# Towards the Realization of the Europe 2020 Agenda for Economic Growth in the European Union: An Empirical Analysis based on Goal Programming

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## Abstract

Goal Programming is a simple and widely used technique to solve policy-making problems involving different and conflicting objectives or criteria. It consists in minimizing for each criterion the distance between the achieved level and its respective goal. Weighted Goal Programming (WGP) is suitable to the analysis of macroeconomic policies involving several competing objectives with preferred weights of importance as it allows finding the optimal strategy for global sustainability which implies several coexisting goals. In this chapter we propose a WGP model that can be used to determine the optimal allocation of labor in each economic sector in order to minimize the deviations from the goals of four different criteria which model economic, environmental, energetic and social objectives. We apply our model to each country of the European Union and measure their performance with respect to the Europe 2020 agenda. Our model provides insights and policy recommendations, such as a better integration of the incoming workforce in a context of increasing immigration flows, development of renewable sources of energy, and green sustained transformation of national economic environments.

**Keywords:** Weighted Goal Programming, Mixed Integer Linear Programming, Multiple Criteria Decision Analysis, The Europe 2020 agenda, Sustainable Development.

## 1 Introduction

As awareness on environmental issue has spiked, with dissemination of social movements in favor of stronger environmental respect, and profusion of international treaties, optimal resource allocation and economic growth cannot be distinguished from sustainability and ecological considerations. Nowadays countries are subject to numerous binding frameworks for policy making (i.e. the 1992 United Nations Framework Convention on Climate Change , and the more recent Cop 21 conference organized in Paris in 2016), introducing greenhouse gas emission targets. As scientific reports (such as the Intergovernmental Panel on Climate Change) encounter large media coverage, the importance of these targets can be expected to increase, further adding constraints on economic policies design and implementation.

These added international and social incentives to more environmental-friendly measures yet encounter complex national and international economic situations. Indeed, most developed countries show low growth and budget recovery after the last global financial crisis, and improving, but still stagnant, labor markets, thus balancing these fundamental policy topics with the more recent environmental stakes is evidently a struggle. An illustrative example did arise in France, when important social unrest from the "yellow jackets" originally emerged from an increase in the taxation of most polluting fuels. These elements further demonstrate the importance of careful consideration of each of the goals in the design of public policy. While such arbitrages are difficult to make by decision makers, several tools can bring a substantial help and support in policy design. The problem of simultaneously conciliating economic, environmental, social and energy policy targets is well captured by the mathematical models of multiple criteria decision analysis (MCDA), which indeed allow to identify the optimal policy design accounting for all different objectives.

The European Union is a typical and interesting case study. After the 2008 economic crisis, in 2010 European institutions and notably the European Council, and European Commission, proposed the introduction of numerical multi-criteria policy targets, the so-called "Europe 2020" strategy. This highly varied set of national targets covers a large subset of national issues, such as economic growth, employment, education and research, reduction of greenhouse gas emissions, progress towards higher energy efficiency, and struggle against poverty and social exclusion. While these sets of actions and associated objectives (such as a decrease by 20% of GHG emissions, or an increase in energy efficiency by 20%) are formulated at the European Union scale, the objectives are nationally transposed, leaving European Union members a relative margin of freedom in their implementation. This feature opens the possibility of evaluating the satisfaction of Europe 2020 objectives by European Union states in MCDA prospective.

The application of MCDA techniques, and specifically Goal Programming (GP) and its variants and extensions, to macroeconomic policies is not novel. They have been widely used to tackle similar issues of decision making with competing objectives; as they allow to identify a Pareto optimal solution with respect to the goals involved. Nevertheless, the use of GP models has before emerged in engineering, where they have been implemented to analyse supply chain optimization problems facing imprecise assessment of both demand and information (Selim and Ozkarahan, 2008a; Tsai, 2009), vendor problems (Kumar et al., 2004; Zhou et al., 2008), production planning (Selim et al., 2008b), or also decision making in manufacturing (Sheikhalishahi and Torabi, 2014; Taghizadeh et al., 2011). The increasing popularity of GP models, already noticed by Ignizio (1982), gave birth for instance to financial portfolio selection applications (Watada 1997; Inuiguchi and Ramik, 2000), with consideration of manager preferences (Mansour et al., 2007), highlighting the flexibility of GP approaches to integrate these constraints as well, and also in the context of optimal allocation of renewable energies with quota constraints (Daim et al., 2010). In marketing, decision making problems seeing an application of GP methods are sales operation (Tyagi et al., 2011) and media planning (Charnes et al., 1968; Jha et al., 2011). In agricultural and environmental management, as the GP methodology constitutes an adequate tool to model environmental interactions (Linares and Romero, 2000), uses of MCDA approaches have dealt with agricultural land planning (Biswas and Pal, 2005; Sharmar et al., 2007), outsourcing management (Araz et al., 2007), and crops selection (Mirkarimi et al., 2013).

The extant MCDA literature cover a large variety of models and applications reviewed by Colapinto, Jayaraman and Marsiglio (2017), and the GP formulation has been applied to macroeconomic policy design and evaluation. Some researchers (Jayaraman et al., 2015, 2017a, 2017b) have used Weighted Goal Programming (WGP) to study the global sustainability and development of the GCC countries. Other authors employ this methodology to study macroeconomic policies in Spain (André, 2009; San Cristóbal, 2012) through the joint analysis of optimal economic and environmental policies. More recently, Omrani, Valipour and Emrouznejad (2018) have applied a WGP model to more efficiently plan regional sustainable development and workforce allocation in Iran. Zografidou et al. (2017) have suggested an optimal design of renewable energy production in Greece by weighting social, financial and production goals. Nomani et al. (2017) implemented a Fuzzy Goal Programming approach to evaluate the satisfaction of sustainability policy targets in India. Finally, Bravo, Jones, Pla-Santamaria and Wall (2018) have studied the robustness of WGP models applied to offshore wind-farm site location determination. Indeed, GP and its variants offer the ability to balance different objectives and are relevant tools to study the satisfaction of several mutually conflicting objectives. Recent economic works o provide multi-criteria models emphasizing the comparison of welfare criteria (Colapinto et al., 2017), and studying the economy/environment trade-off through externality modelling, notably establishing that "independently of the relative importance of economic and environmental factors, it is paradoxically optimal for the economy to asymptotically reach the maximum pollution level that the environment is able to bear" in the multi-criteria decision-making (Marsiglio and Privileggi, 2019).

Our chapter proposes a GP model to describe and measure the progress of each European country towards the satisfaction of the main Europe 2020 goals, following authors' previous work with the use of a Fuzzy GP model (Vié et al., 2019). With respect to Vié et al. (2019) this chapter presents a more detailed analysis with updated and more complete data. The Europe 2020 strategy is used as a reference framework for activities in the EU at national and regional levels. Our model is linear and includes seven economic sectors and four different criteria. The data have been collected using information provided by the European Commission and the EU statistics office, Eurostat. Eurostat regularly publishes comprehensive progress reports for the targets. We referred to the targets for different sectors indicated in the Europe 2020 agenda , including Employment, Research and development (R&D), Climate change and energy, Education, and Poverty and social exclusion. In particular, the Climate change and energy targets are:

a) greenhouse gas emissions 20% lower than 1990 levels
b) 20% of energy coming from renewables
c) 20% increase in energy efficiency

Our model mainly focuses on the analysis of a sustainable economic growth and combines the economic objective (GDP) together with GHG emissions and energy efficiency. Our model does not distinguish skilled from unskilled labor force and supposes that population level is equal to the labor force.

The chapter is organized as follows. Section 2 reviews some basic notions in MCDA and GP. Section 3 presents the model formulation, including a detailed description of the economic sectors and the criteria. Section 4 describes how the data have been collected, while Section 5 illustrates the results. As usual, Section 6 concludes. In the appendices (A to J) we report data calculation and model results.

## 2 A Review of Multiple Criteria Decision Analysis and Goal Programming

Multiple Criteria Decision Analysis or Multiple Criteria Decision Making (MCDM) is a discipline that considers decision making situations involving multiple and conflicting criteria. Some examples of conflicting criteria that have been considered in literature are quality, cost, price, satisfaction, risk, and others. Considering multiple criteria with respect to a single criterion leads to more informed and better decisions. However, typically there does not exist a unique optimal solution and it is necessary to use a decision maker's preferences to differentiate between solutions. Many important advances have been developed in this field in the last sixty years including new approaches, innovative methods, and sophisticated computational algorithms. A classical MCDA model involves several criteria, objectives or attributes, to be considered simultaneously. These dimensions are usually conflicting and the decision-maker will look for the solution of the best compromise.

