# Efficiency and allocation of emission allowances over more sustainable European Countries

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**Abstract**

Uncontrolled CO2 emissions and excessive energy dependence strongly contribute to climate change preventing economic and sustainable development. The European mitigation program is very ambitious: new objectives up to 2030 provide for a 40% reduction of GHG emissions and an increase of 27% for renewables and energy efficiency. Competitiveness would save on imports of oil and gas, to increase the gross domestic product and create new jobs in the renewable energy and energy efficiency. This study uses GHG emissions, total energy consumption and renewable energy consumption as input variables for the evaluation and the analysis of the economic and social sustainability performance of Countries belonging to the European Economic Area. Data Envelopment Analysis (DEA) model allows the identification of the less competitive areas in terms of sustainable growth and the Zero Sum Gains Data Envelopment Analysis model is used to determine how they should vary the inputs so that the economic system reaches efficiency.

*Keywords: Sustainable Development, Greenhouse Gas Emissions, Energy Management, Renewable Energy, ZSG DEA.*

## 1. Introduction

The worrying process of climate change is directly related to greenhouse gas emissions (GHG) of economic activities, which are in turn related to energy consumption (fossil). Intergovernmental Panel on Climate Change (IPCC), an international scientific organization charged with studying climate change and its potential environmental and socio-economic impacts, presented alarming data in its recent Fifth Assessment Report (Pachauri et al., 2014). Damage caused by climate change are well known: extreme weather events (storms, heat waves), rising sea levels, floods, reduction of drinking water resources, increased health risks, change of ecosystems and influence on agriculture and tourism sectors. The reduction in emissions would be to limit the negative effects already in place both prevent new ones. Also the adoption of corporate social responsibility initiatives are an opportunity to boost the competitiveness of the industrial sector (Porter and van der Linde, 1995; Dowell et al., 2000; Wagner et al., 2001, 2002), although it is still difficult to assess the intensity of the benefits that will accrue. The costs of the interventions are equally difficult to evaluate: the transport systems and energy production and use need of adaptation actions. Surely these costs would rise significantly if the charges were not shared with all Countries largest producers of GHGs. The Kyoto Protocol (1997) was the first international agreement to set compulsory limits on GHG emissions. 160 countries (without United States participation) undertake to reach the target of an overall reduction of 5.2% from 1990 levels, by 2012, with cuts shared among Countries depending on their income and degree of industrialization. The protocol was not inflexible: the countries who obtain excess reductions of emissions can "sell" the surplus to other ones, who have not succeeded in reaching their assigned objectives. Otherwise, groups of countries can agree on a different distribution of the obligations from that sanctioned under the protocol, as long as the overall obligations are met. For the European Union the provision was for an 8% cut in emissions.

The results of the emission reduction have exceeded expectations and have encouraged EU to increase the targets. In 2009, The European Parliament and Council approved the 20-20-20 Climate and Energy Package, stating the European objectives to the year 2020, specifically: a 20% reduction of GHGs from 1990 levels; a 20% reduction in energy consumption; to achieve 20% of renewable energy in total EU consumption. Between 1990 and 2012, European emissions of GHGs in fact declined by 18%, due to both the policies on climate and energy and to the economic crisis. In October 2014, the European Council approved new objectives up to 2030, which provided for a 40% reduction of GHG emissions and an increase of 27% in renewables and energy efficiency. Particularly European Union (EU) should invest in sustainable growth also to limit excessive energy dependence which contributes to climate change and sustainable economy (according to Eurostat data, in 2014 53.5% of domestic consumption gross EU energy was covered by imports, of which one third comes from Russia). Conversely competitiveness would save on imports of oil and gas, to increase the gross domestic product (GDP) and create new jobs in the renewable energy and energy efficiency.

The original contribution of this work is twofold. The first part of our work has the objective of measuring the economic and social sustainability performance of Countries belonging to the European Economic Area (EEA) from 1995 to 2014 to evaluate the efforts of European Commission. We use an indicator based on GDP data, population, GHG emissions, total energy consumption and consumption of renewable energy. This indicator is the efficiency score obtained with the technique of data envelopment analysis (DEA) (Banker et al., 1984; Charnes et al., 1978): for Countries with the same level of GHG emission, total energy consumption and renewable energy consumption, that the one with the highest population and GDP will be more efficient. Otherwise, for the one with similar values for population and GDP, the most efficient is the one with the lowest levels of emission total energy consumption and renewable energy consumption. In the second part, focusing on results and on the data of the last year available (2014), we want to identify what should be instead the values of GHG and energy consumption that would make the sample globally efficient. However, the reallocation of inputs is not arbitrary but is constrained to their sum, representing the annual target that European nations must respect. Therefore the model used to optimize this system is called Zero Sum Gains DEA (ZSG-DEA) (Lins et al., 2003; Gomes et al., 2003; Gomes et al., 2005), and returns the best possible projections of inputs without changing the total resources available for distribution among the Countries under evaluation.

