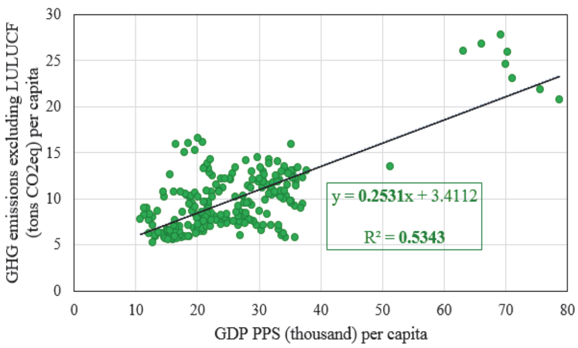

Fig. 5. The correlation between GHG emissions per capita and GDP PPS per capita

3.2. European GHG emissions trajectory towards 2020

3.2.1. Projections of EU MSs

Table 3 reports the percentage reduction of GHG emissions excluding LULUCF for each European MS. For example, considering the historical values of a specific country (Sweden), the following input data are obtained: an initial value of 73 million tons CO_2eq in 1990, an intermediate value of 69 million tons CO_2eq in 2005 and a finish value of 56 million tons CO_2eq in 2015. Starting by these values, mathematical parameters can be calculated. AAGR is equal to -1.0%, -2.0% and -3.5% considering long, medium and short period, respectively.

Table 2. F-test analysis

Parameter	*F-test no.1*		*F-test no.2*		*F-test no.3*	
	GDP PPS	***GHG emissions***	***Population***	***GHG emissions***	***GDP PPS per capita***	***GHG emissions per capita***
Mean	$478*10^3$	$169*10^3$	$18,005*10^3$	$169*10^3$	26	10
Variance	$4.5e^{+11}$	$5.1e^{+10}$	$5.2e^{+14}$	$5.1e^{+10}$	127	15
N	224	224	224	224	224	224
Dof	223	223	223	223	223	223
F	8.92		10.26		8.34	
P (F≤Fcrit)	$2.6e^{-51}$		$0.1e^{-99}$		$9.8e^{-49}$	
Fcrit	1.25		1.25		1.25	

Table 3. Percentage reduction of GHG emissions (2020-2005) in 28 Member States

National target 2020 reached(see Table 1)						
Countries	***AagrLp***	***Aagr Mp***	***Aagr Sp***	***CagrLp***	***Cagr Mp***	***Cagr Sp***
Austria		-21	-20		-21	-20
Belgium	-21	-26	-27	-21	-26	-27
Bulgaria	-12	-4	0	-13	-5	-2
Croatia	-23	-27	-30	-24	-28	-30
Cyprus		-14	-20		-14	-20
Czechia	-20	-19	-20	-20	-19	-21
Denmark	-30	-36	-42	-31	-36	-43
Estonia	-17	-5	-19	-20	-9	-20
Finland	-21	-26	-39	-22	-27	-40
France	-19	-24	-25	-19	-24	-25
Germany	-14			-14		
Greece	-30	-40	-42	-30	-40	-42
Hungary	-26	-28	-25	-26	-28	-25
Ireland		-20			-20	
Italy	-27	-35	-35	-27	-35	-35
Latvia	-13	3	-6	-14	2	-6
Lithuania	-24	-17	-15	-26	-18	-15
Luxembourg		-26	-29	-20	-26	-29
Malta	-21	-29	-38	-22	-31	-39
Netherlands						-16
Poland	-6	-4	-8	-7	-5	-8
Portugal	-15	-26	-18	-16	-27	-19
Romania	-30	-28	-22	-31	-28	-22
Slovakia	-28	-28	-29	-29	-28	-29
Slovenia	-19	-25	-29	-19	-25	-29
Spain	-19	-31	-26	-20	-32	-26
Sweden	-23	-26	-32	-23	-27	-32
United Kingdom	-32	-36	-38	-32	-36	-38
National target 2020 not reached(see Table 1)						
Countries	***Aagr Lp***	***Aagr Mp***	***Aagr Sp***	***Cagr Lp***	***Cagr Mp***	***Cagr Sp***
Austria	-14			-14		
Cyprus	-2			-3		
Germany		-13	-12		-13	-12
Ireland	-12		-16	-12		-16
Luxembourg	-19					
Netherlands	-10	-12	-15	-10	-12	