MCDA models are based on the notion of partial or Pareto order which can be summarized as follows: Given two vectors $a,b \in R^p$, we say that $a \le b$ if and only if $a_i \le b_i$ for all $i = 1...p$. The general formulation of a MCDA model can be stated as follows (Sawaragi et al., 1985): Given a set of $p$ criteria $f_1, f_2, \ldots, f_p$,, determine the optimal solution of the vector function $f(x) := [f_1(x), f_2(x), \ldots, f_p(x)]$ under the condition that $x \in D \subseteq \Re^n$ where $D$ designates the set of feasible solutions. The optimal solution has to be understood in Pareto sense: We say that a point $\hat{x} \in D$ is a global Pareto optimal solution or global Pareto efficient solution if $f(x) \in f(\hat{x}) + (-R_+^p \setminus \{0\})^c$ for all $x \in D$. Practically speaking, a Pareto optimal solution describes a state in which goods and resources are distributed in such a way that it is not possible to improve a single criterion without also causing at least one other criterion to become worse off than before the change. In other words, a state is not Pareto efficient if there exists a certain change in allocation of goods and resources that may result in some criteria being in a better position with no criterion being in a worse position than before the change. If a point $x \in D$ is not Pareto efficient, there is potential for a Pareto improvement and an increase in Pareto efficiency.

GP is a well-known technique to solve MCDA models. The GP model is based on a notion of distance and it seeks to minimize positive or negative deviations of the achievement levels with respect to the aspiration ones. It is an aggregating methodology that allows obtaining a solution representing the best compromise that can be achieved by the decision maker, as noted by Jayaraman et al. (2015).

The WGP model is one the possible variants of the GP model that have been proposed in literature. In this context, the decision maker can show different appreciation of the positive and negative deviations based on the relative importance of the objective and this is expressed by introducing different weights $w_i^+$ and $w_i^-$. The mathematical formulation of the WGP model reads as:

$$\text{Minimize } \sum_{i=1}^{p} w_i^+\delta_i^+ + w_i^-\delta_i^-$$

Subject to:

$$f_i(x) + \delta_i^- - \delta_i^+ = g_i \quad i = 1 \ldots p$$

$$x \in F$$

$$\delta_i^-, \delta_i^+ \geq 0 \quad i = 1 \ldots p$$

## 3 Model Formulation

As previously mentioned, MCDA usually deals with decision making with multiple and conflicting criteria, objectives or attributes, and considers decision makers' preferences to determine the best compromise among optimal solutions. GP was first introduced by Charnes and Cooper (1961). Given a set of *n* linear criteria $F_i(X_1, X_2, \ldots, X_n) = \sum_{j=1}^{n} A_{ij}X_{ij}$ and a set of goals $G_i$ the WGP model reads as

$$\sum_{i=1}^{p} \alpha_i^+ D_i^+ + \alpha_i^- D_i^- \quad (1)$$

Subject to:

$$\sum_{j=1}^{n} A_{ij}X_j + D_i^- + D_i^+ = G_i, \quad i = 1 \ldots p$$

$$X \in \Omega$$

$$D_i^-, D_i^+ \geq 0, i = 1 \ldots p$$

where $\Omega$ is a feasible set, $\alpha_i^+$and $\alpha_i^-$ are weights, $X_j$ are the input variables representing the number of employees in each economic sector, the coefficient $A_{ij}$ states the contribution of the $j^{th}$ variable to the achievement of the $i^{th}$ criterion, and $D_i^-$ and $D_i^+$ are the positive and negative deviations with respect to the aspirational goal levels $G_i$, $i = 1, \ldots, n$, respectively.

Previous researchers – see i.e. Andre' et al. (2009) and San Cristóbal (2012) in Spain, Jayaraman et al. (2017a, 2017b) in the GCC countries – have shown how the government can determine its optimal policy according to different criteria using the GP approach. Considering the Europe 2020 objectives established by the European Commission, our macroeconomic model simultaneously considers the following four criteria with their respective units:

a) $F_1$ is the economic output (in million US$)
b) $F_2$ is the GHG emissions (in Gg of $CO_2$ equivalent kilo tonnes)

c) $F_3$ is the electric consumption (in thousand tonnes of oil equivalent)
d) $F_4$ is the number of employees (in thousands)

The decision variables in our GP model are all relevant economic sectors for the analysis. They are equivalent to the main activities identified by NACE Rev. 2 classification:

- $X_1$: agriculture, forestry and fishing;
- $X_2$: energy industry;
- $X_3$: manufacturing industry;
- $X_4$: construction and residential;
- $X_5$: trade, transports, distribution and repairing;
- $X_6$: commercial services (information, communication, financial and insurance activities);
- $X_7$: general services (administrative, state, technical, scientific, education, health and social services).

Each criterion $F_i$ is linear with respect to each decision variable $X_j$ and takes the form:

$$F_1(X_1, X_2, \dots, X_7) = A_{11}X_1 + A_{12}X_2 + \dots + A_{17}X_7$$

$$F_2(X_1, X_2, \dots, X_7) = A_{21}X_1 + A_{22}X_2 + \dots + A_{27}X_7$$

$$F_3(X_1, X_2, \dots, X_7) = A_{31}X_1 + A_{32}X_2 + \dots + A_{37}X_7$$

$$F_4(X_1, X_2, \dots, X_7) = A_{41}X_1 + A_{42}X_2 + \dots + A_{47}X_7$$

The seven economic categories aim to represent – for each country – its economic, social, environmental, and energy characteristics. We also replicate the choice made in previous publications (San Cristóbal, 2012; Jayaraman et al 2017a), that fit well the NACE (second revision) classification of economic activities created within the European Union. Such a classification is complete, aiming to describe efficiently whole economic patterns. Our choice of categories is restricted either to specific global categories, such as agriculture combined with fishing and forestry, either to an aggregate category as commercial services, which includes both financial and insurance activities as well as information and communication economics.

The GP problem we intend to solve can then be written in the following form:

Minimize $(\alpha_1^+ D_1^+ + \alpha_1^- D_1^-) + (\alpha_2^+ D_2^+ + \alpha_2^- D_2^-) + (\alpha_3^+ D_3^+ + \alpha_3^- D_3^-) + (\alpha_4^+ D_4^+ + \alpha_4^- D_4^-)$ (2)

Subject to:

$$A_{11}X_1 + A_{12}X_2 + \dots + A_{17}X_7 - D_1^+ + D_1^- = G_1$$

$$A_{21}X_1 + A_{22}X_2 + \dots + A_{27}X_7 - D_2^+ + D_2^- = G_2$$

$$A_{31}X_1 + A_{32}X_2 + \dots + A_{37}X_7 - D_3^+ + D_3^- = G_3$$

$$X_1 + X_2 + \dots + X_7 - D_4^+ + D_4^- = G_4$$

$$X_1 \geq \Omega_1, X_2 \geq \Omega_2, X_3 \geq \Omega_3, X_4 \geq \Omega_4, X_5 \geq \Omega_5, X_6 \geq \Omega_6, X_7 \geq \Omega_7$$

$$X_j, j = 1, 2, \dots, 7 \ \textit{are positive and integer}$$

$$D_i^+, D_i^- \geq 0, i = 1, 2, 3, 4$$

The variables $D_i^+, D_i^-$ describe the positive and the negative deviations. The input variables $X_j$ take integer values and must be at least equal to the positive number $\Omega_j$ which is the number of employees in each sector of our analysis (see Appendix A). $A_{1j}$ is the economic output per capita (worker) for the $j^{th}$ economic sector (see Appendix B). $A_{2j}$ describes the GHG emission per capita (worker) for the $j^{th}$ economic sector (see Appendix C). $A_{3j}$ models the energy consumption per capita (worker) for the $j^{th}$ economic sector (see Appendix D).

For each country we solve the above model (2) which takes then the form of a Mixed Integer Linear Programming (MILP) model. We have implemented it using LINGO. So far, we have assumed equal weights for each objective. In other words, all the weights $\alpha_n^+$ and $\alpha_n^-$, n = 1, …, 4, are equal. Our choice is motivated by the fact that the Europe 2020 agenda does not provide any priority or ranking among the objectives and all of them must be jointly met. However, these weights might be modified at the regional level when the national preferences and the economic situation of each country have to be taken into account.

# 4 Data Collection and Computation

In this section we briefly discuss how we have estimated all parameters involved in the model. For each constraint we describe how the data has been collected and how the estimations have been computed. We also provide their interpretation.