Usually GHGs are modeled by DEA as an undesirable output being an undesirable result of a productive process and must be minimized (Scheel, 2001). There are several approaches to modelling undesirable outputs in a DEA model (Lovell et al., 1995; Golany and Roll, 1989; Rheinhard et al., 1999; Gomes and Lins, 2008; Ali and Seiford, 1990). We model the undesirable output as input by using the transformation $f(u_j) = -u_j$ (): thus in the process of reducing the inputs, the undesirable outputs are also reduced. Moreover ZSG-DEA model allows to extend the analysis considering the allocation optimization of emission allowances over European Countries. Wang et al. (2013) propose a new efficient emission allowance allocation scheme on provincial level for China by 2020: in their paper, CO2, total energy consumption and renewable energy consumption are inputs, whereas GDP and population are outputs. Zeng et al. (2016) also evaluate reallocate allowances for 30 provinces and cities across China but they consider CO2 and renewable energy consumption as inputs, whereas GDP, total energy consumption and population as outputs. Gomes and Lins (2008) use ZSG-DEA models to evaluate the carbon dioxide emission of signatory countries of the Kyoto Protocol: in the model proposed, CO2 is a input, whereas GDP, population and energy consumption are outputs. Chang (2012) considers the CO2 emission allowance as the input and the GDP as the output to reallocate the CO2 emission allowance for 25 member states in the EU. The ZSG-DEA model was recently utilized by Chiu et al. (2015) and Pang et al. (2015) to allocate emission permits among a sample of countries and Miao et al. (2016) with carbon emission as undesirable output in China.

This paper is organized as follows. After this brief introduction, section 2 describes the data related to observed Countries. In Section 3, we present the DEA and ZSG-DEA model used for the evaluation of performance. Section 4 provides the obtained results and comments, followed by the conclusions in section 5.

## 2. Methods

*2.1 DEA Model*

The first part of the paper is aimed at the measurement of economic performance and social sustainability. In particular, we want to classify Countries comparing their levels of GDP and population with the amount of GHGs emitted and the consumption of energy. The comparison is based on an efficiency indicator obtained from the data envelopment analysis (DEA) (Charnes et al., 1978). DEA is a linear programming technique used to evaluate the efficiency of a homogeneous set of units characterized by multiple inputs and outputs. In the input-oriented version of DEA, efficiency calculation can be formulated by minimizing inputs in order to meet predetermined levels of output. Banker, Charnes and Cooper (Banker et al., 1984) have formulated the DEA for Decision Making Unit (DMU) that operate under variable returns to scale (VRS). Considering a number J of DMUs, K outputs and I inputs, the input-oriented DEA case, called BCC_DEA is the following:

$$\min \vartheta_o$$
$$\sum_{j=1}^{J} \lambda_j x_{ij} \leq \vartheta_o x_{io} \quad \forall\ i = 1, \dots, I$$
$$y_{ko} \leq \sum_{j=1}^{J} \lambda_j y_{kj} \quad \forall\ k = 1, \dots, K$$
$$\lambda_j \geq 0 \quad \forall\ j = 1, \dots, J$$
$$\textstyle\sum_{j=1}^{J} \lambda_j = 1 \qquad (1)$$

In model (1), $\vartheta_o$ is the efficiency measure of the $o$-th DMU under evaluating, $x_{ij}$ and $y_{kj}$ are the inputs and outputs values, respectively, of each DMU j, $x_{io}$ and $y_{ko}$ are the inputs and outputs values for the under evaluating $DMU_o$ and $\lambda_j$ are the optimal weights of each $DMU_j$. The measure of $\vartheta_o$ ranges from zero to 1, where 1 is full efficiency; values less than 1 indicate that the DMU is operating at less than full capacity given the set of fixed output.

The advantage of the DEA is to produce an aggregate measure of efficiency for each DMU using a plurality of input and output, whose measurement units may also be varied (Charnes et al., 1994). The disadvantage is that the efficiency value that is attributed to each DMU is relative, that is, depends on the efficiency of the other units that are in the sample. In this analysis we implement the DEA input-oriented, where the DMU evaluated are the European Countries, the outputs are the gross domestic products (GDP) and population, the inputs are the amount of GHG emitted, the total consumption of energy and the consumption of energy from renewable sources. Thus, the model proposed in this paper suggests, for Countries with the same level of GHG emission and energy consumption, that the one with the highest population and GDP will be more efficient. Otherwise, for the one with similar values for population and GDP, the most efficient is the one with the lowest levels of emission and energy consumption. Furthermore, the observed DMUs are different in size and show different development levels: for these reasons we analyze DMUs with DEA model (1) under variable returns to scale.

