

# TRANSITIONS PATHWAYS AND RISK ANALYSIS FOR CLIMATE CHANGE MITIGATION AND ADAPTATION STRATEGIES

## Employment implications of energy transitions: the case of the European Union between 1995 and 2009

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# TRANSrisk

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## Preface

Both the models concerning the future climate evolution and its impacts, as well as the models assessing the costs and benefits associated with different mitigation pathways face a high degree of uncertainty. There is an urgent need to not only understand the *costs and benefits* associated with *climate change* but also the *risks, uncertainties and co-effects* related to different *mitigation pathways* as well as *public acceptance* (or lack of) of low-carbon (technology) options. The main aims and objectives of TRANSrisk therefore are to create a novel assessment framework for analysing costs and benefits of transition pathways that will integrate well-established approaches to modelling the costs of resilient, low-carbon pathways with a wider interdisciplinary approach including risk assessments. In addition *TRANSrisk* aims to design a decision support tool that should help policy makers to better understand uncertainties and risks and enable them to include risk assessments into more robust policy design.

## PROJECT PARTNERS

No	Participant name	Short Name	Country code	Partners' logos
1	Science Technology Policy Research, University of Sussex	SPRU	UK	
2	Basque Centre for Climate Change	BC3	ES	
3	Cambridge Econometrics	CE	UK	
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6	Institute for Structural Research	IBS	PL	
7	Joint Implementation Network	JIN	NL	
8	National Technical University of Athens	NTUA	GR	
9	Stockholm Environment Institute	SEI	SE, KE	
10	University of Graz	UniGraz	AT	
11	University of Piraeus Research Centre	UPRC	GR	
12	Pontifical Catholic University of Chile	CLAPESUC	CL	

## Executive Summary

In the view of pressing unemployment and environmental problems, different policies have been proposed to create jobs in the transition to a green economy, including the so-called “green jobs”. There has been an intense debate on the quantification of these employment effects, especially in the European Union. Most studies have focused on estimating gross future employment effects and have ignored the effects between different sectors and countries.

This reports looks at the past net employment impacts from the transformation of the EU energy sector including spill-over effects, by using a multi-regional input-output model and the World Input-Output Database. The analysis is focused on the period (1995-2009) when the EU’s energy structure went through a significant shift, away from the more carbon intensive sources, towards gas and renewables. We estimate the net employment generated from this structural change at 530,000 jobs in the EU (0.24% of total employment in 2009), of which one third is due to trans-boundary or spill-over effects within the EU (i.e. employment generated in one country due to the changes in another). Within the EU, the main gainers were Poland, Germany, Hungary, Italy and Spain, and the main losers were Ireland, Lithuania, France and Czech Republic.

These spill-over effects have traditionally been ignored when assessing the impacts of the deployment of new energy technologies. However, in the light of these results, spill-over effects should be taken into account in order to give a more accurate picture of the employment effects of European energy and climate policies, as is being done in other areas such as trade policy.

Finally and in conclusion, our results support a relatively positive impact on employment from historical deployment of renewables and gas in the EU. Given our findings, the forward looking estimates for the EU (Ragwitz et al. 2009) and (Cambridge Econometrics 2013) do not appear to be overly optimistic. Of course a direct comparison is not possible as the changes being compared are different, but an overall picture of a small gain in employment from the technology shifts involved in moving to a lower carbon future is probably right.

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## 1 EC SUMMARY REQUIREMENTS

### 1.1 Changes with respect to the DoA

No fundamental change to DOA.

### 1.2 Dissemination and uptake

This work has been published in the journal *Applied Energy*.

### 1.3 Short Summary of results (<250 words)

In the view of pressing unemployment and environmental problems, different policies have been proposed to create jobs in the transition to a green economy, including the so-called “green jobs”. There has been an intense debate on the quantification of these employment effects, especially in the European Union. Most studies have focused on estimating gross future employment effects and have ignored the effects between different sectors and countries. This paper looks, for the first time, at the past net employment impacts from the transformation of the EU energy sector including spill-over effects, by using a multi-regional input-output model and the World Input-Output Database. The analysis is focused on the period (1995-2009) when the EU’s energy structure went through a significant shift, away from the more carbon intensive sources, towards gas and renewables. We estimate the net employment generated from this structural change at 530,000 jobs in the EU (0.24% of total employment in 2009), of which one third is due to trans-boundary effects within the EU (i.e. employment generated in one country due to the changes in another). Within the EU, the main gainers were Poland, Germany, Hungary, Italy and Spain, and the main losers were Ireland, Lithuania, France and Czech Republic.

### 1.4 Evidence of accomplishment

This report.

## 2 INTRODUCTION

There is a great deal of interest in the employment effects resulting from the transition to a low carbon and sustainable economy. The increase in unemployment following the financial crisis of 2007-2008 and the declared commitment of different countries to reduce environmental pressures have led together to the introduction of several policies aimed to create "green jobs" (Renner, Sweeney, and Kubit 2008; UNEP 2008).