3.1 The Gross Domestic Product constraint

The GDP per capita denoted $A_{1i}$ (see Appendix B) is expressed in US$ thousands per capita. It is computed for a given sector $i$ in each country by taking the ratio of the economic output (GDP) for the selected sector $i$ in US$ millions in 2015 (Eurostat, 2014, 2015), and the number of employees (expressed in thousands) in the same year for the same economic sector $i$ (OECD Statistics, 2015; Eurostat, 2015). Following the Europe 2020 recommendation that the economic output must be at least conserved with respect to the year of analysis, and following GDP growth rate projections of the International Monetary Fund (IMF) and the OECD up to 2020, we defined the economic GDP objective $G_1$ as the sum of the forecast GDP of all sectors. For instance, a country with a GDP of 100 in 1990 forecasted to grow by 10% to 2020 will have an economic output target of 110. The resulting GDP constraint can be expressed as follows: the economic output of the country needs to be at least as good as current projections.

3.2 The greenhouse gas constraint

The average sectorial greenhouse gas (GHG) emissions per capita $A_{2i}$ (see Appendix C for the data) is expressed in tonnes of $CO_2$ equivalent per capita, for a given sector $i$ in each country. It is computed by dividing sectorial GHG emissions (in thousands of tonnes) in the selected country in 2015, and the number of employees (expressed in thousands) in the same year for the same economic sector and country (OECD Statistics, 2015; Eurostat, 2014, 2015). This delivers the benchmark from which the environmental policy target $G_2$ is computed, accordingly to the Europe 2020 objective consisting in a decrease by 20% of GHG emissions at the scale of the national economy, an objective that we apply to all sectors separately. For instance, a country with a GHG emissions level of 100 in 1990 will have a GHG emission target of 80 at the horizon 2020.

3.3 The energy constraint

The average sectorial energy consumption per capita $A_{i3}$ (see Appendix D for the data) is expressed in tonnes of oil equivalent per capita, for a given economic sector $i$ in each country.

In order to obtain its numerical values, we took the ratio of the energy consumption for the selected sector *i* in the selected country in thousands of tonnes of oil equivalent in 2015 (International Energy Agency, 20141, and of the number of employees (expressed in thousands) in the same year for the same sector *i* and country, (OECD Statistics, 2015; Eurostat, 2014, 2015). The determination of the energy consumption targets $G_3$ proceeded by transforming the resulting consumption with the 20%[2] increase in energy efficiency imposed by the Europe 2020 strategy, with respect to the 1990 level constituting the benchmark of the policy set.

3.4 The employment constraint

This constraint is simple, as the model aims at maintaining employment at the benchmark level set in the year of analysis. This constraint is declined in each economic sector, based on the number of jobs recorded in the year of data collecting (OECD, 2015; Eurostat, 2015). Natural population growth (and estimated forecasts for later years) were considered to formulate the aggregate employment goal $G_4$. Note that this constraint operates in the aggregate level, offering countries flexibility in the allocation of incoming workforce across economic sectors.

## 5 Model Implementation and Discussion

As said above, we implement our model using the software LINGO and the results are presented in Appendix I. We have ticked with "x" any time there is a significant deviation value (detailed results table can be found in Appendix J). In all simulations we have normalized the weights to 1. We would like to point out that confidential and missing data for Cyprus, Croatia and Malta, restrict us to make less precise conclusions than those done for other countries.

From what we observed, the current trend will allow all European countries to have $D_4^+$=0, which means that the entire available labor force will be used for creating a sustainable development. This result outlines the need for a better integration of unemployed workforce, possibly through intensified training policies and inclusive measures in the labor market. In the context of automation, improving the effectiveness of changes in qualification seems relevant to ensure optimal economic performance, employment and social inclusion.

In several countries we observe a significant nonzero value for the deviation $D_4^-$, meaning that the satisfaction of the objectives of the model requires additional workforce to be integrated within the economy in specific sectors. In a context of increasing immigration towards European countries, this study outlines the necessity and the benefits coming from a more efficient integration of new comers within the labor market in Eastern and Northern countries (for instance Germany).

Some countries present a significant deviation in the values taken by $D_1^-$, standing for a negative deviation from the economic goal. For these countries, the satisfaction of the simultaneous objectives leads to a slower economic output than targeted. This can be interpreted as a lack of productivity, that can be verified empirically comparing the average economic product of these countries, with economically well-performing countries. Improving competitiveness and

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[1] Eurostat data in thousands of tonnes of oil equivalent (ktoe) on a net calorific value basis.

[2] Europe 2020 objectives in energy sector deal with an increasing of energy efficiency by 20%, which mathematically implies a reduction of energy consumption by 16.66% from the 1990 consumption to the horizon 2020.

production efficiency may result from organizational changes or evolutions in the length of work time permitted.

A significant deviation in the parameter $D_1^+$, a positive deviation from the economic goal, shows a great economic performance of the country, for which the optimal allocation of workers to reach Europe 2020 goals leads to higher economic growth than expected (for instance, Eastern countries, Belgium, Luxemburg, Germany show this result).

Only two countries show a significant negative deviation from the environmental goal $D_2^-$. The optimal allocation of workers provides the achievement of the environmental goals in Czech and Slovak Republics. These results can be explained by the transformations of national economic patterns following the collapse of USSR during the early nineties and the dissolution of Czechoslovakia in 1993. It illustrates the significant progress made in switching to a cleaner energy production system after the soviet period. A large number of European countries include in their optimal allocation a positive deviation $D_2^+$, stressing that GHG emissions at the optimal allocation are significantly higher than the objective (especially in the United Kingdom, France, and Spain). The importance and the wide diffusion of these positive deviations outlines the need for an increased transformation of European production systems leading to lower environmental impact sectors, especially in industry and agriculture, for which these countries show higher GHG emissions than average.

Five countries (Cyprus, Czech and Slovak Republics, Romania and Sweden) show significant values in the deviation $D_3^-$. This result stands for a negative deviation from the energy consumption reduction goal which means that their optimal allocation goes beyond the required reduction of energy consumption. This result for the Czech and Slovak republics and in Romania might be justified again by their national economic pattern transformation from former soviet-linked countries into Eastern European countries.

Most countries in our sample show important and significant positive deviation $D_3^+$ from the energy production goal, outlining emergency and significant needs for a better energy efficiency, and development of renewable sources of energy, able to satisfy the Europe 2020 energy objective while keeping the other parameters – economic output, number of jobs, environmental impact – at least as good with respect to the sustainability objectives. Different measures may be implemented to reach these goals: for instance development of renewable energies, intensified use of nuclear energy, or waste reduction.

## 6 Conclusion and policy implications

The GP model allows policy makers to identify the best combination of investments and choices that optimizes the multiple and competing objectives that usually co-exist within a national strategy plan. To ensure that each member state tailors the Europe 2020 strategy in the most effective way, the European Commission has proposed that goals are translated into national targets and trajectories. The purpose of the European plan relies on the interactions among interrelated targets: indeed, investing in cleaner, low carbon technologies could help the environment, contribute to fighting climate change and create new business and employment opportunities in Europe. However, some stakeholders will enjoy benefits only in the long term, and that is why these changes meet resistance and conflicting objectives occur. Our implementation of a GP model for European countries, with respect to the Europe 2020 goals in reduction of GHG emissions and increase in energy efficiency, combined with economic output and employment constraints, outlines the need for a better integration and training of the incoming workforce in a context of increasing immigration flows, jointly with deep and sustained transformations of economic national systems towards a more energy-efficient production system, combined with the development of renewable energies in many UE countries.

Improving our model to represent more efficiently the reality and support public policies implies to identify the utility payoffs attached to each deviation that goes beyond the object of this chapter. For future research it would be interesting considering that the utility, or preferences of the policy maker, can be taken into account by switching to a more sophisticated GP variant, where the appropriate coefficients for each sector of deviation are identified.

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## Appendix A – Employment by main sector in EU (in thousands)