While, CAGR presents the following growth rates equal to -1.1%, -2.1% and -3.5%, respectively. Consequently, the future amount of GHG emissions ranges from -51 to -48 million tons CO_2eq in 2020 considering several scenarios. Starting from the value registered in 2005, the percentage reduction of GHG emissions is calculated. It varies from -23% to -32% and 2020 target is reached (in fact, it is equal to -17%).

Results underline that the environmental policies of several countries aim to tackle the climate change also when their 2020 target allows to choose another solution. A reduction of GHG emissions in 2020 compared to 2005 level is verified in all MSs with the only exception of Latvia in two scenarios. In comparison to existing literature (Liobikienė and Butkus, 2017), there are improvements caused by a significant reduction in 2014.

Only six MSs fails their 2020 national target. However, Luxembourg in AagrLp scenario, Austria and Cyprus in both AagrLp and CagrLp scenarios have values that are not far by the goal. Germany presents a particular situation. From one side the estimates towards 2020 have values similar to 2020 target, but there is a trend not positive. In fact, the goal is not reached in four scenarios concerning short and medium period.

Finally, the analysis of data highlights the critical situation of Ireland and Netherlands. Both countries have future values far from the final goal in four and five scenarios, respectively. The first reaches 2020 target in both Aagr Mp and Cagr Mp scenarios, while the second only in Cagr scenario.

A comparison with existing literature show as the critical situation of Netherlands is already underlined by (Liobikienė and Butkus, 2017) and the same is verified also for Ireland by (EC Directive, 2017). Both these studies underline the not good performance of Malta, which instead presents a positive change of direction in this study (this is confirmed analysing the values of the short period). The same observation is true also for United Kingdom and the analysis of this study does not capture the indication proposed by (Gil-Alana and Trani, 2019). The positive performance of several European countries is coherent to (Cucchiella et al., 2018) and (Su et al., 2016) and also the future estimates provide the same indication (Villoria-Sáez et al., 2016).

There are no significant changes between Aagr and Cagr scenarios, while the reference period influences the estimated final value, but it is specific for each country.

3.2.2. Projections of EU 28

The future projection of EU 28 is illustrated in Fig. 6 and Fig. 7 for Aagr and Cagr scenarios, respectively. There are no substantial differences between two mathematical parameters ranging from -1.0% to -1.9%. The best situation is verified in short period and these values, basing only on historical values, mean as EU 28 has applied a positive contribute to tackle the climate change in the last five years (2010-2015) in comparison to 1990 and 2005 levels. In addition to the trajectory of GHG emissions excluding LULUCF towards 2020, it is proposed also one towards 2030 and the percentage reduction is based not only on 1990 level (as defined by 2020 Strategy), but also on 2005 level.

GHG emissions of EU 28 are hypothesized equal to 4037-4239 million tons CO_2eq in 2020 and estimated values for 2030 vary from 3319 to 3844 million tons CO_2eq. From one side, the future estimate towards 2020 compared to 1990 level ranges from -26% to -29%. In this way, 2020 target is certainly reached (equal to 20%) and it is near to the conditional target of 30%. From the other side, the future estimate towards 2030 compared to 1990 level varies from -33% to -42%. Consequently, 2030 target can be reached (equal to 40%) in medium and short periods. When, instead, future projections are evaluated in comparison to 2005 level (as European MSs), a further reduction of 4-5% is obtained.

Finally, starting by a population equal to 508.5 million in 2015 in EU 28 (see Section 2.4), it is possible to obtain the values of GHG emissions per capita. They ranges from 7.94 tCO_{2eq} per capita to 8.34 $tCO2_{eq}$ per capita in 2020 and it is coherent with the estimation defined in Fig. 1 (8.38 tCO_{2eq} per capita). The same is verified also in 2030. In fact, this work proposes a range from 6.53 tCO_{2eq} per capita to 7.56 tCO_{2eq} per capita (Fig. 1 presents a value of 7.23 tCO_{2eq} per capita). These data are consequently coherent to ones proposed by (Climate Action Tracker, 2018).