As a prime example, the European Union (EU) has presented recently the Green Employment Initiative (European Commission 2008), a funding mechanism "to help Member States with employment opportunities and challenges in the transition to a greener economy". At the same time, the EU has adopted the Energy and Climate Framework (European Commission 2014a) for the year 2030 with the aim of reducing greenhouse gas emissions by 40% (from 1990 levels), a binding target (at EU level) to boost the share of renewables to at least 27% of EU energy consumption, and a 27% improvement in energy efficiency. These types of policies are not new in the EU: in 1997 the EU-15 already committed, within the framework of the Kyoto Protocol, to reduce its greenhouse gas emissions by 8% in the period 2008-2012 with respect the year 1990; and in 2008 the EU climate and energy package agreed a reduction of at least 20% in greenhouse gas emissions by 2020 with a 20% share for renewable energies in energy consumption by that date (European Commission 2008b). In parallel with the imposition of these objectives, different instruments have been deployed (Drummond 2013) such as feed-in tariffs to support the development of renewables, which have been in place for at least two decades (Jenner, Groba, and Indvik 2013), and the Emission Trading Scheme, which was launched in the year 2005.

There has been an intense debate on the quantification of the employment effects of these policies. The literature on the employment effects associated with the low-carbon transition and, especially, with renewable energy promotion is abundant (Cameron and van der Zwaan 2015), (Ortega et al. 2015). One estimate (Ragwitz et al. 2009) suggest that policies supporting renewable sources of energy to meet the 20% target by 2020 would provide 410,000 additional jobs in the EU. Another study by Cambridge Econometrics (Cambridge Econometrics 2013) estimates that the 2050 Road Map (European Commission 2011), which requires a reduction in CO<sub>2</sub> emissions of 80-90% from 1990 levels, would result in an increase in employment ranging from 0 to 1.5%. Similar positive results emerge from more local studies in Europe (Moreno and López 2008). They find slightly higher employment in a scenario with more renewables and less fossil fuel energy than the base case. Other studies assessing the potential employment impacts of renewables are (Wei, Patadia, and Kammen 2010) for US, (Cai et al. 2014) for China, (Lehr et al. 2008) for Germany, or (Markaki et al. 2013) for Greece.

All the previous studies have focused on the domestic impacts in a specific country or region, ignoring the trans-boundary effects due to changes in trade flows derived from the



transformation in the energy sector of a specific country. This is especially relevant in an increasing globalized world, in which the production inputs are internationally traded. Moreover, most of the studies have focused on the *ex-ante* (predicted) impacts of different policies, rather than on the *ex-post* (confirmed) results of such interventions, something that requires them to make a number of assumptions about the evolution of the economy.

In this report we use a novel method based on a multiregional input-output model and the World Input-Output Database (Dietzenbacher et al. 2013; Timmer 2012) that allows us to estimate for the first time the domestic and foreign employment impacts due to the past changes in the energy sector in the EU. We quantify the impacts in employment in the whole EU27 due to the changes in the electricity and gas supply<sup>1</sup> of each of the member states. We answer the following question: what would have been the EU employment in 2009 if the structure of the electricity and gas supply sector of each EU country had remained the same as in 1995. We estimate the net changes in employment and the gainers and losers at the worldwide level.

The rest of this report is organised as follows. Section 2 shows the methodology (model and data) and section 3 presents and discusses the results. Section 4 describes the limitations of the studies and indicates directions for future research, and Section 5 concludes

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<sup>1</sup> This sector corresponds to the section E of the NACE 1 classification “Electricity, Gas and Water supply”; it covers the production and distribution of electricity, manufacture of gas, distribution of gaseous fuels, steam and hot water supply, and collection, purification and distribution of water.

## 3 METHOD

Single region input-output methods have been extensively used to assess the employment impacts of different energy technologies including, among others, biofuels (Herreras Martínez et al. 2013; Madlener and Koller 2007; Neuwahl et al. 2008; Silalertruksa et al. 2012), coal-to-liquids (Qi et al. 2012), geothermal (Hienuki, Kudoh, and Hondo 2015), energy efficiency (Mirasgedis et al. 2014), and renewables (Cai et al. 2014; Lehr et al. 2008; Markaki et al. 2013; Tourkolias and Mirasgedis 2011; Ziegelmann, Mohr, and Unger 2000; Mathiesen, Lund, and Karlsson 2011). In addition, multiregional input-output models have been used to assess the economic and environmental implications of low carbon transitions (Mundaca, Román, and Cansino 2015; Su and Ang 2015). In this section we present a multiregional input-output model and database for the calculation of the total employment effects generated by the changes in the electricity and gas supply sector of the EU from a multi-regional perspective.

### 3.1 The model

The starting point for the construction of the model used is a symmetric multiregional input-output <sup>2</sup> table. This table describes (in monetary terms) the flows of goods and services between all the individual sectors and countries, and the use of goods and services by final users. For the sake of simplicity, we show the structure of the multiregional input-output table for three regions, but it can be expanded for any number of regions and sectors. The three main components in the multiregional input-output table are:

$$\mathbf{Z} = \begin{bmatrix} \mathbf{Z}^{11} & \mathbf{Z}^{12} & \mathbf{Z}^{13} \\ \mathbf{Z}^{21} & \mathbf{Z}^{22} & \mathbf{Z}^{23} \\ \mathbf{Z}^{31} & \mathbf{Z}^{32} & \mathbf{Z}^{33} \end{bmatrix} \quad \mathbf{F} = \begin{bmatrix} \mathbf{f}^{11} & \mathbf{f}^{12} & \mathbf{f}^{13} \\ \mathbf{f}^{21} & \mathbf{f}^{22} & \mathbf{f}^{23} \\ \mathbf{f}^{31} & \mathbf{f}^{32} & \mathbf{f}^{33} \end{bmatrix} \quad \mathbf{x} = \begin{bmatrix} \mathbf{x}^1 \\ \mathbf{x}^2 \\ \mathbf{x}^3 \end{bmatrix}$$