| Countries | Agriculture, forestry and fishing | Energy industry | Manufacturing industry | Construction and residential | Trade, transports, distribution, repairing | Commercial services (Information, communication, financial and insurance activities) | Public, administrative services, technical, scientific, education, health, and social services |
|---|---|---|---|---|---|---|---|
| **Austria** | 176.4 | 57.8 | 631.5 | 297.2 | 1,171.6 | 241.4 | 1,510.8 |
| **Belgium** | 59.6 | 53.1 | 502 | 266.2 | 974,5 | 236.7 | 2,311 |
| **Bulgaria**[3] | 56.72 | 32.57 | 536.22 | 147.16 | 793,70 | 79.41 | 237.15 |
| **Croatia**[4] | 36.23 | 14.74 | 254.85 | 102.3 | 415,009 | 38.41 | 133.697 |
| **Cyprus**[5] | 0[6] | 0[7] | 27.68 | 18.51 | 116,087 | 9.13 | 33.22 |
| **Czech Rep.** | 158.9 | 128 | 1367.9 | 411.2 | 1246.4 | 226 | 1,458.1 |
| **Denmark** | 68 | 25 | 284 | 173 | 722 | 179 | 1,225 |
| **Estonia** | 24.3 | 13.6 | 117.9 | 51.9 | 151.9 | 35.7 | 197.1 |
| **Finland** | 108.1 | 31.6 | 339.3 | 189.8 | 525.8 | 144.4 | 1,022.8 |
| **France** | 766 | 318 | 2,678 | 1,789 | 6,238 | 1,618 | 12,572 |
| **Germany** | 620 | 571 | 7,516 | 2,450 | 9,961 | 2,301 | 17,011 |
| **Greece** | 471.7 | 50.3 | 337.9 | 181.4 | 1,300.8 | 163.2 | 1,227.6 |
| **Hungary** | 273.8 | 82.1 | 775.6 | 269.2 | 1,020.2 | 211.6 | 1,488.6 |
| **Ireland** | 110.2 | 22.6 | 202.9 | 139 | 564 | 152.2 | 716.9 |
| **Italy** | 910.4 | 312.4 | 3,833.2 | 1,552.1 | 6,164.6 | 1,260.8 | 7,756.6 |
| **Latvia** | 71.6 | 21.5 | 118.5 | 69.6 | 245.5 | 43.1 | 277.5 |
| **Lithuania** | 120.9 | 26.9 | 202.7 | 104.8 | 358.4 | 45.8 | 419.8 |
| **Luxembourg** | 4.6 | 4.4 | 32.3 | 41.5 | 93.5 | 62.4 | 149.3 |
| **Malta**[8] | 0[9] | 0[10] | 0[11] | 9.99 | 57.72 | 6.91 | 26.28 |
| **Netherlands** | 192 | 67 | 767 | 457 | 2,19 | 503 | 4,249 |
| **Poland**[12] | 130.54 | 300.11 | 2,425.35 | 831.23 | 3,154.54 | 309.27 | 1,230.23 |
| **Portugal**[13] | 451.8 | 59.3 | 714.2 | 274 | 1,143.6 | 165.5 | 1,492.9 |
| **Romania**[14] | 85.466 | 123.239 | 1,180.1 | 365.32 | 1,384.74 | 157.36 | 44.20 |
| **Slovak Rep.** | 73.4 | 47.2 | 490.7 | 163.2 | 609 | 107.6 | 527.37 |
| **Slovenia** | 75.4 | 21.1 | 190.9 | 62.6 | 200.1 | 50.4 | 304.7 |
| **Spain** | 732 | 244.7 | 2057.7 | 1005.7 | 5,632.7 | 821.6 | 6,394.9 |
| **Sweden** | 112.3 | 66 | 580 | 340.4 | 981.5 | 270.7 | 2,233.3 |
| **UK** | 359.3 | 384.9 | 2,563 | 2,056.9 | 8,270.4 | 2,391.6 | 13,599.1 |

Source: Eurostat, 2015 (if not otherwise specified)

[3] Eurostat, Persons employed by NACE Rev. 2, 2014 data.
[4] Eurostat source, cf. supra.
[5] Eurostat source, cf. supra.
[6] Data mentioned as confidential – Eurostat source.
[7] Data mentioned as confidential – Eurostat source.
[8] Eurostat source, cf. supra.
[9] Data mentioned as confidential – Eurostat source.
[10] Data mentioned as confidential – Eurostat source.
[11] Data mentioned as confidential – Eurostat source.
[12] Eurostat source, cf. supra.
[13] Same source, OECD estimations.
[14] Eurostat source, cf. supra. 2014

## Appendix B - Economic output (GDP) per economic sector in EU countries (US$ millions)

| Country | Agriculture, forestry and fishing | Energy industry | Manufacturing industry | Construction and residential | Trade, transports, distribution, repairing | Commercial services (Information, communication, financial and insurance activities) | Public, administrative services, technical, scientific, education, health, and social services |
|---|---|---|---|---|---|---|---|
| Austria | 3,905.4 | 1,182.7 | 57,220.9 | 19,411.5 | 53,535.7 | 33,770 | 81,120.9 |
| Belgium | 2,745 | 233.5 | 52,417.2 | 19,956.6 | 65,047.5 | 38,275.1 | 133,183.7 |
| Bulgaria | 1,873.4 | 963.8 | 6,168.8 | 1,698.7 | 7,693.7 | 4,810.7 | 8,105.2 |
| Croatia[15] | 353 | 10 | 738.2 | 555.8 | 2,880.5 | 2,669.4 | 4,680.4 |
| Cyprus | 1,504.3 | 819.2 | 5,320.6 | 1,905.3 | 5,829.3 | 3,983.6 | 8,478.5 |
| Czech Rep. | 3,785.4 | 1,364.2 | 40,392.3 | 8,571.2 | 24,746.5 | 14,110.5 | 32,263 |
| Denmark | 2,900.8 | 3,477.8 | 34,516.9 | 11,031.9 | 43,738.1 | 25,541.2 | 74,420.8 |
| Estonia | 592.3 | 250.9 | 2,770.9 | 1,092.3 | 3,447.6 | 1,744 | 4,373.8 |
| Finland | 4,443 | 551 | 30,652 | 11,481 | 25,800 | 15,614 | 54,647 |
| France | 33,854 | 2,148 | 218,987 | 106,155 | 290,404 | 184,239 | 698,443 |
| Germany | 17,351 | 4,158 | 622,608 | 124,755 | 387,625 | 242,562 | 800,412 |
| Greece | 6,385.6 | 812.2 | 14,708.1 | 3,696.8 | 28,141.9 | 12,763 | 39,879.3 |
| Hungary | 3,800.8 | 152.9 | 22,618.7 | 3,816.2 | 15,443.7 | 7,980.1 | 24,123.4 |
| Ireland | 2,398 | 898.8 | 87,448.2 | 6,024.7 | 26,020.7 | 34,131.9 | 51,905.5 |
| Italy | 33,158.7 | 5,470 | 232,882 | 70.099 | 248,975.1 | 137,076.5 | 390,895.1 |
| Latvia | 723.9 | 105 | 2,652.4 | 1,381.7 | 5,057.1 | 1,919.5 | 4,924.3 |
| Lithuania | 1,220.5 | 103.7 | 6,493.9 | 2,440.4 | 10,027.6 | 1,859.4 | 6,957.9 |
| Luxembourg | 112.9 | 31.3 | 2,461.8 | 2,340.4 | 7,538.8 | 15,240.8 | 12,295.6 |
| Malta | 103.6 | 0 | 728.2 | 345.6 | 1,361.7 | 1,081.8 | 2,426.3 |
| Netherlands | 10,965 | 12,573 | 71,120 | 28,048 | 116,686 | 74,264 | 221,426 |
| Poland | 9,921.8 | 6,170.6 | 75,087.1 | 29,881 | 91,052.8 | 30,637.6 | 86,313.4 |
| Portugal | 3,654.2 | 497.9 | 21,555.2 | 6,363.9 | 30,258.1 | 13,827.4 | 41,977.9 |
| Romania | 6,651.3 | 1,421 | 30,948.1 | 9,272.9 | 24,074.5 | 14,289.6 | 26,834.4 |
| Slovak Rep. | 794.3 | 127 | 7,737.8 | 1,826.3 | 6,032.5 | 2,782.6 | 8,815.3 |
| Slovenia | 2,600.5 | 362 | 15,940.8 | 5,577.4 | 9,519.4 | 5,927.7 | 14,916.6 |
| Spain | 25,004 | 2,110 | 138,914 | 54,554 | 163,329 | 78,783 | 265,940 |
| Sweden | 5,211.8 | 1.637 | 67,240 | 23,272.6 | 64,369.1 | 41,214.6 | 124,932.1 |
| UK | 14,981.3 | 23,174.5 | 224,465.4 | 141,518.8 | 357,250.9 | 315,841.9 | 708,262.2 |

Source: Eurostat data, NACE Rev. 2 classification, 2014, 2015.

## Appendix C - Emissions of GHG[16] in economic sectors in EU countries[17]

| Countries | Agriculture, forestry and fishing | Energy industry | Manufacturing industry | Construction and residential | Trade, transports, distribution, repairing | Commercial services (Information, communication, | Public, administrative services, technical, |
|---|---|---|---|---|---|---|---|

[15] Due to missing data, Croatia data is extracted from Eurostat 2014 panel data.

[16] $CO_2$, $CH_4$, $N_2O$, HFCs, PFCs, $SF_6$, $NO_4$, NOX, NMVOC, PFC, PM (2, 5 & 10); summed and transformed in $CO_2$ equivalent and thousands of tonnes.

