European Union energy policy for sustainable development

Nonlinear distribution proposed for EU's 20-20-20 energy goals

Alfredo Tolón Becerra
atolon@ual.es
Xavier Lastra Bravo
xlastra@ual.es
Francisco Javier Piñero Contreras
Silvestre Fernández Montero

Departamento de Ingeniería Rural. Universidad de Almería

Recibido: 6 de Septiembre de 2011
Enviado a evaluar: 7 de Septiembre de 2011
Aceptado: 5 de Octubre de 2011

ABSTRACT

There is worldwide concern for the high consumption of energy from fossil fuels, the limited fossil fuel resources, the climate change and global warming and their possible long-term consequences and the population growth. Even more when energy is the main intermediate good necessary for economic growth and development in any country. This usually translates into better quality of life, and thereby, higher primary energy consumption in all sectors, transport, industry, services, household, etc. In this context, the European Union (EU) seeks to reach a balance between sustainable development, competitiveness and secure supply. The current EU energy policy is based on three interrelated pillars or basic goals: the promotion of energy efficiency, the application of greenhouse gas mitigation policies and the increase of share of energy from renewable energy sources. In this paper, a methodology for nonlinear distribution of dynamic targets is proposed and applied to EU energy policy goals.

Palabras clave: Combustibles fósiles, Unión Europea (UE), Política energética, objetivos energéticos 20-20-20.

Política energética de la Unión Europea para un desarrollo sostenible

Propuesta de distribución no lineal de los objetivos energéticos 20-20-20 de la UE

RESUMEN

A nivel mundial, existe una preocupación por el alto consumo de energía procedente de combustibles fósiles, los limitados recursos fósiles, el cambio climático y el calentamiento global y sus posibles consecuencias a largo plazo, y el crecimiento de la población. Más aún cuando la energía es el principal insumo para el desarrollo y el crecimiento económico de todos los países, que se traduce generalmente en una mayor calidad de vida, y por lo tanto en un mayor consumo de energía primaria en todos los sectores: transporte, industria, servicios, doméstico, etc. En este contexto, la Unión Europea (UE) busca alcanzar un equilibrio entre el desarrollo sostenible, la competitividad y la seguridad de abastecimiento. La actual política energética de la UE se basa en tres pilares interrelacionados u objetivos básicos: la promoción de la eficiencia energética, la aplicación de políticas de mitigación de gases de efecto invernadero y el aumento de la cuota de energía procedente de fuentes renovables. En este trabajo, se propone una metodología para la distribución no lineal de los objetivos dinámicos, y que es aplicada a los objetivos de la política energética.

Keywords: Fossil fuel resources, European Union (EU), energy policy, 20-20-20 energy goals.

Politique energétique de l'Union Européenne pour le développement durable
Proposition de distribution non-linéaire des objectifs énergétiques 20-20-20 de l'UE

RESUMÉ

Au niveau mondial, on s'inquiète de la forte consommation d'énergie provenant des combustibles fossiles, des ressources fossiles limitées, du changement climatique et du réchauffement climatique et ses éventuelles conséquences à long terme, et de la croissance de la population. Surtout quand l'énergie est le principal élément pour le développement et la croissance de tous les pays, ce qui aboutit généralement à une meilleure qualité de vie, et donc à une consommation plus élevée d'énergie primaire dans tous les secteurs: transport, industrie, services, domestiques, etc .. Dans ce contexte, l'Union européenne (UE) vise à atteindre un équilibre entre le développement durable, la compétitivité et la sécurité d'approvisionnement. La politique énergétique actuelle de l'UE est basée sur trois piliers interdépendants ou objectifs: la promotion de l'efficacité énergétique, la mise en œuvre des politiques visant à atténuer les gaz à effet de serre et l´augmentation de la part d'énergie provenant de sources renouvelables. Dans cet étude, nous proposons une méthodologie pour la répartition non-linéaire des objectifs dynamiques, appliquée à des objectifs de politique énergétique.

Mots clé: Combustibles fósiles, Union européenne (UE), politique énergétique, objectifs énergétics 20-20-20

1. ENERGY FOR SUSTAINABLE DEVELOPMENT

There is worldwide concern for the high consumption of energy from fossil fuels, the limited fossil fuel resources, the climate change and global warming and their possible long-term consequences and the population growth (Vera and Langlois, 2007; Omer, 2008a; Schreyer and Mez, 2008), which require cleaner, more secure energy sources in keeping with the search for sustainable development (Rosen, 1996; Dincer and Rosen, 1998; Dincer, 1999; Lidula et al., 2007). Omer (2008b) defines sustainable energy as energy, production and consumption which have a minimum negative impact on human health and the healthy functioning of vital ecological systems, including the environment in general.

Also, energy is the main intermediate good necessary for socio-economic growth and development in any country. This usually translates into better quality of life, and thereby, higher primary energy consumption in all sectors, transport, industry, services, household, etc. (Abulfotuh, 2007). In addition, quality of life is usually represented as proportional to the use of energy per capita in each country, and therefore, the energy demand is expected to increase at a faster rate in upcoming years (WRI, 1994). At the same time, urban areas depend on sources of commercial energy and rural areas on non-commercial sources (e.g., firewood and agricultural waste), and consequently, their sustainability is an important factor that must be dealt with (Omer, 2008a).

Regarding to global warming, or the greenhouse effect, this is the consequence of increasing concentrations of CO_2, CFC_S, CH_4, N_2O, halons, ozone and peroxyacetylnitrate in the atmosphere, which in turn, increase the way in which these gases trap heat irradiated by the Earth's surface, raising the temperature on Earth (Dincer and Rosen, 1999). Water vapour is the most important greenhouse gas (GHG) effect, followed by CO_2 (Omer, 2008b). The emission and accumulation of GHG in the atmosphere is the product of world technological progress and development (Omer, 2008a; Sari and Soytas, 2009), and is probably the most important environmental problem caused by energy-related activities (Dincer and Rosen, 1999; EC, 2009). In 2006, 80% of the GHG in the EU-27 were from energy-related activities (EC, 2009).