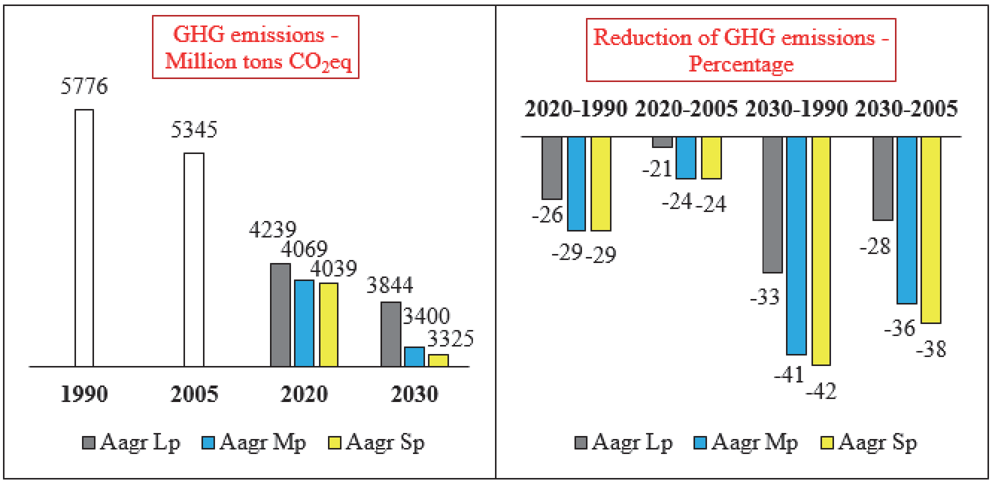

Fig. 6. GHG emissions excluding LULUCF in EU 28. Trajectories towards 2020 and 2030 regarding AAGR scenarios

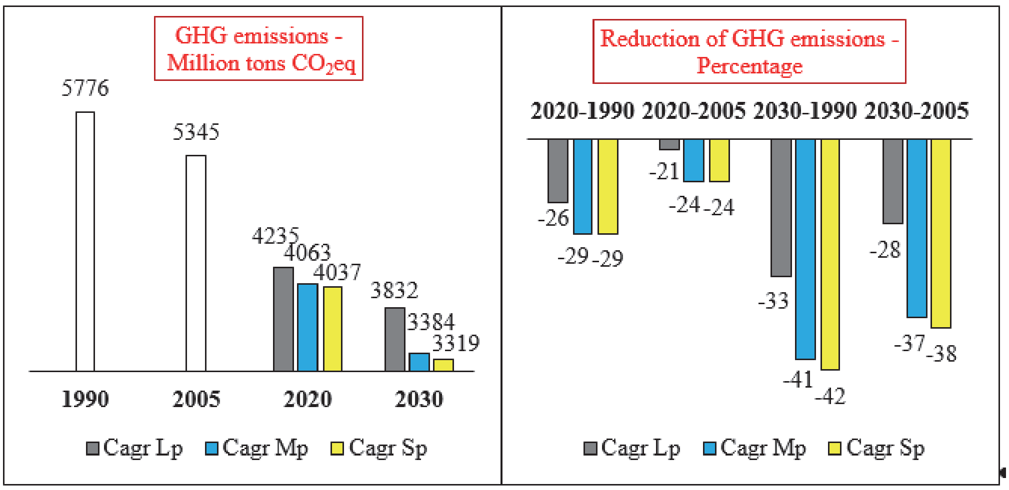

Fig. 7. GHG emissions excluding LULUCF in EU 28. Trajectories towards 2020 and 2030 regarding CAGR scenarios

3.3. A comparison among twenty-eight European Member States

A comparison among MSs is useful to decision makers to implement corrective measures and to evaluate the sustainable performance. In this direction, two rankings of European MSs are proposed in Fig. 8 (GHG intensity per GDP PPS) and Fig. 9 (GHG emissions per capita).