[17] United Nation – Framework Convention on Climate Change – Submitted National Communications, sixth edition, due 1st January 2014, data from 2011 in principle, in equivalent $CO_2$ emissions (Gg), data based on national accounts // Data confirmed in European Environment Agency Data // Eurostat – Air emissions national accounts by NACE Rev. 2 activity, 2014 data, in thousands of tonnes of $CO_2$ equivalent.

| | | | | | | financial and insurance activities) | **scientific, education, health, and social services** |
|---|---|---|---|---|---|---|---|
| **Austria** | 7,577.10 | 13,988.43 | 26,499.85 | 380.91 | 7,669.89 | 223.77 | 1,640.62 |
| **Belgium** | 9,365.88 | 21,862.84 | 33,771.89 | 439.74 | 9,999.41 | 1,183.62 | 6,221.01 |
| **Bulgaria** | 7,510.28 | 28,950.92 | 5,877.21 | 56. 7 | 4,830.7 | 50.59 | 393.02 |
| **Croatia** | 3,442.21 | 6,275.44 | 4,173.59 | 37.08 | 1,358.21 | 116.72 | 521.48 |
| **Cyprus** | 633 | 3,722 | 1,732.52 | 33.76 | 493.40 | 35.97 | 110.95 |
| **Czech Rep.** | 8,065 | 58,424 | 18,556.53 | 187.47 | 9,215.65 | 180.71 | 2,859.96 |
| **Denmark** | 9,671.85 | 19,747.81 | 5,580.18 | 103.51 | 39,777.66 | 117.05 | 1,180.64 |
| **Estonia** | 1,270.52 | 14,875.63 | 2,514.08 | 27.22 | 1,694.24 | 14.86 | 396.05 |
| **Finland** | 5,881.11 | 24,628.42 | 13,845.4 | 8,914 | 10,471.12 | 254.99 | 1,863.34 |
| **France** | 90,340 | 53,015.88 | 95,234.84 | 3,228.13 | 52,662.67 | 2,244.39 | 20,766.18 |
| **Germany** | 63,936 | 353,793 | 160,692.01 | 2,995.36 | 97,468.43 | 4,665.26 | 26,064.59 |
| **Greece** | 8,965.84 | 53,840.83 | 13,348.27 | 57.2 | 6,718.45 | 39.01 | 847.56 |
| **Hungary** | 5,925 | 17,459 | 9,699.31 | 100.21 | 5,387.57 | 561.29 | 2,264.7 |
| **Ireland** | 17,730 | 11,935 | 6,325.86 | 144.57 | 4,249.55 | 255.5 | 866.24 |
| **Italy** | 31,486 | 132,413 | 89,590.47 | 1,739.74 | 49,530.1 | 517.48 | 4,842.16 |
| **Latvia** | 2,456 | 2,084 | 1,342.62 | 18.84 | 2,509.77 | 14.25 | 290.3 |
| **Lithuania** | 3,756 | 4,467 | 4,823.88 | 14.3 | 7,480.83 | 18.38 | 218.76 |
| **Luxembourg** | 663 | 1,003 | 1,458.00 | 17.2 | 3,879.1 | 111.98 | 219.8 |
| **Malta** | 89 | 1,914 | 43.96 | 6.30[18] | 3,443.38 | 12.95 | 61.88 |
| **Netherlands** | 18,097 | 63,000 | 42,131.76 | 941.46 | 32,802.36 | 635.74 | 8,057.37 |
| **Poland** | 29,930 | 174,672 | 62,271.56 | 548.26 | 33,550.04 | 1,430.56 | 9,534.95 |
| **Portugal** | 6,958 | 16,506 | 15,795.2 | 664.9 | 7,167.8 | 133.8 | 1,417.9 |
| **Romania** | 17,093 | 35,558 | 23,034.06 | 153.4 | 8,817.3 | 464.34 | 2,215.37 |
| **Slovak Rep.** | 2,935 | 9,280 | 17,598.00 | 16.65 | 4,884.97 | 5.02 | 888.43 |
| **Slovenia** | 1,691 | 6,359 | 2,289.37 | 50.13 | 4,011.70 | 8.68 | 220.23 |
| **Spain** | 36,262 | 87,124 | 75,513.46 | 957.57 | 37,214.06 | 617.25 | 4,408.9 |
| **Sweden** | 7,338 | 10,974 | 14,001.58 | 63.07 | 13,820.01 | 180.91 | 1,545.78 |
| **UK** | 43,735 | 178,850 | 83,588.16 | 3,020.55 | 94,951.03 | 1,523.58 | 19,002.70 |

## Appendix D - Energy consumption[19] in economic sectors in EU countries

| **Country** | **Agriculture, forestry and fishing** | **Energy industry[20]** | **Manufacturing industry** | **Construction and residential** | **Trade, transports, distribution, repairing** | **Commercial services** (Information, communication, financial and insurance activities) | **Public, administrative services, technical, scientific, education, health, and social services** |
|---|---|---|---|---|---|---|---|
| **Austria** | 539 | 1,935 | 7,517 | 5,627 | 8,197 | 565.2 | 2,260.8 |
| **Belgium** | 645 | 8,393 | 10,638 | 7,390 | 8,699 | 851.6 | 3,406.4 |
| **Bulgaria** | 191 | 518 | 2,622 | 2,165 | 2,946 | 185.2 | 740.8 |
| **Croatia** | 233 | 563 | 1,101 | 2,183 | 1,882 | 142.2 | 568.8 |
| **Cyprus** | 39 | 24 | 220 | 288 | 596 | 39.6 | 158.4 |
| **Czech Rep.** | 593 | 2,908 | 6,829 | 5,673 | 5,881 | 559.6 | 2,238.4 |

[18] Eurostat estimate.

[19] in thousands of tonnes of oil equivalent (ktoe) on a net calorific value basis.

[20] Non-energy use (consumption of raw materials).

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Denmark** | 727 | 251 | 2,090 | 3,956 | 4,014 | 364.8 | 1,459.2 |
| **Estonia** | 132 | 113 | 566 | 888 | 741 | 91.8 | 367.2 |
| **Finland** | 718 | 1,150 | 10,325 | 5,064 | 4,136 | 574.6 | 2,298.4 |
| **France** | 4,516 | 14,003 | 25,883 | 37,318 | 43,544 | 4,206.6 | 16,814.4 |
| **Germany** | 9,386[21] | 22,120 | 54,882 | 51,287 | 54,998 | 6,581.4 | 26,325.6 |
| **Greece** | 281 | 705 | 3,088 | 3,786 | 5,640 | 342.4 | 1,369.6 |
| **Hungary** | 599 | 1,676 | 3,923 | 4,431 | 3,910 | 448.8 | 1,795.2 |
| **Ireland** | 221 | 216 | 2,233 | 2,561 | 3,677 | 246.4 | 985.6 |
| **Italy** | 2,776 | 7,187 | 25,280 | 29,541 | 37,009 | 2,933.2 | 11,732.8 |
| **Latvia** | 153 | 89 | 791 | 1,239 | 987 | 121.8 | 487.2 |
| **Lithuania** | 105 | 1,070 | 971 | 1,400 | 1,644 | 118 | 472 |
| **Luxembourg** | 25 | 36 | 613 | 478 | 2,096 | 78.8 | 315.2 |
| **Malta** | 5 | 4 | 47 | 72 | 185 | 21.5 | 102.5 |
| **Netherlands** | 3,546 | 14,186 | 13,181 | 9,120 | 10,280 | 1,265.2 | 5,060.8 |
| **Poland** | 3,401 | 5,323 | 14,166 | 18,945 | 15,639 | 1,559 | 6,236 |
| **Portugal** | 424 | 1,435 | 4,393 | 2,569 | 5,439 | 380.8 | 1,523.2 |
| **Romania** | 422 | 1,564 | 6,204 | 7,390 | 5,290 | 353.6 | 1,414.4 |
| **Slovak Rep.** | 138 | 919 | 3,296 | 1,952 | 2,199 | 261.4 | 1,045.6 |
| **Slovenia** | 74 | 147 | 1,230 | 1,040 | 1,797 | 85.4 | 341.6 |
| **Spain** | 2,766 | 4,106 | 19,229 | 14,698 | 28,098 | 1,767.6 | 7,070.4 |
| **Sweden** | 377 | 1,969 | 10,757 | 6,633 | 7,732 | 883.4 | 3,533.6 |
| **UK** | 973 | 6,892 | 23,124 | 35,140 | 39,784 | 3,177.8 | 12,711.2 |

Source: International Energy Agency, 2014 data, Eurostat.