According to economic theory, the strong relationship between energy use and economic activity is that energy, along with capital and labour, is a factor necessary for entering into production, and therefore, one of the main motors of economic growth (Kemmler and Spreng, 2007). In this sense, the term "energy efficiency" measures the relationship among an output of performance, service, goods or energy, and an input of energy (European Parliament and European Council, 2006). This term is much used in public policy, but has different meanings depending on the organisation or institution that develops it. Oikonomou et al. (2009) shows that in some policies improvement in energy efficiency is an environmental goal with strong assumptions about the rational use of energy resources by final users and their capacity for response to its cost. Such ex-ante assumptions must be verified with ex-post statistical data, as acquired. Faced with the many barriers present in a given geographic area, energy efficiency policies and programmes work better if they are integrated in market transformation strategies (Geller and Nadel, 1994). Herring (1999) suggests that a more effective way to reduce energy consumption is by taxing it, even though this involves an economic cost to society.

On the other hand, studies have been conducted in order to measure the relationship between GHG emissions reduction and economic growth. For example, it has been established that in the long-term there does not exist a balanced relationship between energy consumption, labour, and income (Sari and Soytas, 2009), therefore, reduction in energy consumption, by not damaging economic growth, can constitute an efficient tool for the reduction of CO_2 emissions. Moreover, it has been determined that there exists a statistically significant non-linear relationship between CO2 emissions and income and a positive relationship between electricity consumption and CO_2 emissions, in the countries of the ASEAN-five (Lean and Smyth, 2010).

Moreover, new technologies have been analyzed and developed in order to reduce GHG emissions by increasing efficiency in energy production. Among these are combined cycle, using gas and steam turbines in oil-fired plants. Implementation of this system in Singapore made it possible to increase efficiency in oil-fired plants by 38-44% in the period of 2000-2006, with an approximate reduction of CO_2 emissions of 16% (Thavasi and Ramakrishna, 2009). Another option is repowering fossil fuel power plants by means of gas turbines, which reduce CO_2 emissions by between 10 and 30% in existing power plants with a cost under 20 € tCO_2 (Escosa and Romeo, 2009).

A clean energy system would reduce GHG emissions by 10.2% by the year 2050 in comparison with levels from the year 2000 according with the 100% renewable-energy system strategy developed by Denmark (Jagoda et al., 2011). The use of biofuels in transport is another option for reducing GHG emissions. For example, in Sweden it was estimated that the current production of ethanol derived from wheat can reduce GHG emissions by 80% in comparison with gasoline (Andrews-Speed, 2009). In a study of the substitution of fossil fuels for bioenergy conducted in Austria (Lund, 2009), it was determined that at a price of CO_2 of 0€ tCO_2-1, emissions are reduced by 2.71 MtCO2 y-1 (3% of total CO2 emissions in Austria), and if the price is increased to 100€ tCO_2-1, they are reduced 5.64 $MtCO_2$ y^{-1} (6.27%).

In addition, the use of renewable energy sources (RES) is closely linked to sustainable development, because a sustainable supply of energy resources, which must be used effectively and efficiently, is required for it, as well as for progress in environmental problems (Dincer, 1999; Omer, 2008a). RES is a sustainable resource available in the long term in a simple long-lasting manner, found at a reasonable cost and that can be used for any task without causing negative effects (Dincer, 1999; Charters, 2001). Several technologies are available for the production of clean, efficient, reliable energy from long-term renewable resources (Abulfotuh, 2007; Omer, 2008a). The most common are wind, solar and hydropower, and in recent years, the use of biomass, biogas, and geothermal have increased. There are also other sources, such as tidal and wave and hydrogen (Abulfotuh, 2007; Omer, 2008a; Jagoda et al., 2011). But its production has some negative impacts that must be resolved for a balanced view of its virtues and deficiencies (Abbasi and Abbasi, 2000).

But, only a strategy of increasing the use of RES does not alone ensure that a sustainable energy system can be achieved (Schreyer and Mez, 2008). The pros and cons have to be determined in order to lay out strategies that make it possible to achieve a sustainable energy supply; that is, that a balance is reached in economic, social and environmental matters. Positive points in the use of RES are the increased diversity in energy supply options, both for developed and developing countries (Charters, 2001; Lund, 2009; Jagoda et al., 2011), less dependence on fossil fuels (Jagoda et al., 2011), contribution to net employment, creation of export markets (Lund, 2009; Cansino et al., 2010) and contribution to reduction in greenhouse gases emissions and climate change (Charters, 2001; Sims et al., 2003; Schreyer and Mez, 2008; Dijkman et al., 2010; Jagoda et al., 2011). The EU estimates a 600-900-mtonne annual reduction in CO2 emissions if the 200–300 mtonne annual fossil fuels consumption is replaced by RES (Cansino et al., 2010). Schreyer and Mez (2008) also point out that RES can reduce emissions by 24%.

On the other hand, despite the RES represent a huge energy potential, much greater than equivalent fossil resources, it is not their magnitude which is the key limitation, but their nature, since they are usually diffused and not fully accessible, and some are even intermittent (Dincer, 1999), and vary widely among regions (Dincer, 1999; Cansino et al., 2010). Furthermore, fuel and power generation from RES requires that a surface be available for it, and competition with food production must be prevented or reduced to the minimum by efficient production (Dijkman et al., 2010).

Economically, the cost of the original investment in each RES is one of the main impediments to their development (Jagoda et al., 2011). One of the most economical technologies is small hydropower, which has a long lifetime and relatively low operation and maintenance costs (EREC, 2008). In Europe, geothermal energy is also an economical option for power generation and not only where there are high ground temperatures (IPCC, 2001). In addition, Solar and wind energy are amongst the most economical renewable energy systems for commercial use and large-scale applications (Abulfotuh, 2007). And the use of solar energy to supplement daily electricity requirements, has such advantages as avoiding consuming resources and degrading the environment with polluting emissions, oil spills or toxic products (Omer, 2008a). Also, solar energy (both photovoltaic and solar thermal) is becoming increasingly popular for small businesses, and wind energy is attractive for medium businesses (Jagoda et al., 2011).