*2.2 ZSG-DEA Model*

DEA model used in the previous step gives us information on which Countries are efficient and which have margins for their improvement. The second part of our work has as objective the identification of the input values (emissions and energy) that make the system globally efficient. However, the reallocation of inputs of each DMU cannot be arbitrary, but is bound by the input of the other DMU: in fact to meet the mitigation targets to climate change, the amount of emissions and the total energy consumption of all Countries cannot overcome their European thresholds. The model utilized to face this problem is called ZSG-DEA (Zero Sum Gains DEA) (Lins et al., 2003; Gomes et al., 2003; Gomes et al., 2005). It returns the best possible projections of inputs (or outputs) without changing the total resources available for distribution among the units under evaluation. The formulation (2) represents the ZSG-DEA BCC model, input-oriented:

$$\min \vartheta_{Ro}$$
$$\sum_{j=1}^{J} \lambda_j x_{ij} \left[1 + \frac{x_{io}(1-\vartheta_{Ro})}{\sum_{j\neq o} x_{ij}}\right] \leq \vartheta_{Ro} x_{io} \quad \forall\ i = 1, \dots, I$$
$$y_{ko} \leq \sum_{j=1}^{J} \lambda_j y_{kj} \quad \forall\ k = 1, \dots, K$$
$$\lambda_j \geq 0 \quad \forall\ j = 1, \dots, J$$
$$\sum_{j=1}^{J} \lambda_j = 1 \quad (2)$$

where $\vartheta_{Ro}$ is the efficiency measure of the $o$-th DMU under the restriction that the input sum must be constant and $x_{ij}\left[1 + \frac{x_{io}(1-\vartheta_{Ro})}{\sum_{j\neq o} x_{ij}}\right] = x_{ij}{'}$ is the new input level after the optimal reallocation.

This is a non-linear mono-objective programming problem. The formulation output-oriented is dual. In the general case, however, the inefficient DMUs may be many and the problem becomes non-linear multi-objective. Gomes and Lins propose a proportional reduction strategy, in which the DMU achieve maximum efficiency through "cooperation": this strategy implies the amount of input subtracted from inefficient DMUs, is added to the inputs of efficient DMU. Gomes et al. (2003) showed that the optimal reallocation of inputs can be obtained by decomposing the problem in more steps. For each step the solution is given by a single equation:

$$\vartheta_{Ro} = \vartheta_o \left[1 + \frac{\sum_{j\in W} x_{ij}(1 - q_{oj}\vartheta_{Ro})}{\sum_{j\notin W} x_{ij}}\right] \quad (3)$$

where $W$ represents the set of cooperative DMU and $q_{oj} = \vartheta_o/\vartheta_j$ is the proportionality factor. This model needs only the calculation of DEA scores followed by the solution of a single equation and treats both constant and variable returns to scale models.

## 3. Data

The sample of countries observed in this paper comprises the 30 countries forming the 'European Economic Area (EEA), 28 of the European Union (EU-28) plus Iceland and Norway. Belgium, Bulgaria, Czech Republic, Denmark, Germany, Estonia, Ireland, Greece, Spain, France, Croatia, Italy, Cyprus, Latvia, Lithuania, Luxembourg, Hungary, Malta, Netherlands, Austria, Poland, Portugal, Romania, Slovenia, Slovakia, Finland, Sweden and United Kingdom, member states of UE, have developed an internal single market through a standardized system of laws, ensure the free movement of people, goods, services and capital within the internal market and maintain common policies on trade, agriculture, regional development, climate and environment. Iceland and Norway are in the European market but are not members of the UE. For each Country, from 1995 to 2014, the utilized data are:

- Gross inland energy consumption (expressed in thousand tonnes of oil equivalent (TOE)): it is the quantity of energy necessary to satisfy inland consumption of the geographical entity under consideration (Font Eurostat). It includes all products, i.e. solid fuels, petroleum products, gas, renewables, nuclear.
- Renewable energy consumption: renewable energies cover hydro power, wind energy, solar energy, tide, wave and ocean, biomass and renewable wastes and geothermal energy.
- Population (unit): it is the usual resident population, nationals or foreigners, and represents the number of inhabitants of a given area on 31st December (Font Eurostat).
- Gross domestic product at current market prices expressed in millions of euro (Font Eurostat).
- Greenhouse Gases (expressed in thousand tonnes of $CO_2$ equivalent): they are the estimated emissions released into the atmosphere by all sectors of economic activity, including international aviation but excluding land use, land-use change and forestry (Font Eurostat and European Environment Agency). These gases include direct emissions such as carbon dioxide ($CO_2$), methane ($CH_4$), nitrous oxide ($N_2O$), perfluorocarbons (PFCs), hydrofluorocarbons (HFCs) and sulphur hexafluoride ($SF_6$) as well as indirect emissions such as sulfur dioxide ($SO_2$), Nitrogen oxide ($NO_x$), carbon monoxide (CO) and non-methane volatile organic compounds (NMVOCs).

In order to analyze the general positioning of the considered Countries in terms of energetic and emitting efficiency two indicators have been chosen:

- energy intensity, the total energy consumption per GDP unit;
- emission intensity, GHG emissions per GDP unit.