## Appendix E - Europe 2020 GP goals

| **Goals** | **Economy** | **Environment** | | **Energy** | | **Labor (In thousands)** | |
|---|---|---|---|---|---|---|---|
| **Country** | **GDP 2020 Output, $G_1$[22]** | **GHG 1990 adjusted emissions[23]** | **GHG 2020 adjusted emissions objective $G_2$[24]** | **1990 adjusted level of consumption[25]** | **Europe 2020 objective adjusted consumption, $G_3$[26]** | **Total number of jobs in 2015** | **Total number of jobs in 2020 ($G_4$)** |
| **Austria** | 25,3207.24 | 44,783.98751 | 37,318.4968 | 19,257.3521 | 16,047.1515 | 4086.7 | 4,127.7308 |
| **Belgium** | 219,980.146 | 104,774.2633 | 87,308.3936 | 36,863.2895 | 30,718.1791 | 4403.1 | 4,627.70235 |
| **Bulgaria** | 20,124.1921 | 86,528.42057 | 72,104.1329 | 17,070.5778 | 14,224.9125 | 1882.951 | 1,367.26662 |
| **Croatia** | 24,608.6206 | 13,146.9679 | 10,955.3684 | 6,995.8871 | 5,829.67272 | 995.229 | 811.482554 |
| **Cyprus** | 99,634.8986 | 4,698.694239 | 3,915.42191 | 938.4375 | 781.999969 | 204.633 | 247.772675 |
| **Czech Rep.** | 119,073.993 | 153,336.5209 | 127,775.323 | 34,344.7404 | 28,619.4722 | 4996.5 | 4,996.5 |
| **Denmark** | 153,603.942 | 88,577.76917 | 73,811.855 | 12,862 | 10,717.9046 | 2676 | 2,812.50289 |

[21] State of the Art on Energy Efficiency in Agriculture, Country data on energy consumption in different agro-production sectors in the European countries, agree, FP7 Program of the EU, 2012.

[22] Based on Eurostat data previously mentioned, combined with growth rate forecasts from IMF, European Commission, OECD for each year, in millions of US$.

[23] In thousands of tonnes of $CO_2$ equivalent, adjusted to remain consistent and consider the representability of the global economic national patterns in respect to the GHG emissions criteria, Eurostat data.

[24] In thousands of tonnes of $CO_2$ equivalent, adjusted in the same way, Eurostat data.

[25] Eurostat data for Europe 2020 Statistics, 1990, in million tonnes of oil equivalent; adjusted data to remain consistent and consider the representability of the global economic national patterns.

[26] Europe 2020 objectives in energy sector deal with an increasing of energy efficiency by 20%, which mathematically implies a reduction of energy consumption by 16.66..% from the 1990 consumption to the horizon 2020 : assume that X = a*Y where X is the energy consumption, a the efficiency and Y the total product, the possible uses of energy ; if we increase a by 20% we obtain X' = 1,2*a*Y, so a*Y = X'/1,2 which implies (5/6)*X=a.Y, so X'=(1-5/6)*X.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Estonia** | 83,171.9581 | 11,192.33462 | 9,326.57244 | 5,901.53571 | 4,917.74971 | 592.4 | 563.366506 |
| **Finland** | 820,160.365 | 48,751.5178 | 40,624.6398 | 21,492.7429 | 17,909.9026 | 2361.8 | 2,421.43841 |
| **France** | 2,190,576.46 | 371,294.9451 | 309,400.078 | 141,807.95 | 118,168.565 | 25979 | 30,116.7812 |
| **Germany** | 1,239,551.34 | 965,454.0876 | 804,512.891 | 236,892.325 | 197,402.374 | 40430 | 35,989.5619 |
| **Greece** | 103,397.869 | 86,248.26403 | 71,870.6784 | 14,426.8645 | 12,021.9062 | 3732.9 | 3,255.44646 |
| **Hungary** | 173,794.38 | 67,836.52567 | 56,528.1768 | 21,972.4803 | 18,309.6678 | 4121.1 | 3,360.23242 |
| **Ireland** | 692,546.877 | 39,259.86781 | 32,715.2478 | 6,853.88889 | 5,711.34561 | 1907.8 | 2,764.46669 |
| **Italy** | 602,875.178 | 381,169.0226 | 317,628.147 | 110,702.862 | 92,248.6952 | 21790.1 | 19,003.055 |
| **Latvia** | 32,592.0349 | 19,742.82409 | 16,451.6953 | 6,347.48718 | 5,289.36107 | 847.3 | 716.423094 |
| **Lithuania** | 23,923.4809 | 51,061.97919 | 42,549.9473 | 11,442.0408 | 9,534.65261 | 1279.3 | 1,070.55496 |
| **Luxembourg** | 37,281.0115 | 8,118.19132 | 6,794.88883 | 3,004.65 | 2,503.77485 | 388 | 465.291916 |
| **Malta** | 269,440.916 | 3,692.682825 | 3,077.1126 | 262.2 | 218.49126 | 100.9 | 111.401753 |
| **Netherlands** | 544,074.804 | 189,398.4085 | 157,825.694 | 51,490 | 42,906.617 | 10148 | 10,878.5305 |
| **Poland** | 209,057.592 | 387,013.087 | 322,498.005 | 63,467.7451 | 52,887.672 | 8381.264 | 8,091.99793 |
| **Portugal** | 137,296.491 | 44,726.91459 | 37,270.9379 | 12,174.1519 | 10,144.7208 | 4301.3 | 3,848.52231 |
| **Romania** | 70,362.1455 | 199,171.7597 | 165,969.827 | 42,563.6129 | 35,468.2586 | 3340.422 | 2,752.17912 |
| **Slovak Rep.** | 51,076.038 | 65,111.064 | 54,257.0496 | 14,912.72 | 12,426.7696 | 2018.469 | 2,048.92824 |
| **Slovenia** | 482,344.805 | 16,395.04576 | 13,661.9916 | 3,792.5 | 3,160.29025 | 905.2 | 923.449412 |
| **Spain** | 530,605.115 | 205,972.288 | 171,636.708 | 30,622.8788 | 25,518.0449 | 16889.3 | 16,805.0222 |
| **Sweden** | 1,069,709.51 | 61,950.71469 | 51,623.5306 | 58,353.6378 | 48,626.0864 | 4584.2 | 5,161.35035 |
| **UK** | 1,107,326.7 | 619,593.5555 | 516,307.31 | 129,764.154 | 108,132.47 | 29625.2 | 33,846.48 |

## Appendix F – $A_{ij}$ coefficients for the economic constraint (In thousands of US$ per capita)

| Country | Agriculture, forestry and fishing | Energy industry | Manufacturing industry | Construction and residential | Trade, transports, distribution, repairing | Commercial services (Information, communication, financial and insurance activities) | Public, administrative services, technical, scientific, education, health, and social services |
|---|---|---|---|---|---|---|---|
| **Austria** | 22.1394558 | 20.4619377 | 90.6110847 | 65.314603 | 45.6945203 | 139.892295 | 53.6940032 |
| **Belgium** | 46.057047 | 4.39736347 | 104.416733 | 74.9684448 | 66.7496152 | 161.703 | 57.6303332 |
| **Bulgaria** | 33.0277494 | 29,5889233 | 11,5043192 | 11,542983 | 9,69341215 | 60,57748 | 34,1762278 |
| **Croatia** | 9.74357559 | 0,67847208 | 2,89660585 | 5,43325252 | 6,94081333 | 69,4993361 | 35,007517 |
| **Cyprus**[27] | - | - | 192,218208 | 102,91131 | 50,214925 | 436,224266 | 255,222757 |
| **Czech Rep.** | 23.8225299 | 10,6578125 | 29,5286936 | 20,844358 | 19,8543806 | 62,4358407 | 22,1267403 |
| **Denmark** | 42.6588235 | 139.112 | 121.53838 | 63.7682081 | 60.5790859 | 142.688268 | 60.7516735 |
| **Estonia** | 24.3744856 | 18.4485294 | 23.5021204 | 21.0462428 | 22.6965109 | 48.8515406 | 22.1907661 |
| **Finland** | 41.1008326 | 17.4367089 | 90.3389331 | 60.4899895 | 49.0680867 | 108.130194 | 53.4288228 |
| **France** | 44.1958225 | 6.75471698 | 81.7725915 | 59.3376188 | 46.5540237 | 113.868356 | 55.5554407 |
| **Germany** | 27.9854839 | 7.28196147 | 82.8376796 | 50.9204082 | 38.9142656 | 105.415906 | 47.052613 |
| **Greece** | 13.5374179 | 16.1471173 | 43.5279669 | 20.3792723 | 21.634302 | 78.2046569 | 32.4855816 |
| **Hungary** | 13.8816654 | 1.86236297 | 29.1628417 | 14.1760773 | 15.1379141 | 37.713138 | 16.2054279 |
| **Ireland** | 21.7604356 | 39.7699115 | 430.991621 | 43.3431655 | 46.1359929 | 224.256899 | 72.4027061 |
| **Italy** | 36.4221221 | 17.5096031 | 60.7539393 | 0.04516397 | 40.3878759 | 108.721843 | 50.3951603 |