Among the main challenges to RES development and competitive installation are to reduce their high cost (IPCC, 2001; EC, 2007a; Schreyer and Mez, 2008; Lund, 2009), increase financing for research and infrastructures, especially large-scale facilities (IPCC, 2001; EC, 2007a; Schreyer and Mez, 2008; Jagoda et al., 2011), improve the grid infrastructure, develop storage mechanisms and incentivise innovation by small and medium businesses (Kranz et al., 2006; Schreyer and Mez, 2008). In addition, promote competitive fossil and renewable energy systems simultaneously (Kranz et al., 2006), train more technicians and specialists (Kranz et al., 2006; Schreyer and Mez, 2008), create proper market mechanisms to build a real internal market for green power (Schreyer and Mez, 2008; Jagoda et al., 2011), facilitate export (Kranz et al., 2006; Schreyer and Mez, 2008) is needed. And, simplify administrative procedures and improve institutional and economic agreements (IPCC, 2001; EC, 2007a; Schreyer and Mez, 2008) through greater interaction between technology and politics that incentivise and improve access to RES on the power market (DEFRA, 2002, Kranz et al., 2006, Omer, 2008a).

Regarding to society, a greater social acceptance of the RES must be improved (Kranz et al., 2006; Schreyer and Mez, 2008) and any local impact be reduced (IPCC, 2001). Omer (2008a) believes that RES are environmentally-friendly when they are developed sensibly and appropriately, and have the complete participation of local communities. Valle Costa et al. (2008) believe that regardless of the mechanism applied to promote RES, political support and interest and participation by local and regional stakeholders condition the success or failure of their promotion. It is therefore important to include any use of RES in urban and regional planning (Schreyer and Mez, 2008).

2. EUROPEAN UNION ENERGY POLICY: 20-20-20 GOALS

The European Union (EU) energy policy seeks to reach a balance between sustainable development, competiveness and secure supply (EU, 2006), based on three interrelated pillars or basic goals. They are the promotion of energy efficiency and the use of renewable energies, the application of greenhouse gas (GHG) mitigation policies and the reduction of air pollution and other directives and documents directed at the energy sector (Hernández et al., 2004; Streimikiene and Šivickas, 2008). EU energy policy is in agreement with government policies implemented around the world in incorporating energy efficiency and energy savings in its work programmes for facing a series of challenges that include the perception of resource shortages, high cost of energy, secure energy supply and environmental protection (Schreyer and Mez, 2008; Andrews-Speed, 2009). Furthermore Jaccard and Mao (2002) believe that policies designed to increase security of energy supply, promotion of RES and cogeneration and increase of end-use energy efficiency have a positive impact on GHG mitigation. And, for the EU, possibly the only energy policy that contributes to all of the basic goals of its energy policy is the promotion of energy efficiency, because it has a direct relationship with the reduction of GHG emissions and the mitigation of climate change, management of energy security, lowering the cost of consumer energy services and improvement of economic competitiveness (Omer, 2008a; EC, 2009). The importance of energy efficiency policies in achieving sustainable development stresses the question of how to make these policies the most effective possible (Varone and Aebischer, 2001).

In general, the instruments applied to date for promoting RES in EU Member States (United Kingdom, Germany, Norway, Belgium, Spain, the Netherlands, among others) have been positive, but their short period of application does not allow definite conclusions to be made about their effectiveness (Cansino et al., 2010). Mechanisms such as government subsidies for RES, tax exemptions, rebates on taxes, tax refunds, soft loans, feed-in-tariffs by applying lower tax rates on activities promoted or penalisation of non-renewable sources have been effective up to now in promoting their use and application because they make it possible to compensate their high cost, promoting their penetration in the power market and benefiting the environment (Kranz et al., 2006; EC, 2007; Lund, 2009; Cansino et al., 2010; Jagoda et al., 2011). But an analysis of the effects of applying these mechanisms is necessary, not only with regard to power, but also industry and trade, for a greater consensus on their benefit (Lund, 2009; Jagoda et al., 2011). Fiscal incentives are beneficial when applied on a large scale (EU, OECD), but nationally, different policies, availability of RES and agreements make their implantation difficult (Cansino et al., 2010).

The EU-RES market has an annual business volume of 15 million Euros, equivalent to half of the world market, in which the EU is a leading exporter, and employs around 300 000 people (EU, 2006). According to estimates, renewable energy resources have the potential for supplying about one third of the electricity demand by 2020, and currently satisfy around 20% of the electricity requirements in Denmark, 8% in Spain and 6% in Germany (EU, 2007b). Furthermore, the EU is the second largest power market in the world with 450 million consumers, and is the worldwide leader in demand management, promotion of new and renewable energy forms, and development of low CO2 emissions technologies, thus becoming the ideal region for leading the worldwide search for energy solutions people (EU, 2006). But in spite of these data, the contribution of renewable energies continues to be relatively low, only 6% in 2000, and is not expected to surpass 8% to 10% of total consumption in 2010 (EU, 2005; EU, 2007b).

The European Commission, in its Green Paper on Energy Efficiency, or Doing More with Less (EU, 2005), stressed:

- A potential for energy savings in the EU of 20%. It opened debate on how the EU as a whole could reduce its energy consumption by 20% over projections for the year 2020. This potential savings is equivalent to about 390-400 Mtoe, and would represent a 780-860 Mt reduction in CO_2 emissions (EC, 2006a; EC, 2008a).
- A CO_2 emissions reduction of 60% from 2006 to 2030. To limit the increase in global temperatures predicted to the agreed target of a maximum of two degrees above preindustrial levels, it considered that global GHG emissions would reach their highest point in 2025 at the latest, and, following that point, would be reduced less than 15%, but perhaps as much as 50% below 1990 levels. In the same document, it set an overall strategic goal that would balance the goals of sustainable use of energy, competitiveness and secure supply. A possible CO_2 emissions goal considered was for a minimum level of the combined overall energy in the EU to be generated from secure energy sources with low carbon emissions.
- Several different aspects related to energy efficiency, such as an increased share of renewable energies, fossil fuel-based power production efficiency, more efficient electricity networks, vehicle efficiency, etc., which can only be developed by research and technological development along with regulatory and economic measures.