Figure 1 shows a positioning map in 2014. First, we can observe that the two indicators assume an almost linear relationship for all Countries except Iceland. Its emission intensity is in the European average (0.40 thousand tonnes / million euro), while the energy intensity is the highest in the sample (0,47 thousand tonnes / million euro). In fact Iceland, characterized by a cold climate and a sparse population in the area, needs a lot of energy for heating and transportation. In addition there are numerous fishing and aluminum industries which are "energy intensive."

Moreover two clusters of Countries could be selected:

- the first one is characterized by an emission intensity lower than 0.40 thousand tonnes/mln euro and an energy intensity lower than 0.13 thousand tonnes/mln euro. These Countries are mainly localized in the north (Ireland, Sweden and others), center-south (Italy, Germany and others) and west (Spain, Portugal and others) of Europe.
- the second one is characterized by an emission intensity higher than 0.40 thousand tonnes/mln euro and an energy intensity higher than 0.13 thousand tonnes/mln euro. These Countries are mainly localized in the east of Europe (Finland, Poland, Bulgaria and others).

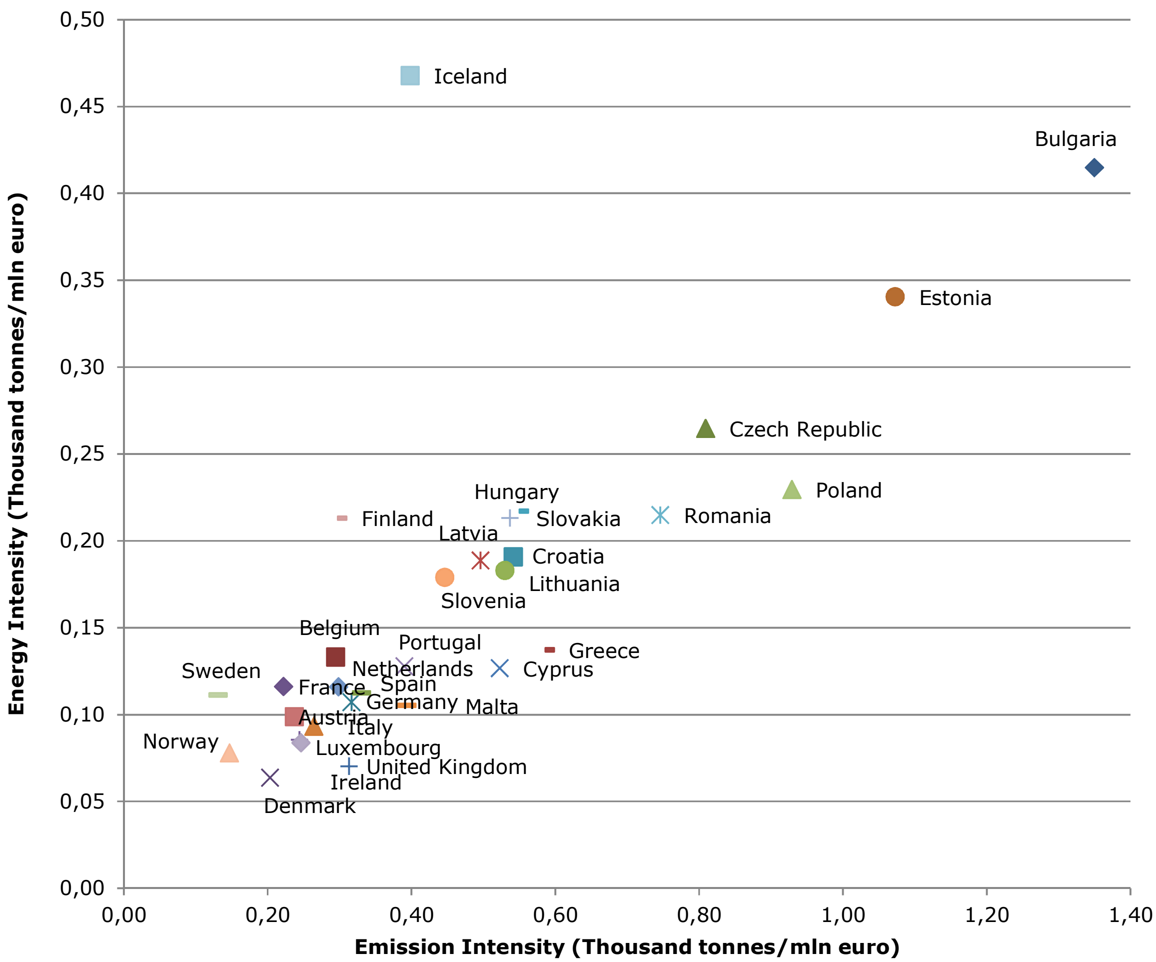


**Figure 1.** Emission and Energy Intensity for European Countries in 2014.

## 4. Results

The thirty nations of the considered sample are part of a geographic area relatively not very extended, but differ considerably for the climate, morphology and industrial development. So, in the first part of the paper we assess which countries are efficient (or inefficient) from the point of view of energy consumption and control of GHG emissions, given its level of economic and social development with the aim to determine the inefficient and efficient Countries and deduce the possible reasons. The BCC-DEA input-oriented is applied (1) to the observed thirty DMU in which outputs are the GDP and the population, the inputs are the amount