[27] Due to missing or confidential data, some coefficients for these countries were undetermined.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Latvia** | 10.1103352 | 4.88372093 | 22.3831224 | 19.8520115 | 20.5991853 | 44.5359629 | 17.7452252 |
| **Lithuania** | 10.0951199 | 3.85501859 | 32.0370005 | 23.2862595 | 27.9787946 | 40.5982533 | 16.5743211 |
| **Lux.** | 24.5434783 | 7.11363636 | 76.2167183 | 56.3951807 | 80.628877 | 244.24359 | 82.35499 |
| **Malta[28]** | - | - | - | 34.5876701 | 23.5898413 | 156.623715 | 92.3355025 |
| **Neth.** | 5.7109375 | 187.656716 | 92.7249022 | 61.3741794 | 53.4032037 | 147.642147 | 52.1124971 |
| **Poland** | 76.0040753 | 20.5614702 | 30.9592842 | 35.9481056 | 28.8640225 | 99.0645684 | 70.1604906 |
| **Portugal** | 8.08809208 | 8.39629005 | 30.1809017 | 23.2259124 | 26.4586394 | 83.5492447 | 28.1183602 |
| **Romania** | 77.82393 | 11.5304409 | 26.2250254 | 25.3829519 | 17.3855993 | 90.8071834 | 607.126858 |
| **Slovak Rep.** | 10.8215259 | 2.69067797 | 15.7689016 | 11.1905637 | 9.90558292 | 25.8605948 | 16.7156204 |
| **Slovenia** | 34.4893899 | 17.1563981 | 83.5034049 | 89.0958466 | 47.5732134 | 117.613095 | 48.9550377 |
| **Spain** | 34.1584699 | 8.62280343 | 67.5093551 | 54.2448046 | 28.9965736 | 95.8897274 | 41.5862641 |
| **Sweden** | 46.4096171 | 24.8030303 | 115.931034 | 68.3683901 | 65.5823739 | 152.251939 | 55.9405812 |
| **UK** | 41.6957974 | 60.2091452 | 87.579165 | 68.8019836 | 43.1963267 | 132.063012 | 52.0815495 |

## Appendix G – $A_{ij}$ coefficients for the environmental constraint (In tonnes of $CO_2$ equivalent per capita )

| Countries | Agriculture, forestry and fishing | Energy industry | Manufacturing industry | Construction and residential | Trade, transports, distribution, repairing | Commercial services (Information, communication, financial and insurance activities) | Public, administrative services, technical, scientific, education, health, and social services |
|---|---|---|---|---|---|---|---|
| **Austria** | 42.9540816 | 242.01436 | 41.9633001 | 1.28165882 | 6.54650905 | 0.92695112 | 1.08592799 |
| **Belgium** | 157.145638 | 411.729567 | 67.2746833 | 1.65191961 | 10.2610713 | 5.0005112 | 2.69191129 |
| **Bulgaria** | 132.405063 | 888.801154 | 10.9605196 | 0.38526668 | 6.08626768 | 0.63702874 | 1.65720044 |
| **Croatia** | 95.012559 | 425.771084 | 16.3766647 | 0.36249707 | 3.2727218 | 3.03874092 | 3.90046897 |
| **Cyprus[29]** | - | - | 62.5911127 | 1.82332289 | 4.25026919 | 3.93933421 | 3.33982541 |
| **Czech Rep.** | 50.7551919 | 456.4375 | 13.5657073 | 0.45590467 | 7.39381659 | 0.79959735 | 1.96142651 |
| **Denmark** | 142.233088 | 789.9124 | 19.6485282 | 0.59830636 | 55.0937161 | 0.6539162 | 0.96378857 |
| **Estonia** | 52.2847737 | 1093.79632 | 21.3237998 | 0.52454721 | 11.1536471 | 0.41627451 | 2.00936073 |
| **Finland** | 54.4043478 | 779.38038 | 40.8057619 | 46.9652266 | 19.9146482 | 1.76585873 | 1.8218068 |
| **France** | 117.937337 | 166.716604 | 35.5619279 | 1.80443432 | 8.44223549 | 1.38713597 | 1.65178086 |
| **Germany** | 103.122581 | 619.602452 | 21.3799912 | 1.22259592 | 9.78500452 | 2.02749544 | 1.53221974 |
| **Greece** | 19.0075048 | 1070.39423 | 39.5035987 | 0.31532525 | 5.16486009 | 0.23903186 | 0.69042033 |
| **Hungary** | 21.6398831 | 212.655298 | 12.505557 | 0.37224368 | 5.28089492 | 2.65258507 | 1.52136101 |
| **Ireland** | 160.889292 | 528.097345 | 31.1772351 | 1.04006475 | 7.53465957 | 1.67869251 | 1.20831915 |
| **Italy** | 34.5847979 | 423.857234 | 23.3722407 | 1.12089621 | 8.03460079 | 0.41043702 | 0.62426334 |
| **Latvia** | 34.301676 | 96.9302326 | 11.3301181 | 0.27066092 | 10.2231039 | 0.33055684 | 1.04611532 |
| **Lithuania** | 31.0669975 | 166.05948 | 23.798145 | 0.13640267 | 20.8728432 | 0.40135371 | 0.52110291 |
| **Lux** | 144.130435 | 227.954545 | 45.1394118 | 0.41445783 | 41.4877005 | 1.79450321 | 1.47220362 |

[28] Due to missing or confidential data, some coefficients for these countries were undetermined.
[29] Due to missing or confidential data, some coefficients for these countries were undetermined.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Malta**[30] | - | - | - | - | 59.6524149 | 1.87548863 | 2.35491114 |
| **Netherl.** | 9.42552083 | 940.298507 | 54.9305841 | 2.06008096 | 15.0125195 | 1.26389066 | 1.89629889 |
| **Poland** | 229.273113 | 582.036287 | 25.6752885 | 0.65958235 | 10.6354683 | 4.62561718 | 7.75055518 |
| **Portugal** | 15.4006197 | 278.347386 | 22.1159339 | 2.42664234 | 6.26775096 | 0.80845921 | 0.94976221 |
| **Romania** | 199.99766 | 288.528794 | 19.5187671 | 0.4199031 | 6.36748251 | 2.95076956 | 50.1226046 |
| **Slovak Rep.** | 39.986376 | 196.610169 | 35.8630589 | 0.10201593 | 8.02129228 | 0.04663569 | 1.68465344 |
| **Slovenia** | 22.4270557 | 301.374408 | 11.9924987 | 0.80079872 | 20.0484908 | 0.1722619 | 0.72278635 |
| **Spain** | 49..5382514 | 356.044136 | 36.6979929 | 0.95213781 | 6.60678946 | 0.75128286 | 0.6894394 |
| **Sweden** | 65.3428317 | 166.272727 | 24.1406586 | 0.18527615 | 14.0804982 | 0.6683044 | 0.69214973 |
| **UK** | 121.722794 | 464.666147 | 32.6134042 | 1.46849774 | 11.4808266 | 0.63705344 | 1.39734997 |

## Appendix H – $A_{ij}$ coefficients for the energy constraint[31]

| Countries | Agriculture, forestry and fishing | Energy industry | Manufacturing industry | Construction and residential | Trade, transports, distribution, repairing | Commercial services (Information, communication, financial and insurance activities) | Public, administrative services, technical, scientific, education, health, and social services |
|---|---|---|---|---|---|---|---|
| **Austria** | 3..05555556 | 33.4775087 | 11.9034046 | 18.9333782 | 6.99641516 | 2.34134217 | 1.49642573 |
| **Belgium** | 10.8221477 | 158.060264 | 21.1912351 | 27.7610819 | 8.92662904 | 3.59780313 | 1.47399394 |
| **Bulgaria** | 3..36730017 | 15.9027415 | 4.88982052 | 14.7115783 | 3.71171117 | 2.3320825 | 3.12364279 |
| **Croatia** | 6.43131193 | 38.1979782 | 4.32018835 | 21.3400328 | 4.53484141 | 3.70225728 | 4.25439613 |
| **Cyprus**[32] | - | - | 7.94797688 | 15.5557956 | 5.13408047 | 4.33639947 | 4.76821192 |
| **Czech Rep.** | 3.73190686 | 22.71875 | 4.992324 | 13.7962062 | 4.71838896 | 2.47610619 | 1.53514848 |
| **Denmark** | 10.6911765 | 10.04 | 7.35915493 | 22.867052 | 5.55955679 | 2.03798883 | 1.19118367 |
| **Estonia** | 5.43209877 | 8.30882353 | 4.80067854 | 17.1098266 | 4.87820935 | 2.57142857 | 1.8630137 |
| **Finland** | 6.64199815 | 36.3924051 | 30.4302977 | 26.6807165 | 7.86610879 | 3.97922438 | 2.24716465 |
| **France** | 5.89556136 | 44.0345912 | 9.66504854 | 20.8596982 | 6.98044245 | 2.59987639 | 1.3374483 |
| **Germany** | 15.1387097 | 38.7390543 | 7.30202235 | 20.9334694 | 5.5213332 | 2.86023468 | 1.54756334 |
| **Greece** | 0.59571762 | 14.0159046 | 9.13879846 | 20.8710033 | 4.33579336 | 2.09803922 | 1.11567286 |
| **Hungary** | 2.18772827 | 20.4141291 | 5.0580196 | 16.4598811 | 3.83258185 | 2.12098299 | 1.20596534 |
| **Ireland** | 2.00544465 | 9.55752212 | 11.0054214 | 18.4244604 | 6.51950355 | 1.61892247 | 1.3748082 |
| **Italy** | 3.04920914 | 23.0057618 | 6.595012 | 19.0329231 | 6.00347143 | 2.32645939 | 1.51262151 |
| **Latvia** | 2.13687151 | 4.13953488 | 6.67510549 | 17.8017241 | 4.0203666 | 2.82598608 | 1.75567568 |
| **Lithuania** | 0.86848635 | 39.7769517 | 4.79033054 | 13.3587786 | 4.58705357 | 2.57641921 | 1.12434493 |
| **Lux** | 5.43478261 | 8.18181818 | 18.9783282 | 11.5180723 | 22.4171123 | 1.26282051 | 2.11118553 |