Aware of this situation, the European Commission issued communication COM(2007)1, which proposed an energy policy for fighting climate change and boosting secure, competitive energy in the EU (EC, 2007b). Based on the Commission proposal, the European Council approved the so-called 20/2b0/20 goals (Council of the European Union, 2007), which have become the strategic goals of EU-27 energy policy (EU-27)[1]. They are:

- Increase energy efficiency to achieve a goal of 20% savings in EU energy consumption, according to the Commission's Green Paper on energy efficiency projection for 2020.
- Reduce greenhouse gas emissions by at least 20% over 1990 by 2020.
- Reach a 20% proportion of renewable energies in overall EU energy consumption by 2020.
- Increase the use of biofuels in transportation to at least 10% of the total fuel (gas-oil and gasoline) consumed in the EU in 2020.

Since these goals were approved, the various regulations, communications and directives passed by the EU on the 20% increase in energy efficiency goal and the

1 The European Union 27 is composed by: Austria, Belgium, Bulgary, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Poland, Portugal, Romania Slovakia, Slovenia, Spain, Sweden, and the United Kingdom.

20% reduction of GHG emissions goal have not specified how to pass it on to each Member State, as it has for its goal of increasing the proportion of renewable energies by 20%. Appendix I of the Directive of the European Parliament and of the Council on the promotion of the use of energy from renewable sources amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC (European Parliament and European Council, 2009), set overall national goals related to the proportion of energy from renewable resources in the final gross energy consumption for 2020, weighted as a function of their GDP and modulated to reflect their different starting situations (Reference year 2005), thereby setting nonlinear objectives for each State.

The specific goals of the various EU energy policy directives are usually evaluated using quantitative indicators (Streimikiene and Šivickas, 2008). Svensson et al. (2006) state that the importance, weight and priority of a policy's various impact categories, expressed as an indicator, depend on their values and are political, not scientific, and can change according to the political agenda.

Energy efficiency is quantifying by "energy intensity" indicator (Kemmler and Spreng, 2007; EC, 2009; European Communities, 2011). Energy intensity (EI) measures the energy consumption of an economy and its global energy efficiency, and therefore, if an economy becomes more efficient in its use of energy and its gross domestic product remains constant, the values of this indicator will go down (Vera and Langlois, 2007), understanding that there is an energy consumption situation that tends toward sustainability. EI is defined as the ratio of Gross Inland Consumption of Energy (GIC) to Gross Domestic Product (GDP) (EC, 2011). EI indicator has been used in several comparative analyses of the situation as it has of worldwide energy evolution (Mielnik and Goldemberg, 2000; Sun, 2002, 2003; Alcántara and Duro, 2004; Ang and Liu, 2006; Markandya et al., 2006; Baksi and Green, 2007; Ezcurra, 2007; Le Pen and Sévi, 2010; Liddle, 2010; Mendiluce et al., 2010).

The total emissions of all greenhouse gases are expressed in CO_2 equivalent, in sectors 1-7, excluding 5 - LULUCF (land use, land use change and forestry) (EEA, 2009). CO_2 intensity is defined as the ratio between total CO_2 equivalent emissions and gross inland energy consumption (GIC), and is an indicator of the carbon intensity of the energy system (EC, 2008), and this ratio is measured in tonnes of CO_2 equivalent per tonnes oil equivalent (t of CO2 toe of GIC-1) (European Commission, 2008).

The energy from renewable sources is the sum of the final consumption of renewables for heat production (including the final consumption of district heat from renewables), the gross electricity generation from renewables, and liquid biofuels for transport; and the gross final consumption of energy is the final energy consumption (industry, transport, other sectors) of all energy sources, including consumption of the energy branch and distribution losses for electricity and heat production. Therefore, the share of renewables to gross final consumption of energy (GFC) is the energy from renewable sources divided by the gross final consumption of energy (EC, 2006b; European Parliament and European Council, 2009), expressed as a percentage (%). The final energy consumption (FEC) covers energy supplied to the final consumer's door for all energy uses, and it is calculated as the sum of final energy consumption from all sectors (industry, transport, households, services and agriculture).

3. METHODOLOGY FOR NONLINEAR DISTRIBUTION OF ENERGY GOALS

The directives and regulations that deal with the EU goals of reducing the gross inland consumption by 20% and reducing GHG emissions by 20%, do not specify how this goal is to be transferred to each country, so each state might consider its goal is to lower the gross inland consumption or the GHG emissions within its territory by 20%. Although a common goal is politically less costly, we believe that it is also more unfair, because countries that consume energy less efficiently would be benefited over those which have made a greater effort to make their continued economic growth more energy efficient.

Hernández et al. (2004) believe that for a future coherent energy policy, Member States must actively participate in the United Nations Conferences on Climate Change, and define a clear, but flexible position on integrating European goals in national and regional goals. In this sense, setting thresholds and quantitative targets can help catalyse the efforts of the different actors involved in reaching a higher share of energy from renewable sources, and the more ambitious those quantitative targets are, the stronger their effect on policy making and execution of energy efficiency programmes is. Hull et al. (2009) recommend more local data collection for the best modelling possible of the future impact of energy efficiency policies in the EU, and also monitoring progress toward the targets set after applying specific measures.

Therefore, we believe that this reduction should not be so linear for all the member countries on the fair and logical principle that the countries with a lower values in the reference year should not be obligated to reduce it in the same proportion as the rest, especially those with much higher values in the reference year. Based on the stipulations of the EU, the Member States with the highest values in the reference year are those which should make the greatest effort to reduce their gross inland consumption or their GHG emissions.

Regarding to RES, the EU considered two options for setting national targets to distribute economic effort more evenly among the Member States 1) based on the RES potential of each country, and 2) an equally shared flat-rate increase in the percentage of RES plus a weighted increase based on the GDP. These two options were assessed and the second was chosen as the most respectful of the criteria of equality (EC, 2008b). In this case, the EU Member States with the lowest values in the referent year are those which should make the greatest effort to increase their share of RES.

In addition, milestones should therefore be set which are dynamic and redefined over time, varying according to the geographic area they are for, and found based on the distance from the target to be reached, so all the areas converge at the same point. This way, the coefficient of reduction or increase, if expressed in relative terms of improvement per unit, should vary from 1 (theoretical case of null energy intensity or no consumption; no CO2 intensity or emissions, or a fully renewable energy share) to infinite (hypothetical case of infinite or extremely high energy intensity or consumption, infinite or very high CO2 intensity, or absence of renewable energy share). Malta, the EU-27 Member State which had no RES in GFC in the starting year (2005) is an example of the second case, which the EU has decided should reach a 10% share by 2020. Based on this share assignment, no country should have a share under 10% in 2020.