2015 is chosen as reference because it is the last year with data available. For this motive, it can be useful in future works analyse the temporal evolution of these two indexes. Furthermore, the EU 28 value can be used as reference level.

Ten MS have a value higher than 303 gCO_2eq per GDP PPS (average value of EU 28) considering GHG intensity. Sweden and Estonia have the maximum and minimum value equal to 160 and 637 gCO_2eq per GDP PPS, respectively.

Fifteen MSs have a value greater than 8755 $kgCO_2eq$ per capita (average value of EU 28) considering GHG emissions per capita. Croatia and Luxembourg present the extreme values equal to 5646 and 20,753 $kgCO_2eq$ per capita, respectively. Six MSs (Sweden, France, Italy, United Kingdom, Malta and Spain) present a value greater than the European average in both indexes. Only Germany is absent among five most populated MSs. The analysis of six critical countries underlines that Luxembourg, Austria and Ireland have a value of GHG intensity greater than European average one, while Germany, Cyprus and Netherlands is lower in both indexes.

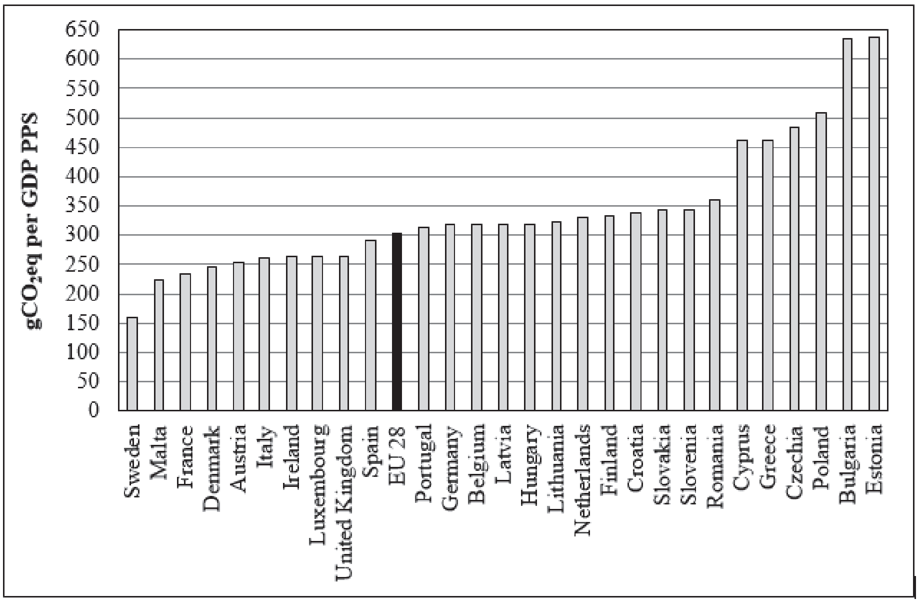

Fig. 8. GHG intensity (gCO_2eq) per GDP PPS in 2015 regarding EU 28 countries

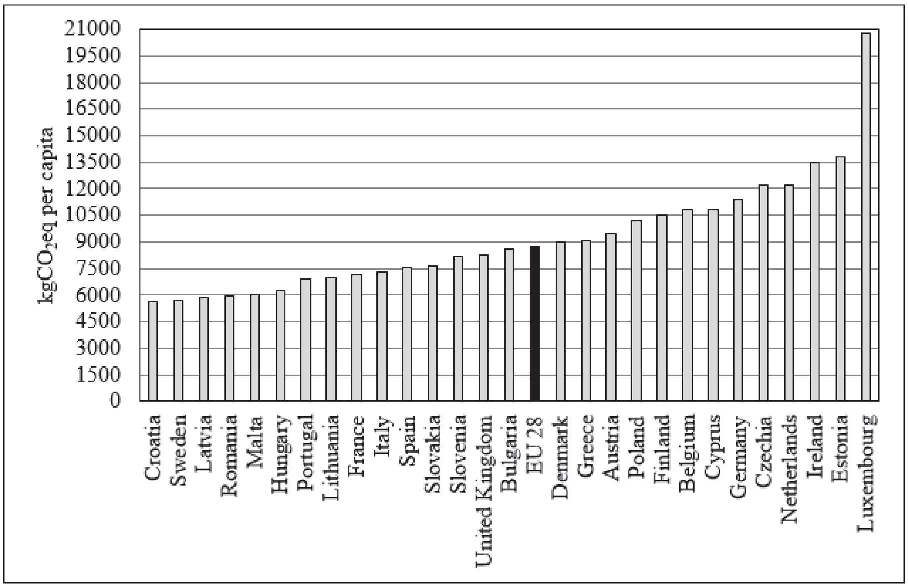

Fig. 9. GHG emissions ($kgCO_2eq$) per capita in 2015 regarding EU 28 countries