Where  $\mathbf{Z}^{rs}$  is the matrix of intermediate deliveries from country  $r$  to country  $s$ , and its element  $z_{ij}^{rs}$  denotes the sales of sector  $i$  in country  $r$  to sector  $j$  in country  $s$ ;  $\mathbf{f}^{rs}$  is a column vector with final demands (i.e. private consumption, government consumption and investments) and its element  $f_i^{rs}$  indicates the final demand in country  $s$  for good  $i$  produced by country  $r$ ; and  $\mathbf{x}^r$  is the column vector of gross outputs in country  $r$ . Further,

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<sup>2</sup> Notation: Bold-face, lower-case letters refer to vectors; bold-face, capital letters refer to matrices; italic, lower-case letters refer to elements of a vector or matrix; subscripts reveal industry dimension; superscripts reveal country dimension; diagonal matrices are denoted by  $\hat{\cdot}$ .

the global multiregional input-output table is extended with a vector  $\mathbf{e}^r$  with element  $e_i^r$  indicating the (national) employment by sector  $i$  in country  $r$ . We define:

$$\mathbf{e} = \begin{bmatrix} \mathbf{e}^1 \\ \mathbf{e}^2 \\ \mathbf{e}^3 \end{bmatrix}$$

The relation between  $\mathbf{x}$ ,  $\mathbf{Z}$  and  $\mathbf{F}$  is defined by the accounting equation:  $\mathbf{x} \equiv \mathbf{Z}\mathbf{i} + \mathbf{F}\mathbf{i}$  where  $\mathbf{i}$  is the column summation vector (i.e. a vector with ones) of appropriate length.

The multi-regional matrix of input coefficients is defined as:  $\mathbf{A} = \mathbf{Z}(\hat{\mathbf{x}})^{-1}$  where  $(\hat{\mathbf{x}})^{-1}$  denotes the inverse of the diagonal matrix of the gross output vector. The element  $a_{ij}^{rs}$  of  $\mathbf{A}$  denotes the inputs from sector  $i$  of region  $r$  that are used by sector  $j$  of region  $s$  to produce one unit of output. Thus, we can define the matrix of total input coefficients as  $\mathbf{B}$ , where the element  $b_{ij}^s = \sum_r b_{ij}^{rs}$  denotes the inputs from sector  $i$  that are used by sector  $j$  of region  $s$  to produce one unit of output (regardless of the origin country of those inputs).

We define the intermediate trade shares matrix as  $\mathbf{T}$  where the element  $t_{ij}^{rs} = z_{ij}^{rs} / \sum_r z_{ij}^{rs}$  of  $\mathbf{T}$  denotes, for each sector  $j$  of country  $s$ , the share of inputs that are produced domestically (when  $r = s$ ) or imported (when  $r \neq s$ ).

Therefore, the multi-regional matrix of input coefficients can now be expressed as  $\mathbf{A} = \mathbf{T} \circ \mathbf{B}$  (where  $\circ$  denotes the element by element multiplication, i.e. Hadamard product).

Finally, the employment coefficients are defined as  $\mathbf{c}^r = (\hat{\mathbf{x}}^r)^{-1} \mathbf{e}^r$ . Stacking them gives the vector  $\mathbf{e}$ .

The accounting equation  $\mathbf{x} \equiv \mathbf{Z}\mathbf{i} + \mathbf{F}\mathbf{i}$ , can now be written as the standard input-output model:  $\mathbf{x} = \mathbf{A}\mathbf{x} + \mathbf{F}\mathbf{i}$ . For arbitrary final demands  $\mathbf{F}$  the solution to this model is given by  $\mathbf{x} = \mathbf{L}\mathbf{F}\mathbf{i}$ , where  $\mathbf{L} \equiv (\mathbf{I} - \mathbf{A})^{-1} = (\mathbf{I} - \mathbf{T} \circ \mathbf{B})^{-1}$  denotes the Leontief inverse, and the employment would be given by

$$\mathbf{e} = \hat{\mathbf{c}}\mathbf{x} = \hat{\mathbf{c}}\mathbf{L}\mathbf{F}\mathbf{i} = \hat{\mathbf{c}}(\mathbf{I} - \mathbf{T} \circ \mathbf{B})^{-1} \mathbf{F}\mathbf{i} \quad (1)$$

Previous expressions can be applied to data from different years, thus for a specific year  $t$ , the employment would be given by

$$\mathbf{e}_t = \mathbf{c}_t (\mathbf{I} - \mathbf{T}_t \circ \mathbf{B}_t)^{-1} \mathbf{F}_t \mathbf{i} \quad (2)$$

Expression (2) can be used to compute the changes in employment due to the changes in the input structure of a specific sector  $j$  in region  $s$  between two years,  $t=0$  and  $t=1$ . The idea is to re-calculate the employment in the year 1, but with the input structure of the year 0 (for the sector analysed) and all the remaining parameters constant (i.e. employment coefficients, economic structure of other sectors, trade structure and final demand of the year  $t=1$ ).