of GHG emitted, the total energy consumption and the consumption of energy by renewable source. The DEA is calculated for each year of observation from 1995 to 2014, obtaining in this way also information on the efficiency trend between Countries. The radar chart of Figure 9 shows simultaneously the temporal variation in efficiency in 1995, 2000, 2005, 2010, 2011, 2012, 2013 and 2014 for all Countries. We observe firstly that Denmark, Germany, France, Italy, Hungary, Malta, Poland, Romania, Sweden and United Kingdom have unitary efficiencies in all the years considered. These countries are therefore always more efficient than the others through the variation of inputs and outputs in time. Ireland, Greece, Spain, Croatia, Latvia, Portugal and Norway have efficiencies ranging between 0.9 and 1. Cyprus, Luxembourg, Netherlands, Slovenia and Slovakia assume positive extensive variations in efficiency, i.e. the efficiency is increasing over time and improves performance. Conversely Belgium, Bulgaria, Czech Republic, Estonia, Lithuania, Austria, Finland and Iceland are characterized by a negative change in efficiency over time, their performance in terms of emissions and energy consumption is the worse observed in the sample. We can also observe that the lowest efficiency values are recorded for Finland, Czech Republic and Estonia, respectively, with 0.603, 0.592 and 0.402 in 2014 (Tab. 1). Also from data of table 1 we can observe that Germany and Malta are both efficient, despite the first presents the highest values of emissions and total energy consumption and the second the lower values of the sample. Overall, the sample has a rather high average efficiency, 0.916 in 2000 and 0.905 in 2014.

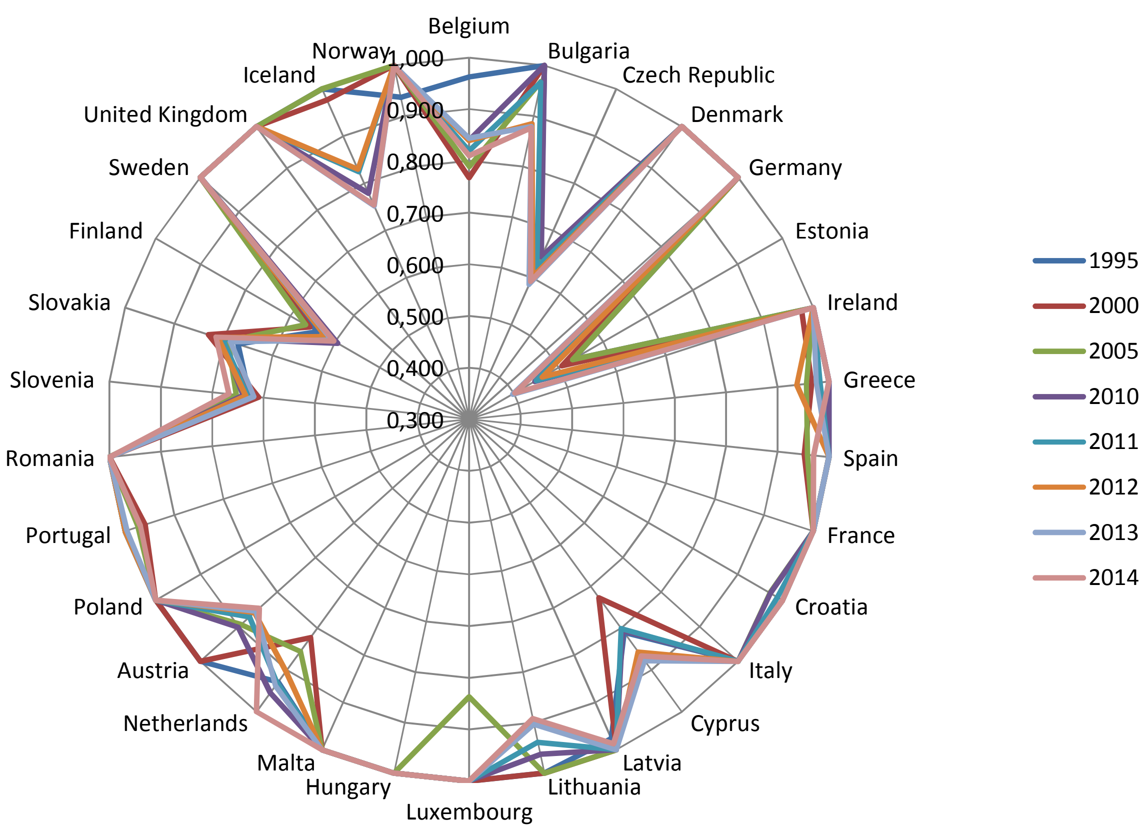


**Figure 2.** DEA efficiency scores for all countries in 1995, 2000, 2005, 2010, 2011, 2012, 2013, 2014.

**Table 1.** National values of GHG, gross inland and renewable energy consumption and DEA efficiency scores for all countries in 2000 and 2014