Finally, these indexes have no 2020 and 2030 targets and, consequently, this work sets them according to values proposed by both 2020 and 2030 Europe Strategy. Starting by initial value of 5716 million tons CO_2eq in 1990, the application of a reduction of 20% determines a value of 4573 million tons CO_2eq in 2020. When, instead the initial point of reference is fixed equal to 5345 million tons CO_2eq (value of EU 28 in 2005) the expected reduction will be equal to 4276 million tons CO_2eq. When, instead, the final goal is more ambitious aiming to a reduction of 30%, the estimated value is equal 4001 and 3742 million tons CO_2eq in 2020 compared to 1990 and 2005 levels, respectively. Considering 2030 as final year of reference, the reduction of 40% of GHG emissions proposes the following estimated values: 3430 and 3207 million tons CO_2eq in 2030 compared to 1990 and 2005 levels, respectively.

The following step is represented by the estimation of GDP PPS and population. The methodology used by (Awasthi et al., 2018) is proposed in this analysis. It has considered AAGR as mathematic parameter in a short period (referred to 2010-2015 interval). This value is equal to 2.8% and 0.2% for GDP PPS and population, respectively. Starting by initial value of 14,714 billion GDP PPS in 2015, an estimated value of 16,893 billion GDP PPS is proposed in 2020. Consequently, the ratio between 4573 million tons CO_2eq and 16,893 billion GDP PPS is equal to 271 gCO_2eq per GDP PPS (Fig. 10). Considering the population as variable, the initial value is equal to about 508.5 million inhabitants in 2015 and the future projection is about 513.6 million inhabitants in 2020. Consequently, the ratio between 4573 million tons CO_2eq and 513.6 million is equal to 8904 kgCO_2eq per capita (Fig. 11).