Assume that we want to assess the employment effects of the change in the input structure between the years  $t_0$  and  $t_1$  of the electricity and gas supply sector in two of the countries (countries 2 and 3)<sup>3</sup>. The input matrices for the years  $t_0$  and  $t_1$  are denoted by  $\mathbf{B}_{t_0}$  and  $\mathbf{B}_{t_1}$ , where the element  $b_{ij,t}^s$  denotes the inputs from sector  $i$  that are used by sector  $j$  of region  $s$  to produce one unit of output, in the year  $t$ . Thus, for countries 2 and 3, the technology of the electricity and gas supply sector in the year  $t$  is defined as  $b_{iEGW,t}^2$  and  $b_{iEGW,t}^3$  (for all  $i$ ). Thus, replacing in  $\mathbf{B}_{t_1}$  the elements  $b_{iEGW,t_1}^2$  by  $b_{iEGW,t_0}^2$  and  $b_{iEGW,t_1}^3$  by  $b_{iEGW,t_0}^3$  (for all  $i$ ) gives a new matrix  $\overline{\mathbf{B}}_{t_1 t_0}$ , representing the input structure of the year  $t_0$  for the electricity and gas supply sector in country 2 and 3, and for all the other sectors and countries the technology of the year  $t_1$ .

Thus the change in the employment of the three regions due to the change in the electricity and gas supply of countries 2 and 3 can be calculated as

$$\Delta \mathbf{e}_t = \mathbf{c}_{t_1} (\mathbf{I} - \mathbf{T}_{t_1} \circ \mathbf{B}_{t_1})^{-1} \mathbf{F}_{t_1} \mathbf{i} - \mathbf{c}_{t_1} (\mathbf{I} - \mathbf{T}_{t_1} \circ \overline{\mathbf{B}}_{t_1 t_0})^{-1} \mathbf{F}_{t_1} \mathbf{i} \quad (3)$$

## 3.2 The database

We use data from the European Commission FP7-funded World Input-Output Database (Dietzenbacher et al. 2013; Timmer 2012). This database comprises a set of harmonised symmetric input-output tables, valued at current and previous year prices. The World Input-Output Database distinguishes between 35 industries, spans the period 1995 ( $t_0$ ) to 2009 ( $t_1$ ) and covers 41 regions: 27 EU Member States, 13 other major countries in the world and

<sup>3</sup> Note that in our case study, countries 2 and 3 would be replaced by the 27 MS of the EU and country 1 by the other 14 regions of the World Input-Output Database.

the Rest of the World as an aggregated region. It also includes data on international trade and satellite accounts related to various environmental and socio-economic indicators, including the figures for employment by sector and country that we have used in this paper. The World Input-Output Database does not report employment figures for the Rest of the World. We estimate these figures using data from the International Labour Organization and the labour productivity of the World Input-Output Database countries.

In order to use expression (3) to calculate the change in the employment resulting from the change in the electricity and gas supply sector technologies, we proceed as follows. First the multiregional input-output tables in current and previous year prices are used to express the table of 1995 in 2009 prices. This step is necessary in order to keep the effects of changes in prices out of the analysis (Arto and Dietzenbacher 2014). When checking the deflators of the gross output in the socioeconomic accounts of the World Input-Output Database we found that the figures for Bulgaria and Romania were not consistent with EUROSTAT data and so we decided to keep these two countries out of the analysis. Therefore the analysis was limited to the changes in the electricity and gas supply sector of the remaining 25 member states, which, in 2009, represented more than 98% of the EU GDP and 97% of the total primary energy supply.

Given the multiregional input-output tables of 1995 in 2009 prices, we calculated, for the (25) EU countries, all the technical coefficients of the electricity and gas supply sector (sector 17<sup>4</sup> in the World Input-Output Database) for the year 1995 at 2009 prices. Then, we replaced the total technical coefficients of the electricity and gas supply of the EU countries in 2009 by these total coefficients of 1995 at 2009 prices, which results in the  $\overline{\mathbf{B}}_{t,t_0}$  expression (3).

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<sup>4</sup> Sector 17 in the World Input-Output Database database includes also water supply. Unfortunately, it is not possible to separate out that component but it is very small and almost all the changes can be attributed to electricity and gas production. Hence, we feel it is reasonable to refer to it as the electricity and gas supply sector for the purposes of this analysis.

## 4 RESULTS

During the period 1995-2009 the energy system of the EU suffered a series of transformations, characterized by an increase in the share of renewables and gas in the total primary energy supply and, especially, in the electricity and heat input mix (Figure 1Error! Reference source not found.a and b)<sup>5</sup>. According to the energy balances of the International Energy Agency (International Energy Agency 2014), the contribution of gas to the total energy supply in the EU27 increased from 20% in 1995 to 25% in 2009, while renewables went up from 5% to 10% (Figure 1a). On the contrary, coal reduced its share in the total primary energy supply from 22% in 1995 to 16% in 2009, and oil, although remaining the main component of the total primary energy supply, reduced its contribution to the energy mix from 38% to 35%. The share of nuclear energy in the total primary energy supply remained constant (14% in both years).