| | 2000 | | | | 2014 | | | |
|---|---|---|---|---|---|---|---|---|
| Country | GHG. Thousand tonnes of CO2 equivalent | Gross inland energy Consumption. Thousand tonnes of oil equivalent | Renewable Energy Consumption. Thousand tonnes of oil equivalent | BCC-DEA Efficiency | GHG. Thousand tonnes of CO2 equivalent | Gross inland Consumption. Thousand tonnes of oil equivalent | Renewable Energy Consumption. Thousand tonnes of oil equivalent | BCC-DEA Efficiency |
| Belgium | 153921 | 59331 | 638 | 0.767 | 117933 | 53367 | 3357 | 0.810 |
| Bulgaria | 58510 | 18523 | 776 | 1.000 | 57714 | 17732 | 1789 | 0.877 |
| Czech Republic | 151492 | 41094 | 1342 | 0.630 | 126768 | 41456 | 3635 | 0.592 |
| Denmark | 73424 | 19736 | 1797 | 1.000 | 53876 | 16905 | 4435 | 1.000 |
| Germany | 1060345 | 342333 | 8983 | 1.000 | 924766 | 312969 | 35406 | 1.000 |
| Estonia | 17127 | 4973 | 513 | 0.507 | 21186 | 6727 | 859 | 0.402 |
| Ireland | 71154 | 14426 | 235 | 0.977 | 60505 | 13563 | 961 | 1.000 |
| Greece | 130201 | 28292 | 1403 | 0.967 | 104265 | 24430 | 2446 | 1.000 |
| Spain | 395305 | 123642 | 6815 | 0.952 | 342698 | 116681 | 17768 | 0.970 |
| France | 568821 | 257540 | 15742 | 1.000 | 475396 | 248498 | 21317 | 1.000 |
| Croatia | 25375 | 8422 | 1557 | 1.000 | 23269 | 8195 | 2007 | 1.000 |
| Italy | 562571 | 174219 | 10113 | 1.000 | 428050 | 151027 | 26512 | 1.000 |
| Cyprus | 9178 | 2413 | 46 | 0.727 | 9177 | 2224 | 133 | 0.866 |
| Latvia | 10542 | 3864 | 1191 | 1.000 | 11710 | 4452 | 1613 | 0.987 |
| Lithuania | 18810 | 7063 | 675 | 1.000 | 19375 | 6695 | 1277 | 0.892 |
| Luxembourg | 10734 | 3654 | 39 | 1.000 | 12025 | 4215 | 190 | 1.000 |
| Hungary | 74247 | 25298 | 830 | 1.000 | 57741 | 22773 | 1918 | 1.000 |
| Malta | 2972 | 801 | 0 | 1.000 | 3317 | 886 | 18 | 1.000 |
| Netherlands | 230212 | 78104 | 1353 | 0.822 | 197976 | 76807 | 3400 | 1.000 |
| Austria | 82143 | 29023 | 6574 | 1.000 | 78330 | 32671 | 9785 | 0.847 |
| Poland | 393053 | 88648 | 3802 | 1.000 | 381745 | 94308 | 8591 | 1.000 |
| Portugal | 85976 | 25285 | 3759 | 0.959 | 67522 | 22097 | 5527 | 0.969 |
| Romania | 142750 | 36649 | 4041 | 1.000 | 112130 | 32290 | 6124 | 1.000 |
| Slovenia | 19194 | 6451 | 788 | 0.710 | 16656 | 6682 | 1225 | 0.767 |
| Slovakia | 49843 | 18302 | 488 | 0.830 | 40780 | 16181 | 1420 | 0.815 |
| Finland | 71087 | 32436 | 7751 | 0.657 | 61050 | 34593 | 10155 | 0.603 |
| Sweden | 70823 | 48898 | 14741 | 1.000 | 56681 | 48169 | 17266 | 1.000 |
| United Kingdom | 744022 | 230560 | 2264 | 1.000 | 556652 | 189340 | 12108 | 1.000 |
| Iceland | 4370 | 3348 | 2413 | 0.976 | 5156 | 6058 | 5229 | 0.754 |
| Norway | 55806 | 26432 | 13486 | 1.000 | 55196 | 29237 | 13096 | 1.000 |
| EU-28 Sum | 5283833 | 1729979 | 98254 | - | 4419289 | 1605931 | 201241 | - |
| EEA Sum | 5344008 | 1759759 | 114153 | - | 4479640 | 1641226 | 219566 | - |
| EU-28 Mean | 188708 | 61785 | 3509 | 0.911 | 157832 | 57355 | 7187 | 0.907 |
| EEA Mean | 178134 | 58659 | 3805 | 0.916 | 149321 | 54708 | 7319 | 0.905 |