To provide incentive for reducing EI, CO_2 intensity and for increasing RES share, a methodology is proposed for calculating weighted coefficient targets for decreasing or increasing GIC, GHG emissions and RES share using a reverse logarithmic distribution formula. For policy makers to have several evaluation tools for the goals of the EU energy policy, we propose several ways of weighting the nonlinear function in two geographic scenarios (EU-27 and EU-15[2]).

Table 1. Weighting hypotheses for EU energy policy goals

Gross inland consumption	**GHG emissions**	**Share of ES**
1 Member States that consume primary energy with the highest EI should make the greatest effort to reduce their GIC (weighted as a function of EI) 2 Member States that consume the most primary energy per inhabitant should make the greatest effort to reduce their gross inland consumption (weighted as a function of GIC per capita) 3 Member States that consume the most primary energy and with the highest EI should make the greatest effort to reduce their GIC (weighted as a function of the per capita EI)	1 Member States that have the highest GHG emissions for their primary energy consumption must make the greatest effort at reduction (weighting as a function of CO2 intensity). 2 Member States that have the highest GHG emissions per capita should make the greatest effort to reduce their emissions (weighted as a function of GHG emissions per capita). 3 Member States that have the highest GHG emissions as a function of their GDP should make the greatest reduction effort (weighted as a function of GHG emissions to GDP).	1 Member States that consume the most NRES in the GFC per inhabitant must make the strongest effort to increase their energy from renewable sources (weighted as a function of NRES in GFC per capita). 2 Member States that consume the most NRES in the GFC per euro GDP must make the strongest effort to increase their energy from renewable sources (weighted as a function of NRES in GFC per GDP). 3 Member States that have the most material wealth per inhabitant must make the strongest effort to increase their energy from renewable sources (weighted as a function of GDP per capita).

2 The European Union 27 is composed by: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden, and the United Kingdom.

The starting premise of the proposed methodology for reaching the EU goals of reducing the GIC and reducing the GHG emissions by 20%, was the EU-GIC in 2020 is equal to EU-GIC in the reference year by a total residual coefficient, complementary to the reduction coefficient. EU-GIC is the sum of the gross inland consumption in each of the geographic units GICi. The residual coefficient for EU is equal to 0.8 for both goals. For each Member States a residual coefficient was calculated using a reverse logarithmic distribution formula based on the relative indicators of each hypothesis. In addition, a weighting factor modulating the residual coefficients was calculated for each of the relativising hypotheses and in each of the total geographic areas considered, with which the residual coefficients for each member country under each hypothesis and scenario are obtained.

4. RESULTS OF THE NONLINEAR DISTRIBUTION METHODOLOGY APPLIED TO EU'S 20-20-20 ENERGY GOALS

1. 20% SAVINGS IN EU ENERGY CONSUMPTION IN THE PERIOD 2005-2020

The GIC reduction goals for the year 2020 in each member country were found by applying the methodology proposed to each of the countries in the EU-27 and EU-15 as a function of the EI in the starting year 2005 (Table 2). The higher the original EI in each country is the higher its reduction coefficient, as may be seen in Bulgary, with 40.25% in the case of the EU-27 and Finland with 22.87% in the EU-15. It may be observed that all of the EU-15 countries, with the exception of Portugal, Belgium and Finland, have lower reduction rates than the countries that have joined since 2004, because of their greater energy efficiency as a function of the EI, according to the measurement and evaluation parameters set by EU energy policy.

The results found in each country are different in each of the geographic aggregation scenarios (EU-27 and EU-15). For example, in Spain, the reduction would be greater when only the EU-15 countries are considered (22.64% compared to 20.39%). The reductions in each of the two geographic scenarios did not show any significant differences, remaining close to 20% (23.70±8.22% in the EU-27 and 20.13±3.77% in the EU-15.) However, wide variation is observed in the reduction rates of the EU-27 countries, with results like Ireland, which must reduce its GIC by half the percentage of the whole EU, and Bulgary, which must double it.

According to this hypothesis, countries with a relatively low GDP in 2005, such as Bulgary, Romania, Slovakia, Estonia, Czech Republic and Lithuania should make a greater effort to meet the EU goal, even though they are not the countries that consume the most primary energy. These results stress the differences from the most industrialised countries, which in general have lower reduction rates due to their higher energy efficiency, measured as a function of energy intensity.

With the methodology applied, there would be considerably less heterogeneity in the EI of the member countries in 2020, according to the results found with Hypothesis 1. The mean EI in 2020 for the EU-27 is 110.65±39.35 and for the EU-15, 85.80±39.35 toe M€05-1. The reduction in its EI stresses that countries like Romania, Bulgary, Slovakia and Estonia, with a reduction in their gross inland consumption of 40.25, 36.39, 35.62 and 34.76% would reduce their EI by 81.68, 78.51, 76.76 and 75.38%. These figures are influenced by a significant increase in their GDP, but are only orientative because the GDP used for their calculation is constant from 2005.