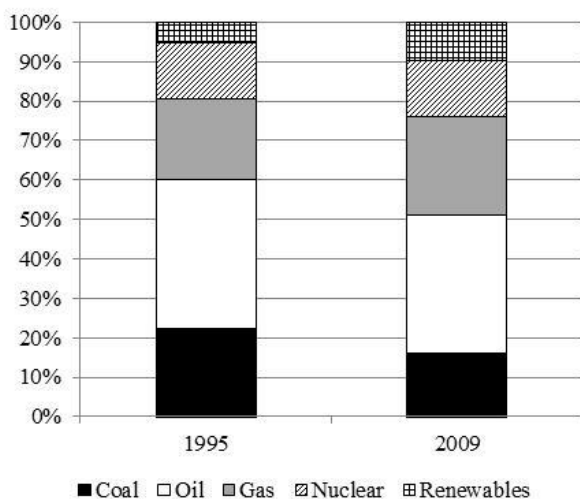
In the case of the electricity mix (Figure 1b), the share of gas and renewables increased notably, from 11% and 13% respectively in 1995 to 24% and 19% in 2009. In 2009 nuclear energy was still the main source for heat and power generation in the EU (28%), but showed a decline with respect to the levels of 1995 (32%). Coal fuelled technologies reduced their contribution to the mix from 35% in 1995 to 26% in 2009 and the share of oil decreased from 9% to 3%. In parallel, the transformation efficiency, measured as the quotient between the electricity and heat generation divided by the energy inputs, increased by 3 percentage points, from 37% to 40% (Figure 1Error! Reference source not found.b). Detailed data at the country level can be found in the Appendix<sup>6</sup>. This increase was mainly driven by the growth in the transformation efficiency in gas powered plants (from 36% to 46%) due to the penetration of integrated gasification combined cycle technology. On the contrary, the transformation efficiency of renewables fell from 73% to 60%, due to the increase in the share of renewables electricity from biomass, biogas and waste, which have lower transformation efficiency than other renewables such as hydropower, solar or wind. All these changes contributed to reduce the emissions of CO<sub>2</sub> in the EU (Rafaj et al. 2013).

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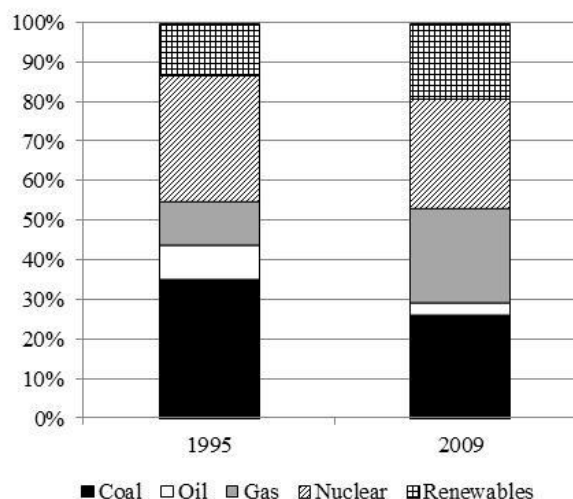
<sup>5</sup> The electricity and heat mix include the following transformation technologies: Main activity electricity plants (IEA code: MAINELEC), Autoproducer electricity plants (AUTOELEC), Main activity combined heat and power plants (MAINCHP), Autoproducer heat and power plants (AUTOCHP), Main activity heat plants (MAINHEAT) and Autoproducer heat plants (AUTOHEAT).

<sup>6</sup> As noted, major changes in the energy mix occurred in the analyzed period (1995-2009). From 2009 to 2014, the main change has been the increase in renewables at the expense of gas, of 3% in the primary energy supply and of 8% in the electricity mix.

a) Total primary energy supply, EU27



b) Electricity and heat generation mix, EU27



Source: International Energy Agency

**Figure 1: Total primary energy supply and electricity and heat generation mix in the EU27, 1995 and 2009 (%)**

These changes in the energy system also had some impact on the input structure of the electricity and gas supply sector of the EU. Comparing these structures for the years 1995 and 2009 (see Table 1), we observe that in both years, inputs coming from the “Mining and Quarrying” (mainly from coal mining)<sup>7</sup> sector and the own “Electricity and gas supply” (mainly from gas supply) accounted for almost 60%. Other relevant sectors supplying inputs to the electricity and gas supply are “Renting of Machinery and Other Business Activities”, “Construction”, “Coke, Refined Petroleum and Nuclear Fuel”, “Wholesale Trade” or “Financial Intermediation”. Although this overall picture has not changed much between 1995 and 2009, we can see modifications in the patterns of use of some specific inputs. For instance, the reduction in the use of coal in the electricity sector generated a decrease in the share of inputs from the “Mining and Quarrying” from 25.7% in 1995 to 22.1% in 2009. Similarly, the increase in the use of gas translated into an increase in the share of intermediate inputs from the own “Electricity and gas supply” sector, passing from 30.8% in 1995 to 36% in 2009. Furthermore, the reduction in the share of oil and nuclear energy in the electricity sector can also be observed in the decrease in the intermediate inputs from the “Coke, Refined Petroleum and Nuclear Fuel” (from 4.8% in 1995 to 2.9% in 2009).

<sup>7</sup> This sector covers the extraction of fossil fuels and other metallic and non-metallic minerals. In the case of fossil fuel extraction in the EU, coal dominates over gas and oil.