In the second part of our paper we want to determine the input values (emissions, total energy consumption and renewable energy consumption) that make globally efficient the system, setting the outputs. The reallocation takes place without changing the total inputs available for distribution among the units under evaluation. We choose to apply the ZSG-DEA (3) to the inputs of the last year of observation, 2014, whose corresponding efficiencies of classical DEA were calculated in the previous step. After some iterations, we obtain the reallocation of the values of GHG emissions, total energy consumption and renewable energy consumption over different countries. Table 2 shows that all countries achieve unitary efficiency and that reallocate values lie in the efficient frontier. By examining the input variations of the Countries that are most inefficient with the classic DEA, emissions must fall by -58.3% in Estonia, -38.6% in the Czech Republic, -37.5% in Finland , -21.9%in Iceland and -20.4 in Slovenia. Countries with initial efficiency between 0.8 and 0.9, suffer a less significant decrease of GHG, i.e. -9.1% in Bulgaria. Countries with initial efficiency greater than 0.9, can significantly increase GHG emissions, i.e. + 0.6% in Spain. Instead Denmark, Germany, Ireland, Greece, France, Croatia, Italy, Luxembourg, Hungary, Malta, Netherlands, Poland, Romania, Sweden, United Kingdom and Norway, proved efficient in the classic DEA (efficiency score = 1), are "rewarded" by ZSG-DEA with an increase of + 3.7%. Same goes for the reallocation of the total energy consumption and renewable energy, respectively -57.6% and -58.2 for Estonia, -37.6% and -38.4% for the Czech Republic, -20.6% and -21.6 for Iceland, etc. The Countries that were already efficient can increase their consumption of + 5.3% and + 4.0% respectively. Using the values of energy consumption before and after the reallocation, we can calculate the shares of renewable in gross final energy consumption: observe that as a result of a more efficient reallocation of consumption, all countries report an increase in the share of renewables.

**Table 2.** Reallocated values of GHG, gross inland and renewable energy consumption and ZSG-DEA efficiency scores for all countries in 2014 and share of renewable in gross final energy consumption before and after reallocation.

| Country | Reallocated GHG. Thousand tonnes of CO2 equivalent | Reallocated Gross inland energy Consumption. Thousand tonnes of oil equivalent | Reallocated Renewable energy Consumption. Thousand tonnes of oil equivalent | Initial BCC-DEA Efficiency | Final ZSG-DEA efficiency after reallocation | Initial Share of Renewable Energy | Final Share of Renewable Energy after reallocation | Percentage Change |
|---|---|---|---|---|---|---|---|---|
| Belgium | 99069 | 44977 | 2865 | 0.810 | 1.000 | 6.29 | 6.37 | 0.08 |
| Bulgaria | 52449 | 16168 | 1652 | 0.877 | 1.000 | 10.09 | 10.22 | 0.13 |
| Czech Republic | 77842 | 25540 | 2268 | 0.592 | 1.000 | 8.77 | 8.88 | 0.11 |
| Denmark | 55854 | 17583 | 4671 | 1.000 | 1.000 | 26.23 | 26.56 | 0.33 |
| Germany | 958711 | 325520 | 37292 | 1.000 | 1.000 | 11.31 | 11.46 | 0.14 |
| Estonia | 8836 | 2815 | 364 | 0.402 | 1.000 | 12.77 | 12.93 | 0.16 |
| Ireland | 62726 | 14106 | 1013 | 1.000 | 1.000 | 7.09 | 7.18 | 0.09 |
| Greece | 108092 | 25409 | 2576 | 1.000 | 1.000 | 10.01 | 10.14 | 0.13 |
| Spain | 344690 | 117743 | 18157 | 0.970 | 1.000 | 15.23 | 15.42 | 0.19 |
| France | 492846 | 258464 | 22453 | 1.000 | 1.000 | 8.58 | 8.69 | 0.11 |
| Croatia | 24123 | 8524 | 2114 | 1.000 | 1.000 | 24.49 | 24.80 | 0.31 |
| Italy | 443762 | 157084 | 27924 | 1.000 | 1.000 | 17.55 | 17.78 | 0.22 |
| Cyprus | 8240 | 2004 | 121 | 0.866 | 1.000 | 5.96 | 6.03 | 0.08 |
| Latvia | 11984 | 4571 | 1677 | 0.987 | 1.000 | 36.23 | 36.69 | 0.46 |
| Lithuania | 17911 | 6209 | 1199 | 0.892 | 1.000 | 19.08 | 19.32 | 0.24 |
| Luxembourg | 12466 | 4384 | 200 | 1.000 | 1.000 | 4.51 | 4.57 | 0.06 |
| Hungary | 59860 | 23686 | 2020 | 1.000 | 1.000 | 8.42 | 8.53 | 0.11 |
| Malta | 3438 | 921 | 19 | 1.000 | 1.000 | 2.00 | 2.02 | 0.02 |
| Netherlands | 205243 | 79887 | 3581 | 1.000 | 1.000 | 4.43 | 4.48 | 0.06 |
| Austria | 68740 | 28765 | 8724 | 0.847 | 1.000 | 29.95 | 30.33 | 0.38 |
| Poland | 395758 | 98090 | 9048 | 1.000 | 1.000 | 9.11 | 9.22 | 0.12 |
| Portugal | 67802 | 22261 | 5638 | 0.969 | 1.000 | 25.01 | 25.33 | 0.32 |
| Romania | 116246 | 33585 | 6450 | 1.000 | 1.000 | 18.97 | 19.21 | 0.24 |
| Slovenia | 13251 | 5333 | 990 | 0.767 | 1.000 | 18.33 | 18.56 | 0.23 |
| Slovakia | 34460 | 13718 | 1219 | 0.815 | 1.000 | 8.78 | 8.89 | 0.11 |
| Finland | 38146 | 21685 | 6447 | 0.603 | 1.000 | 29.36 | 29.73 | 0.37 |
| Sweden | 58761 | 50101 | 18186 | 1.000 | 1.000 | 35.84 | 36.30 | 0.45 |
| United Kingdom | 577084 | 196933 | 12752 | 1.000 | 1.000 | 6.39 | 6.48 | 0.08 |
| Iceland | 4028 | 4749 | 4151 | 0.754 | 1.000 | 86.31 | 87.41 | 1.09 |
| Norway | 57222 | 30409 | 13794 | 1.000 | 1.000 | 44.79 | 45.36 | 0.57 |
| Sum EEA | 4479640 | 1641226 | 219566 | - | - | - | - | - |