Table 2. Reduction percentages in the three hypotheses for energy consumption

IE			**GIC per capita**			**GIC to PIB**		
	EU-27	EU-15		EU-27	EU-15		EU-27	EU-15
Bulgary	40.3		Luxembourg	28.5	28.0	Malta	48.4	
Romania	36.4		Finland	25.0	24.5	Estonia	47.9	
Slovakia	35.6		Belgium	24.0	23.4	Luxembourg	47.2	48.9
Estonia	34.8		Sweden	23.8	23.2	Cyprus	45.8	
Czech R.	34.6		Netherlands	22.7	22.1	Latvia	43.1	
Lithuania	32.0		Czech R.	21.4		Bulgary	42.8	
Hungary	31.0		France	21.4	20.8	Slovenia	42.7	
Poland	30.8		Germany	20.9	20.3	Lithuania	42.6	
Latvia	28.6		Austria	20.9	20.3	Slovakia	42.2	
Slovenia	25.7		Estonia	20.8		Czech R.	38.2	
Finland	22.9	25.0	U. Kingdom	20.2	19.6	Finland	36.5	38.5
Belgium	22.4	24.6	Ireland	19.7	19.1	Hungary	36.4	
Malta	21.6		Slovenia	19.6		Romania	34.9	
Portugal	21.6	23.8	Denmark	19.5	18.9	Ireland	33.4	35.5
Cyprus	21.4		Slovakia	19.3		Belgium	31.9	34.1
Spain	20.4	22.6	Spain	18.8	18.1	Portugal	31.4	33.6
Greece	19.6	21.8	Cyprus	18.6		Denmark	31.3	33.5
Netherlands	19.6	21.8	Italy	18.3	17.7	Sweden	31.0	33.3
Luxembourg	19.1	21.4	Greece	17.0	16.4	Austria	30.9	33.1
France	18.9	21.2	Hungary	16.8		Greece	30.1	32.4
Sweden	18.3	20.6	Bulgary	16.0		Poland	27.2	
Germany	17.6	19.9	Portugal	16.0	15.3	Netherlands	27.2	29.6
Austria	16.4	18.8	Lithuania	15.7		Spain	19.3	21.9
Italy	16.3	18.6	Poland	15.5		France	14.5	17.3
U. Kingdom	13.6	16.0	Malta	15.0		Italy	13.5	16.3
Ireland	10.7	13.2	Latvia	12.9		U. Kingdom	11.4	14.3
Denmark	10.0	12.6	Romania	12.1		Germany	10.5	13.4

As a function of the GIC per capita, the differences in reduction between the EU-27 (19.26±3.74%) and the EU-15 (20.50±3.31%) are not significant, both are different from the means based on the EI, as the mean in the EU-27 geographic scenario is closer and in the EU-15 farther from the EU 20% reduction goal. The reduction rates found for the EU-15 countries in the two EU geographic scenarios do not show major differences and a lower reduction percentage is only observed in the EU-27 scenario (Table 2).

By country, Bulgary, the Member State which must make the greatest effort to reduce its energy consumption based on the EI, would only have to make a 16.06%

reduction based on the GIC per capita. On the contrary, Romania had the lowest reduction percentage based on the GIC per capita (12.06%), but when based on the EI it would have to do so by 36.39%. In the case of Luxembourg also, which had a lower reduction percentage (19.12%) than the EU-27 as a function of the EI, as the country which consumes the most primary energy per capita, based on this indicator would have to reduce it by 28.54%, and therefore, the energy efficiency policies to be implemented in this country must be directed mainly at reducing its GIC per capita. Finland is the EU-15 country which must reduce its GIC the most based on the EI (22.87%), and the second based on the GIC per capita (25.01%), although no significant variation is observed in its values. The most variation in the reduction rates, as a function of EI or GIC per capita is observed in Portugal, 21.59% vs. 15.97%, respectively, Luxembourg, 19.12 vs. 28.54%, Denmark, 10.04 vs. 19.53%, and Ireland, 10.68 vs. 19.65%.

The dispersion in GIC per capita based on the reduction rates calculated would be reduced by 2020 to 2.90±1.00 toe inh-1 for the EU-27, and 3.32±1.12 toe inh-1 for the EU-15 scenario. In this hypothesis, the dispersion is greater among the EU-15 countries because the lowest reduction rates were found for the countries that have joined since 2004.

As a function of per capita EI, the reductions found express differences with the other hypotheses, by being much higher than with the other weightings in both geographic scenarios, with 33.05±11.31% for the EU-27 and 29.03±10.19% for the EU-15. Of the EU-27, only Germany (10.49%), the United Kingdom (11.42%), Italy (13.49%), France (14.49%) and Spain (19.31%), the countries with the highest populations, and representing all together 62% of the EU population, had reduction rates below 20% (Table 2), demonstrating the population effect. On the contrary, countries with lower populations (Malta, Estonia, Luxembourg, Cyprus, Latvia, Slovenia and Lithuania) had higher reduction rates. Of the EU-15, Luxembourg, Finland and Ireland, the three countries with the lowest populations had the highest reduction rates, 48.92%, 38.52% and 35.50%, respectively. These results are coherent with those found in the EU-27 scenario.

An analysis of the EI expected for 2020 based on the reduction rates calculated shows that they are higher in all the countries than the per capita EI in the EU-27 (0.18 Mtoe $€_{05}^{-1}$ inh^{-1}). The most developed countries with the highest populations in the EU, Germany, the United Kingdom, Italy, France and Spain, have the best results, with an expected per capita EI in 2020 of 1.30, 1.23, 1.42, 1.48 and 1.62 Mtoe $€_{05}^{-1}$ inh^{-1}. The mean per capita EI in the EU-27 and was 25.75±35.96 Mtoe $€_{05}^{-1}$ inh^{-1} in the EU-27 and 11.20±20.97 in the EU-15. In both results, the high dispersion observed among the countries is maintained over time but is lower than in the starting year. Poland is the only country that joined since 2004 which according to the results (3.80 Mtoe $€_{05}^{-1}$ inh^{-1}), will have a low per capita EI, only higher than the most developed countries. In general, all of the countries in the EU-15, except for Luxembourg and Finland have a per capita EI lower than those that have joined since 2004.

2. 20% REDUCTION OF GHG EMISSIONS IN THE PERIOD 1990-2020

Target GHG reductions for 2020 were found for each of the EU-27 and EU-15 member countries by applying the methodology proposed using CO_2 intensity in 1990 (Table 3). The reduction coefficients for each of the countries are higher the higher their initial CO_2 intensity is, as can be observed for Ireland, with 24.27% for the EU-27 and 24.76% for the EU-15. The absolute GHG emissions in each country are reduced unequally but in such a way that the total allows the EU goal of 20% to be reached. Sweden, Finland and France had lower reduction percentages of 11.18, 16.56 and 16.72, respectively. Of the countries that joined the EU in 2004, Poland must reduce GHG emissions the most with 22.79%.