**Table 1: Intermediate input structure of the electricity/gas sector in the EU, 1995 and 2009 (%)**

Code	Sector	1995	2009	2009-1995
c1	Agriculture, Hunting, Forestry and Fishing	0.1	0.2	0.1
c2	Mining and Quarrying	25.7	22.1	-3.6
c3	Food, Beverages and Tobacco	0.1	0.1	0.0
c4	Textiles and Textile Products	0.1	0.0	0.0
c5	Leather, Leather and Footwear	0.0	0.0	0.0
c6	Wood and Products of Wood and Cork	0.1	0.2	0.1
c7	Pulp, Paper, Paper , Printing and Publishing	0.5	0.4	-0.1
c8	Coke, Refined Petroleum and Nuclear Fuel	4.8	2.9	-1.9
c9	Chemicals and Chemical Products	0.6	0.7	0.1
c10	Rubber and Plastics	0.3	0.3	0.0
c11	Other Non-Metallic Mineral	0.3	0.3	0.0
c12	Basic Metals and Fabricated Metal	2.0	1.7	-0.4
c13	Machinery, Nec	1.2	1.4	0.2
c14	Electrical and Optical Equipment	1.7	2.3	0.6
c15	Transport Equipment	0.2	0.2	0.0
c16	Manufacturing, Nec; Recycling	0.1	0.2	0.1
c17	Electricity, Gas and Water Supply	30.8	36.0	5.2
c18	Construction	5.3	4.0	-1.3
c19	Sale, Maintenance and Repair of Motor Vehicles	0.5	0.7	0.1
c20	Wholesale Trade and Commission Trade	2.8	3.5	0.7
c21	Retail Trade	1.7	1.6	-0.1
c22	Hotels and Restaurants	0.3	0.3	0.0
c23	Inland Transport	2.4	2.8	0.4
c24	Water Transport	0.0	0.1	0.1
c25	Air Transport	0.1	0.1	0.0
c26	Other Supporting and Auxiliary Transport Activities	0.8	0.7	-0.2
c27	Post and Telecommunications	0.6	1.1	0.4
c28	Financial Intermediation	3.6	2.8	-0.8
c29	Real Estate Activities	1.3	1.3	-0.1
c30	Renting of Machinery and Other Business Activities	8.0	8.7	0.7
c31	Public Admin and Defence; Compulsory Social Security	2.6	1.6	-1.0
c32	Education	0.2	0.2	0.1
c33	Health and Social Work	0.1	0.1	0.0
c34	Other Community, Social and Personal Services	0.8	1.4	0.6
c35	Private Households with Employed Persons	0.0	0.0	0.0
		100.0	100.0	

Note: the intermediate input structure represent the share of the total intermediate inputs of the electricity and gas supply sector of the EU that is demanded from each (row) sector, regardless the country where this supplying sector is located. It has been calculated by summing the intermediate inputs of the electricity and gas supply sector of all the EU member states and dividing them by the total intermediate input of the electricity and gas supply sector.

*Source: own elaboration based on data from the World Input-Output Database*

The changes in the energy system and in the input structure of the electricity and gas supply in each member state have also been transmitted to other sectors of the economy and to other countries through supply chains. Thanks to the multiregional input-output tables we can explore these economic cascading effects. Here we focus on the effects in terms of employment. According to our calculations, if the input structure of the electricity and gas supply sector of each of the EU countries in 2009 would have remained as in 1995, a net total of 530 thousand jobs (k-jobs) less would have been needed in the EU. Or, in other