## 5. Conclusions

The EU member states have been shown to be sensitive to the issue of climate change, adhering to the Kyoto Protocol in 1997, giving off the 20-20-20 Climate and Energy Package in 2009 and finally approving new objectives up to 2030: a 40% reduction of GHG emissions and an Increase of 27% for renewables and energy efficiency. Following an agreement with the EU, also Iceland and Norway participating in the fulfillment of the joint European commitments. The transition to a low-intensity carbon economy involves costs due to adaptation actions of transport systems and energy production and use. However, among the indirect benefits we have to consider the possibility of increasing the competitiveness of the industrial sector, to reduce energy dependency on non-European countries, to increase the GDP and create new jobs in the renewable energy and energy efficiency. The commitment of the states of the EEA has produced results of the emission reduction that exceeded expectations: in 2014, greenhouse gas emissions were down by about 23% compared with 1990 levels; renewable energy consumption accounts for a 13.4% share of the EEA's gross inland energy consumption. On the contrary a reduction of the total energy consumption of about 4% is still not satisfactory. The joint fulfillment of commitments of the EEA members allowed to obtain results oriented to sustainable growth. However, the thirty nations of the sample considered, although part of a geographic area relatively little extended, will greatly differ in climate, morphology and industrial development. So, in the first part of the work we applied the DEA model to evaluate which nations are efficient (or inefficient) from the point of view of energy consumption and control of GHG emissions, given its level of economic and social development. Denmark, Germany, France, Italy, Hungary, Malta, Poland, Romania, Sweden and United Kingdom show maximum efficiency (equal to 1) throughout the period considered, from 1995 to 2014. Ireland, Greece, Spain, Croatia, Latvia, Portugal and Norway assume high efficiency values (between 0.9 and 1) for all the time interval observed. Cyprus, Luxembourg, Netherlands, Slovenia and Slovakia also have lower efficiencies of 0.9 but still growing over the years. Conversely Belgium, Bulgaria, Czech Republic, Estonia, Lithuania, Austria, Finland and Iceland are characterized by a negative change in efficiency over time, their performance in terms of emissions and energy consumption is the worse in the sample. We may also note that in 2014 the lowest efficiency values are recorded precisely for Finland, Czech Republic and Estonia. In the second part of our work we have applied the ZSG-DEA reallocation to determine the values of GHG emissions, total energy consumption and renewable energy consumption over different countries (emissions, total energy consumption and renewable energy consumption) that make the system globally efficient, fixed the outputs. All countries achieve unitary efficiency if the emissions of particularly inefficient countries decrease (-58.3% in Estonia, -38.6% in the Czech Republic, Finland -37.5%, -21.9% in Iceland, -20.4 in Slovenia, etc) and emissions of the most efficient countries increase (+ 0.6% in Spain, + 3.7% in Denmark, Germany, Ireland, Greece, France, Croatia, Italy, etc.). Same goes for the reallocation of the total energy consumption and renewable energy, respectively -57.6% and -58.2 for Estonia, -37.6% and -38.4% for the Czech Republic, -20.6% and -21.6 for Iceland, etc. The Countries that are already efficient can increase their consumption of + 5.3% and + 4.0% respectively. In addition, as a result of a more efficient reallocation of consumption, all Countries report an increase in the share of renewables. Finally, since this study used only European data for the analyses, it is possible that future research with a greater set of Countries will determine the relationship between the economic efficiency and the efforts in sustainable development and their associated policy implications more precisely.

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