Also, the results are different for each country in each of the geographic scenarios (EU-27 and EU-15). For example, the reduction in Spain would be larger when only EU-15 countries are taken into consideration (19.40% compared to 19.96). The mean reductions for two geographic scenarios in the EU do not show significant differences, and are slightly less than 20% (19.99±2.43% in the EU-27 and 19.93±3.01% in the EU-15). But among the reduction percentages in the member countries in the EU-27, there are differences, with results that go from 11.18% in Sweden to 24.27% in Ireland. Comparing the results for the EU-15 countries in the two geographic scenarios, differences are not significant, although they are slightly higher in the EU-15, and there is a difference of 0.52±0.02 percentage points between the reduction percentages in the EU-27 and EU-15.

Comparing the results based on CO_2 intensity with those found as a function of GHG emissions per capita (Table 3), significant differences are found in the results. Although no inverse behaviour is observed in the results based on the GHG emissions per capita, there are appreciable differences in the reduction percentages in most of the countries, such as Luxembourg, Sweden, Estonia, Finland, Belgium and Netherlands, which increase their reduction percentages by 7.28, 5.60, 4.82, 4.77, 2.64 and 2.12 percentage points, respectively, and on the contrary, Malta, Portugal, Greece, Spain, Poland, Cyprus, Romania, Italy, Hungary, Slovenia and Ireland reduced them by 7.09, 6.85, 4.39, 3.83, 2.84, 2.71, 2.67, 2.38, 2.20, 2.17 and 2.10 percentage points respectively, compared to the results based on CO_2 intensity (Table 5). There is no significant difference between the mean reduction for the EU-27 (19.73±3.30) and EU-15 (19.90±3.43), and the reduction for the whole EU is 20%.

Analysing the results by countries, Luxembourg is the Member State which should make the greatest effort (28.01%), according to these criteria. On the contrary, Malta had the lowest reduction percentage based on GHG emissions per capita (13.14%), when based on CO_2 intensity, it was 20.23%. These results show that population has no direct effect on the reduction percentages, since the least populated countries are at opposite extremes.

When the results based on the GHG emissions to GDP ratio are compared to those based on the other two relative indicators used in this study (Table 3), completely different behaviour is observed in the reduction percentages in the EU countries. The reductions found are larger than the other weighted reductions found for the two geographic scenarios, with 22.29±8.71% for the EU-27 and 20.30±3.76% for the EU-15. In the results for the EU-27 countries, the effect of the GDP is noticed, because the more industrialised countries (EU-15) have the lowest reduction percentages. Of the EU-15 countries, only Sweden (13.32%), France (16.52%), Italy (16.77%), Austria (16.94%), Denmark (17.30%) and Spain (18.53%) had reduction percentages below 20% (Table 3).

Table 3. Reduction percentages in the three hypotheses for GHG emissions

CO2 intensity				**GHG per capita**			**GHG to GDP**	
	EU-27	EU-15		EU-27	EU-15		EU-27	EU-15
Ireland	24.3	24.8	Luxembourg	28.0	28.1	Bulgary	38.6	
Greece	23.1	23.6	Estonia	26.2		Estonia	37.7	
Poland	22.8		Czech R.	23.6		Romania	34.5	
Bulgary	22.0		Ireland	22.2	22.3	Poland	33.9	
Czech R.	21.8		Germany	22.0	22.1	Slovakia	32.8	
Romania	21.4		Belgium	21.4	21.5	Lithuania	32.1	
Estonia	21.4		Finland	21.3	21.5	Czech R.	31.5	
Denmark	21.2	21.7	Netherlands	21.3	21.5	Latvia	30.5	
Luxembourg	20.7	21.2	Slovakia	21.1		Hungary	27.4	
U. Kingdom	20.6	21.2	U. Kingdom	20.9	21.0	Luxembourg	22.5	26.3
Cyprus	20.6		Denmark	20.9	21.0	Slovenia	22.3	
Portugal	20.2	20.8	Bulgary	20.8		Greece	21.8	25.7
Malta	20.2		Lithuania	20.8		Ireland	21.6	25.4
Slovakia	20.2		Poland	20.0		Cyprus	19.1	
Hungary	20.1		Romania	18.7		Malta	19.1	
Germany	20.0	20.5	Greece	18.7	18.8	Germany	18.0	22.1
Italy	19.9	20.4	Austria	18.6	18.7	Belgium	17.7	21.8
Slovenia	19.8		Latvia	18.3		Finland	17.1	21.2
Latvia	19.7		France	18.3	18.4	U. Kingdom	17.0	21.1
Spain	19.4	19.9	Hungary	17.9		Netherlands	17.0	21.1
Austria	19.2	19.7	Cyprus	17.9		Portugal	16.2	20.4
Netherlands	19.2	19.7	Slovenia	17.7		Spain	14.3	18.5
Lithuania	18.9		Italy	17.5	17.6	Denmark	13.0	17.3
Belgium	18.8	19.3	Sweden	16.8	16.9	Austria	12.6	16.9
France	16.7	17.3	Spain	15.6	15.7	Italy	12.4	16.8
Finland	16.6	17.1	Portugal	13.4	13.5	France	12.2	16.5
Sweden	11.2	11.8	Malta	13.1		Sweden	8.8	13.3

Under this hypothesis, Bulgary is the Member State which must reduce its GHG emissions the most (38.55%), followed by Estonia, Romania and Poland (37.67, 34.45, and 33.88%, respectively). In the EU-15 scenario, Luxembourg, Greece and Ireland are the countries with the highest reduction percentages (26.34, 25.65 and 25.43%). These results corroborate the effect of the GDP on the results.

3. 20% SHARE OF RES BY 2020

The results found as a function of NRES in GFC per capita in the starting year, show wider differences than as a function of share of NRES in GFC (Table 4). In general, no direct correspondence between the increase coefficient and the NRES in GFC per capita is observed. But most of the countries do respond positively to the hypothesis posed. Among the countries contrary to the hypothesis is Finland, which in spite of being the country with the second most energy from non-renewable sources consumed per capita, has the second lowest increase coefficient. This result is explained because its share of renewables in GFC in 2005 was high, so the formula produced a coefficient that increases its share over 100%. Sweden, with a value near the mean NRES in GFC per capita in the reference year, had a low increase coefficient, but due to its high original share of RES in GIC, according to the methodology, should have the highest share (94.95%). No direct effect of population is observed due to the differences in absolute amounts of RES in GFC in the starting year.