[30] Due to missing or confidential data, some coefficients for these countries were undetermined.
[31] In tonnes of oil equivalent.
[32] Due to missing or confidential data, some coefficients for these countries were undetermined.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Malta**[33] | - | - | - | 7.20576461 | 3.2049061 | 3.11278413 | 3.90074971 |
| **Netherl.** | 1.846875 | 211.731343 | 17.1851369 | 19.9562363 | 4.70480549 | 2.51530815 | 1.19105672 |
| **Poland** | 26.0527183 | 17.7371253 | 5.84080648 | 22.7916355 | 4.95761193 | 5.04091907 | 5.06897908 |
| **Portugal** | 0.93846835 | 24.1989882 | 6.15093811 | 9.37591241 | 4.75603358 | 2.30090634 | 1.02029607 |
| **Romania** | 4.93763602 | 12.6907878 | 5.2571905 | 20.2288405 | 3.82021725 | 2.24704821 | 32.000724 |
| **Slovak Rep.** | 1.88010899 | 19.470339 | 6.71693499 | 11.9607843 | 3.61083744 | 2.42936803 | 1.98267247 |
| **Slovenia** | 0.98143236 | 6.96682464 | 6.44316396 | 16.6134185 | 8.98050975 | 1.69444444 | 1.12110272 |
| **Spain** | 3.77868852 | 16.7797303 | 9.34489965 | 14.6146962 | 4.98837147 | 2.15141188 | 1.10563105 |
| **Sweden** | 3.35707925 | 29.8333333 | 18.5465517 | 19.4858989 | 7.87773816 | 3.26339121 | 1.58223257 |
| **UK** | 2.70804342 | 17.9059496 | 9.02223956 | 17.0839613 | 4.8104082 | 1.3287339 | 0.93470891 |

## Appendix I – Model results: Significant deviations in the results of the GP model

| | $D_1^-$ | $D_1^+$ | $D_2^-$ | $D_2^+$ | $D_3^-$ | $D_3^+$ | $D_4^-$ | $D_4^+$ |
|---|---|---|---|---|---|---|---|---|
| **Austria** | x | | | x | | x | | |
| **Belgium** | | x | | | | x | | |
| **Bulgaria** | | x | | | | | | x |
| **Croatia** | | | | x | | x | | x |
| **Cyprus** | x | | | | x | | | |
| **Czech Rep.** | x | | X | | x | | | |
| **Denmark** | | x | | x | | x | | |
| **Estonia** | | | | x | | x | | x |
| **Finland** | x | | | x | | x | | |
| **France** | x | | | x | | x | | |
| **Germany** | | x | | | | x | | x |
| **Greece** | | x | | x | | x | | x |
| **Hungary** | | | | | | x | | x |
| **Ireland** | x | | | x | | x | | |
| **Italy** | | x | | | | x | | x |
| **Latvia** | | | | | | | | x |
| **Lithuania** | | x | | | | x | | x |
| **Luxembourg** | | x | | x | | x | | |
| **Malta** | x | | | x | | x | | |
| **Netherlands** | | | | | | x | | |
| **Poland** | | x | | | | x | | x |
| **Portugal** | | | | x | | x | | x |
| **Romania** | | x | | | x | | | x |
| **Slovak Rep.** | x | | X | | x | | | |
| **Slovenia** | x | | | x | | x | | |
| **Spain** | | x | | x | | x | | |
| **Sweden** | x | | | | x | | | |

[33] Due to missing or confidential data, some coefficients for these countries were undetermined.

| UK | | x | | x | | x | | |
|---|---|---|---|---|---|---|---|---|

## Appendix J – Model results: Detailed results of the GP model

| | $D_1^-$ | $D_1^+$ | $D_2^-$ | $D_2^+$ | $D_3^-$ | $D_3^+$ | $D_4^-$ | $D_4^+$ |
|---|---|---|---|---|---|---|---|---|
| **Austria** | 4,460,1580 | 0 | 0 | 20,677,980 | 0 | 10,695,990 | 0 | 0 |
| **Belgium** | 0 | 104,524,100 | 0 | 0 | 0 | 9,862,652 | 0 | 0 |
| **Bulgaria** | 0 | 15,466,390 | 0 | 0 | 0 | 0 | 0 | 843,812.3 |
| **Croatia** | 0 | 0 | 0 | 5,525,223 | 0 | 1,517,922 | 0 | 36,6813 |
| **Cyprus** | 7,892,4460 | 0 | 0 | 0 | 779,739,100 | 0 | 0 | 0 |
| **Czech Rep.** | 128,010,800 | 0 | 30,208,690 | 0 | 3,858,174 | 0 | 0 | 0 |
| **Denmark** | 0 | 50,315,840 | 0 | 2,490,308 | 0 | 2,306,434 | 0 | 0 |
| **Estonia** | 0 | 0 | 0 | 12,036,040 | 0 | 160,5637 | 0 | 1,439,487 |
| **Finland** | 614,629,900 | 0 | 0 | 25,281,090 | 0 | 477,1897 | 0 | 0 |
| **France** | 185,143,400 | 0 | 0 | 13,856,240 | 0 | 38,919,930 | 0 | 0 |
| **Germany** | 0 | 960,975,200 | 0 | 0 | 0 | 34,115,800 | 0 | 4,593,585 |
| **Greece** | 0 | 2,990,281 | 0 | 11,953,400 | 0 | 3,203,648 | 0 | 477,454 |
| **Hungary** | 0 | 0 | 0 | 0 | 0 | 4,439,730 | 0 | 3,559,426 |
| **Ireland** | 114,504,200 | 0 | 0 | 35,501,810 | 0 | 13,858,420 | 0 | 0 |
| **Italy** | 0 | 446,004,600 | 0 | 0 | 0 | 24,601,410 | 0 | 2,804,939 |
| **Latvia** | 0 | | 0 | 0 | 0 | 0 | 0 | 560,002.7 |
| **Lithuania** | 0 | 5,675,707 | 0 | 0 | 0 | 1,462,300 | 0 | 339,897.1 |
| **Luxembourg** | 0 | 7,099,267 | 0 | 573,367.9 | 0 | 2027462 | 0 | 0 |
| **Malta** | 262,580,900 | | 0 | 460,428.6 | 0 | 194,785.3 | 0 | 0 |
| **Netherlands** | 0 | 0 | 0 | 0 | 0 | 10,347,080 | 0 | 0 |
| **Poland** | 0 | 120,342,200 | 0 | 0 | 0 | 12,580,790 | 0 | 307,363 |
| **Portugal** | 0 | 0 | 0 | 11,565,290 | 0 | 6,551,841 | 0 | 682,089.1 |
| **Romania** | 0 | 46,271,050 | 0 | 0 | 9,368,044 | 0 | 0 | 860,759.8 |
| **Slovak Rep.** | 22,878,340 | 0 | 500,978,300 | 0 | 2,023,232 | 0 | 0 | 0 |
| **Slovenia** | 425,353,700 | 0 | 0 | 970,167.7 | 0 | 1,611,453 | 0 | 0 |
| **Spain** | 0 | 198,577,300 | 0 | 706,137,600 | 0 | 52,337,540 | 0 | 0 |
| **Sweden** | 656,521,500 | 0 | 0 | 0 | 14,326,920 | 0 | 0 | 0 |
| **UK** | 0 | 898,065,800 | 0 | 396,765,400 | 0 | 1,751,931 | 0 | 0 |