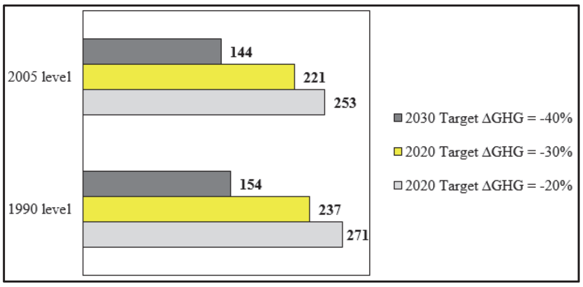

Fig. 10. GHG intensity (gCO_2eq) per GDP PPS in EU 28-A new reference framework

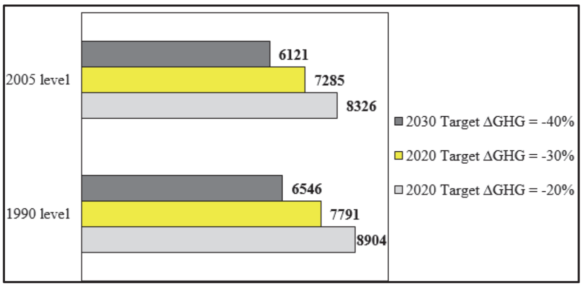

Fig. 11. GHG emissions (kgCO_2eq) per capita in EU 28-A new reference framework

Considering that MSs are evaluated in comparison to 2005 levels, three MSs (Sweden, Malta and France) have already reached 2020 target with a reduction of GHG of 20% in both indexes in 2015. Furthermore, from one side Sweden (160 gCO_2eq per GDP PPS) has a value lower than 221 gCO_2eq per GDP PPS (benchmark represented by EU 28 in 2020 with ΔGHG=30%). From the other side, Croatia, Sweden, Latvia, Romania and Malta (from 5646 to 6007 kgCO_2eq per capita, respectively) have a value lower than 6121 kgCO_2eq per capita (benchmark represented by EU 28 in 2030). In this way, the comparison among MSs can be defined in function of both (i) European average value and (ii) target value.

3.4. Policy implications and discussion

The CE is gaining increasing attention from academia, practitioners and policy-makers. It is based on closing the loop in the production-consumption scheme. Several approaches are used to demonstrate its potential. CE models are a tool to tackle climate change (Petit-Boix and Leipold, 2018).

The underlying goal is to highlight as the value of products and materials is maintained for as long as possible (Ghisellini et al., 2016). The lifecycle of production of goods and the habits of life adopt by citizens are characterized by the release of emissions. This has caused a serious damage to the ecosystems. In fact, human actions have not contrasted this phenomenon. Policy-makers have launched a carbon pricing mechanism for achieving low carbon in 1990s in some countries (Sweden and Finland) and subsequently the number of countries involved in this policy environmentally friendly is increased through the Kyoto Protocol and the Paris Agreement.

The EU launched the EU ETS to fight global warming in 2005. Coal and gas prices have influenced CO_2 prices during the First Phase, while this role is played by electricity price in the Second Phase (Keppler and Mansanet-Bataller, 2010). Auctioning is the default method for allocating allowances (instead of free allocation) since 2013 (during the Third Phase) (Cai and Pan, 2017). EU has recently modified EU ETS for the period after 2020 (during the Fourth Phase) in order to reach the aim of the Paris Agreement reducing GHG emissions by at least 40% by 2030 (EC Directive, 2016).

Several works define its limits: green investments are not encouraged and the carbon price is not maintained sufficiently high (Caldés et al., 2019). In particular, about 75% of emissions regulated by carbon pricing are covered by a price below 10 € per ton of CO_2 in 2017. However, from this perspective there is a significant change in the last period: a value of 25 € per ton of CO_2 is reached in the first months of 2019. This price does not include the carbon tax. The report of the High-Level Commission on Carbon Prices defines that the price necessary to achieve Paris target of "well below 2°C." varies from 40 $ per ton of CO_2 to 80 $ per ton of CO_2 by 2020 and from 50 $ per ton of

CO_2 to 100 $ per ton of CO_2 by 2030 (Stiglitz et al., 2017).

The carbon price permits to translate environmental advantages in economic values, but both the estimated reduction of GHG emissions and the carbon price are characterised by a great volatility. In addition, a period of economic crisis determines also a reduction of emitted pollutants. The equilibrium between levels of GHG emissions and growth of GDP is relevant and for this motive, the presentation of results in terms of GHG emissions intensity of the economy is useful. Progress towards meeting the EU's climate commitments are monitored by European Commission. Its indications are the following: (i) the relevance of economic allocations for the climate financing in the next Multiannual Financial Framework and (ii) the application of new legislations concerning energy efficiency, renewable energy, emissions standards for cars, vans and heavy-duty vehicles, carbon capture and storage, and fluorinated gases. It is useful to control year after year the level of emissions of each MS, their future trajectories in comparison to robust models and the definition of benchmarks.

Four policy implications were identified through this study. Firstly, carbon price has a key-role towards the development of a low-carbon society and sustainable initiatives are not always encouraged in presence of its low value. The instability of carbon price represents a great limit. After a promising start with a value of 30 € per ton of CO_2, it is rapidly decreased to values lower than 10 € per ton of CO_2. Recently, there is a new incremental trend but it is already insufficient. In fact, the use of carbon pricing should consider also non-climate benefits, as the access to modern energy and the health of ecosystems.