Weighting this way, most of the countries would have shares similar to those set by the EU (Table 4), except for Sweden, Austria, Portugal, Denmark, Italy, Ireland, Netherlands and Luxembourg. The countries with the lowest increase coefficient were Portugal, Finland and Estonia (1.000, 1.517, and 1.660, respectively), and Luxembourg had the highest coefficient of 43.557. The mean share was 25.31%±19.30, in a range that goes from 10.00% (Malta) to 94.95% (Sweden). The countries that should have the largest shares in 2020, besides Sweden, would be Austria, Denmark and Latvia (67.58, 46.32 and 42.60%, respectively).

As a function of NRES in GFC per capita, Slovakia, the country with the third highest value in 2005, had the highest share in 2020 (75.67%), followed by the Czech Republic (61.94%) and Lithuania (53.41%), as observed in Table 4. Luxembourg and Slovakia and the Czech Republic are the Member States which must increase their RES in GFC, with increase coefficients of 13.881, 13.354 and 11.881, respectively. On the contrary, Sweden (1.380), Portugal (1.406) and Finland (1.515) would have to make less effort. The shares vary in a range from 10.00% in Malta to 75.67% in Slovakia, with a mean of 27.53%±17.22.

Comparing the results found with the other two hypotheses and the shares proposed by the EU (Table 4), most shares are observed to be similar to those of the EU. Exceptions are Lithuania, Spain, Poland, Slovakia, the Czech Republic and Hungary. In general, by this hypothesis, most of the more developed countries, the EU-15 Member States, should make less effort and increase less the energy from renewable energies in the GFC. Luxembourg, the United Kingdom, Netherlands, Belgium, Ireland are the exceptions in this group, with increase coefficients over the mean (4.67±1.38). The irregularity in the absolute amounts of RES in GFC and GDP did not allow a direct effect of the GDP to be observed.

As a function of GDP per capita, Luxembourg, the country with the highest GDP per capita in 2005, had the highest increase coefficient for 2020 (1.881), followed by the United Kingdom and Cyprus with 8.816 and 5.620, respectively (Table 4). On the contrary, Sweden (1.380), Portugal (1.795) and Latvia (1.965) are the Member States that have to make the smallest increase. Sweden, the country with the highest income per capita, had a low increase coefficient. This is because its share was assigned following one of the criteria above of not going over a 100% share. No direct relationship between the GDP per capita and the increase coefficients found is observed, due to the heterogeneity of the RES in GFC.

Table 4 shows that the shares found under this hypothesis were the most similar to those set by the EU, except for Finland, Austria and Denmark, which had shares of over 50%. The shares vary in a range of 10.00% (Malta) to 80.18% (Finland), with a mean of 25.70%±18.85. The mean coefficient was 3.76±2.61, lower than for Hypotheses 2 and 3 and similar to Hypothesis 1.

Table 4. Reduction percentages in the three hypotheses for RES for EU-27 Member States

NRES in GFC per capita		**NRES in GFC to GDP**		**GDP per cápita**	
Portugal	17.0	Sweden	49.8	Sweden	49.8
Finland	38.5	Portugal	23.9	Portugal	30.5
Estonia	21.9	Finland	38.5	Latvia	42.6
Latvia	42.6	Spain	10.8	Slovenia	26.0
Romaniaa	27.8	Austria	33.3	Romaniaa	27.8
Spain	15.5	Denmark	27.0	Estonia	28.0
Slovenia	27.5	Latvia	42.6	Lithuania	25.0
Italy	10.3	France	20.3	France	23.8
Lithuania	25.0	Romaniaa	27.8	Germany	14.8
France	25.8	Estonia	28.0	Spain	18.7
Sweden	95.0	Slovenia	34.4	Bulgary	19.4
Bulgary	19.4	Bulgary	19.4	EU-27	21.1
EU-27	21.1	Germany	15.8	Austria	60.4
Slovakia	16.7	EU-27	21.1	Slovakia	16.7
Denmark	46.3	Greece	16.9	Greece	16.9
Czech R.	15.7	Italy	15.2	Czech R.	16.1
Greece	16.9	Lithuania	53.4	Finland	80.2
Germany	18.0	Ireland	13.1	Poland	17.2
Poland	17.2	Belgium	12.2	Italy	15.2
Austria	67.6	Netherlands	12.4	Hungary	14.3
Hungary	14.3	Cyprus	12.9	Ireland	10.8
Ireland	10.8	Poland	35.2	Denmark	70.2
Netherlands	10.6	Hungary	30.6	Belgium	12.2
Cyprus	12.9	U. Kingdom	11.3	Netherlands	12.4
Belgium	14.7	Czech R.	61.9	Cyprus	12.9
U. Kingdom	11.3	Slovakia	75.7	U. Kingdom	11.3
Luxembourg	34.2	Luxembourg	10.9	Luxembourg	10.9
Malta	10.0	Malta	10.0	Malta	10.0

5. CONCLUSIONS

The innovative, reasonable and simple methodology proposed aims opening discussion on the importance of weighting the application of overall policies according to the reality of each geographic area. It also promotes discussion of specific pragmatic targets that should be set for the EU energy policy goals. This methodology is not intended to be the only one, but a first approximation for reflection and improvement, which must be compared in the future with real evolution.

The heterogeneity of the results found for each of the hypotheses, for each EU energy policy goal, reinforces the need to include the largest number of criteria in the formulation of energy policies, so that their application in the different regions that make up the EU are modified according to their reality. In order to reach the goals, pragmatic milestones are set to show progress during the period of application according to the context and characteristics typical of each geographic area.

The absolute values of GIC, GHG emissions for each country is reduced unequally, but in such a way that the sum allows the EU goal of a 20% reduction to be met. Similar effect is observed for RES, where the share of RES is increased unequally, but the Member States as a whole meet the EU goal of 20% share of RES in GFC in 2020.

This research is a starting point for future work related to the distribution of targets at lower territorial levels. Its application will make it possible to modulate policies to be applied within each Member State for the purpose of achieving similar convergence of all the regions that comprise it.

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