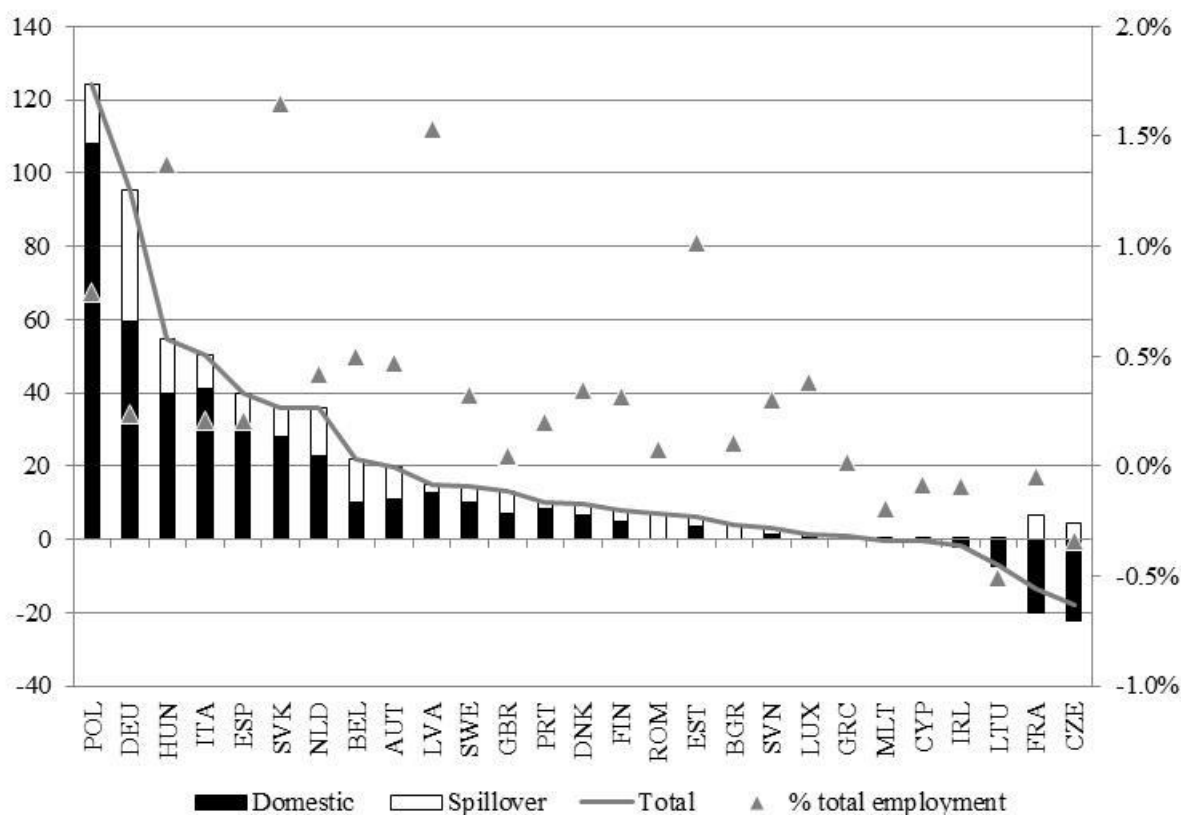


words, the changes in the input structure of the electricity and gas supply between 1995 and 2009 contributed to generate 530 k-jobs (see Table A.1).

The multiregional input-output model also allows one to distinguish between the “domestic” impacts in one country due to the changes in its own electricity and gas supply sector from those impacts in the employment in one country due to the changes in the electricity and gas supply of other countries (spill-over effects). We find that two thirds of the additional jobs in the EU were directly generated in the member states where the changes in the electricity and gas supply sector took place, while the rest were generated through spill-over effects (See Figure 2).

Figure 2 shows the impacts on employment due to changes in the input structure of the electricity and gas supply sector by member state and differentiating the domestic and spill-over effects. In 21 out of the 27 member states the total effect in the employment was positive. The countries that most benefited in terms of employment were Poland (124 k-jobs), Germany (95 k-jobs), Hungary (55 k-jobs), Italy (50 k-jobs), Spain (40 k-jobs), Slovakia (36 k-jobs) and the Netherlands (36 k-jobs). In four Eastern European countries, the change in the employment represents more than 0.8% of the total employment in the year 2009: Slovakia (1.6%), Latvia (1.5%), Hungary (1.4%) and Poland (0.8%). These countries are more energy intensive than the average, which contributed to magnified direct and indirect employment effects due to the changes in the electricity and gas supply. By contrast, the changes in Western Europe countries were more limited and in no case exceeded 0.5% of total employment, the largest beneficiaries being Belgium, Austria and the Netherlands, with gains of 0.5, 0.4 and 0.4 percent respectively.

Sector wise (see Table A.1 in the Appendix) one can observe that the EU industry that most benefited in terms of employment was “Renting of Machinery and Other Business Activities” (159 k-jobs), followed by “Electricity and gas supply” (64 k-jobs), “Construction” (44 k-jobs), “Other Community, Social and Personal Services” (41 k-jobs), “Inland Transport” (38 k-jobs), “Wholesale Trade” (38 k-jobs), “Retail Trade; Repair of Household Goods; and Electrical and Optical Equipment” (26 k-jobs). The relevance of employment in the services sectors is consistent with the trends towards outsourcing observed during the last decades in developed economies. In addition, the increase in the use of gas for power generation is well reflected by the increase in employment in “Electricity and gas supply” (i.e. gas supply sector), and “Inland Transport” (linked to pipeline transportation).



Note: 1) The domestic effect refers to those impacts in one country due to the changes in its own electricity and gas supply sector, while the spill-over effect computes the impacts in the employment of one country due to the changes in the electricity and gas supply of other countries. 2) The impacts are derived from the changes in the input structure of the electricity and gas supply sector in all the 27 EU member states except Romania and Bulgaria. Thus, the impacts in the employment in Bulgaria and Romania only cover spill-overs from the change in the electricity and gas supply of other member states.

Source: own elaboration based on data from the World Input-Output Database

**Figure 2: Impacts on employment by member state: total, domestic and spill-over effects (1000 jobs and %)**

On the other hand, 28 k-jobs were lost in the “Mining and Quarrying” sector, 10 k-jobs in “Public Admin and Defence; Compulsory Social Security”<sup>8</sup>, and 3 k-jobs in “Coke, Refined Petroleum and Nuclear Fuel”. These negative figures in the “Mining and Quarrying” and “Coke, Refined Petroleum and Nuclear Fuel” are linked to the changes in the electricity sector in the EU. Most of the losses in the “Mining and Quarrying” sector were concentrated

<sup>8</sup> We have further investigated the losses in the “Public Admin and Defence; Compulsory Social Security” and found that it stems from an error in the French national input-output table of 1995 used in the World Input-Output Database, in which the intermediate deliveries of the “Public Admin and Defence; Compulsory Social Security” are overestimated in comparison with the official data from EUROSTAT.

in the Czech Republic (13 k-jobs), Germany (11 k-jobs), and Poland (10 k-jobs), reflecting the reduction in the share of coal in the electricity mix. In the case of “Coke, Refined Petroleum and Nuclear Fuel”, 70% of the net employment losses were located in Italy and are related to the reduction in the use of oil in the electricity mix in that country (50% in 1995 versus 9% in 2009).