Secondly, the decision-makers cannot be interested only to reach an environmental improvement or an economic opportunity, but equilibrium between these two aspects is the final goal according to the principle of sustainability. Initially, this work has demonstrated the presence of a linear relationship of emissions with GDP PPS. The application of renewable energy plants, the adoption of technique of recycle and reuse in waste management, the optimization of industrial processes in terms of efficiency represent valid case-studies to favour this transformation.

Thirdly, each MSs can be defined as an entity and its performance is controlled by a central structure. The robustness of the model presented in this work is defined by two mathematical parameters wide used in decision processes. Future scenarios are constructed on the real values registered in the past. The trustworthiness of data is certified by their source (Eurostat, 2018). A dynamic aspect is not incorporated in future estimates and consequently, the effects of new measures are not considered. For example, Denmark, France, Finland, Italy, Portugal, Sweden and United Kingdom have set phase-out goals of coal power plants. The same measure is applied also by Austria and the Netherlands, characterised by not ambitious estimates in comparison to the previous MSs (Table 3).

Fourthly, new benchmarks are proposed in this work. GHG intensity per GDP PPS and GHG emissions per capita are two indexes well known. However, a target value referred to 2020 and 2030 is defined for the first time. The adoption of economic awards for countries that have reached relevant results in comparison to benchmarks can be a solution. These benefits could be invested as much in new advanced technologies as in applications of the processes that aim to increase their efficient and efficacy. While, economic penalties can be an alarm for countries that are not interested to apply eco-friendly solutions.

This work has limits, which could be solved in future research steps. In fact, as above cited defined it does not consider dynamic aspects and consequently, the effects of new policies are not measured. AAGR and CAGR are mathematical parameters that are able to capture the previous trend but they are not appropriate in a context characterized by several modifications. At the same time, the value of GHG emissions for each country is considered in absolute terms. This estimate is extremely complex and a decomposition analysis can be examined in order to measure the performance of each sector. Following this approach, this work has not measured the difference between ETS and not-ETS sector because the target value defined by 2020 Strategy is considered as reference. The changes introduced in the Phase 3 of EU-ETS (valid for period 2013-2020) are partially measure in the current panel data. Future evaluations could be consider some challenges, such as massively reduced free allocation, tighter caps, backloading and limited offsets (introduced in Phase 3 and Phase 4 of EU ETS). At the same time, will be useful to discuss the possible impacts of such changes on the emission behaviours of the major sectors in EU. In this direction, the role of carbon price is strategic to tackle the climate change and its impact on the future trends of GHG emissions is relevant.

4. Conclusions

A sustainability world agenda is based on the future projections of GHG emissions. This work considers the situation in Europe and a model of linear regression is examined. The analysis of historical data, regarding 2008-2015 period, underlines a linear correlation. An increase of 1000 GDP PPS means an additional 0.325 tons CO_2eq of GHG emissions and an increase of one citizen means an additional 9.6 tons CO_2eq of GHG emissions.

Future estimates towards 2020 and 2030 are proposed basing on common mathematical parameters (AAGR and CAGR) and historical data referred to 1990-2015 period. Environmental performance of several countries varies significantly. Ireland and Netherlands present a critical situation and 2020 target is far. EU 28 is able to reach 2020 and 2030 targets. In particular, Europe can reach significant results applying recent policies environmentally friendly.

However, results change significantly in function of year of reference (2005 or 1990). Some countries have reached important results, but at the same time this is not valid for all MSs.

The analysis does not regard only the percentage reduction of GHG emissions, but it is conducted also on two indicators: GHG emissions per GDP PPS and GHG emissions per capita. Different results are obtained and Sweden presents generally the best performance. Two values (European average and target) can be used as reference value/benchmark and this phase become crucial. In this way, it is possible to define when a country is able to reach a goal and corrective actions can be applied monitoring environmental performances. A model-based scenario quantification supports the European Commission in impact assessments and analysis of policy options.

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