The employment impacts of the transformation in the European electricity and gas supply sector were not restricted to the EU (see Table A.2 of the Appendix). These effects were transmitted through supply chains, through international trade, with a net generation of employment of 645 k-jobs (see Table A.2 of the Appendix). Russia (171 k-jobs) and China (166 k-jobs) absorbed more than 50% of the impact<sup>9</sup>. In the case of Russia, most of the employment was generated in the sectors linked to the exports of gas to the EU: “Wholesale Trade” (62 k-jobs), “Inland transport” (which includes pipeline transportation) (38 k-jobs), and “Mining and Quarrying” (9 k-jobs).

Australia was the only country of the set analysed showing a net reduction in the employment. This negative effect was mainly concentrated in the “Mining and Quarrying” sector and is linked to the reduction to the demand of coal in the electricity and gas supply sector of the EU.

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<sup>9</sup> Most of the employment generated in China was located in “Other Community, Social and Personal Services” sector (74 k-jobs), which is usually not very relevant in the supply chain of the electricity and gas supply. In this case, this number is due to the high imports from the Chinese “Other Community, Social and Personal Services” of the Dutch electricity and gas supply reported by the World Input-Output Database in comparison with the official data from EUROSTAT.

## 5 DISCUSSION

Our analysis has the typical limitations of input-output studies: not accounting for time lags, homogeneity of outputs, sectoral aggregation, absence of economies of scale, invariance of technological coefficients, linearity of technological coefficients and missing interactions between prices and quantities (Murray and Lenzen 2013).

In addition, this analysis does not capture the employment due to changes in investments in different technologies across the sectors. On the one hand, a net positive effect could be expected as more jobs would have been created from the investments related to manufacturing and installation of renewables (Ortega et al. 2015) (Wei, Patadia, and Kammen 2010). But, on the other hand, there could also have been an indirect but negative effect due to the increase in the price of electricity and gas in the EU compared to other Non-European countries that may have affected competitiveness (European Commission 2014b) (Alberici et al. 2014) and, hence, the investment decisions across the economy. Such increases could be ameliorated with a well-designed mechanism for recycling revenues from subsidies (Böhringer, Keller, and van der Werf 2013) and from a further integration on the EU electricity market but the extent to which they do needs further investigation, which is beyond the scope of this report.

Besides, data availability has restricted the exercise to the period 1995-2009. The World Input-Output Database contains data for the period 1995-2011. However, the deflators that are necessary for the exercise are only available until 2009. Future exercises may expand the analysis beyond 2009 as soon as the data are available.

Finally, it is important to highlight that this database has been constructed by integrating data from different official statistics, mainly the National Accounts and Input-Output Tables developed by National Statistics Institutes and trade statistics from EUROSTAT and United Nations. Accordingly, the level of accuracy of the database is aligned with the quality standards of the data in those sources. It is possible that the final dataset derived from the integration process might have deviated slightly from the original data, partly as a result of errors during the integration process, although such errors are normally detected and corrected in the updated versions. Thus, even if we cannot provide an interval of confidence to our results, the accuracy of the results should be understood in the context of the quality of official statistics that have been used to build the database.

## 6 CONCLUSION

The results presented here provide some new, interesting evidence on the implications of the changes in the input structure of the European electricity and gas supply sector in the 14 years from 1995 to 2009. The use of a multiregional input-output model allows us to capture, not only the impacts directly and indirectly generated in each of the member states, but also the employment effects generated abroad as a result of international trade, something that closes a gap in this research line.

The analysis shows that the change in the input structure of the European electricity and gas supply sector, motivated in significant part by the desire for a shift towards a green economy, had a net positive impact on employment in the EU as a whole (+530 k-jobs), and specifically in 21 out of 27 of its member states. Furthermore, it shows that one third of the employment generated was due to spill-over effects. In other words, 176 k-jobs were generated in other member states different from those in which the change in the electricity and gas supply sector took place. These spill-over effects have traditionally been ignored when assessing the impacts of the deployment of new energy technologies. However, in the light of these results, spill-over effects should be taken into account in order to give a more accurate picture of the employment effects of European energy and climate policies, as is being done in other areas such as trade policy (Arto et al. 2015).

Previous studies (O’Sullivan et al. 2014) have pointed out that the promotion of renewable energy supports not only the creation of jobs in the short to medium term, but also the development of a globally competitive industry in the longer term. These new industries (like the renewable energy industry), which are knowledge-intensive, enable leading countries to maintain first-mover advantages for longer, since competition via labour costs is not feasible in many cases, which limits the possibilities of relocation (Walz and Eichhammer 2012; Walz and Marscheider-Weidemann 2011). Hence, certain export-oriented countries have created enabling environments (via economic instruments, regulations, etc.) for the development of these industries, with the hope that other countries will follow the promotion of these technologies, becoming new markets for the domestic industry (Duscha et al. 2014). Our results about the relevance of spill-over effects partly corroborate this and suggest the strategy makes sense, since changes in the energy mix of some countries benefit other countries involved in the production of renewable energy-related goods and services.

The analysis also shows which trading partners gained and lost in employment terms as a result of the structural changes. In this case, Russia was a major beneficiary due to the increase in the use of gas in the electricity and gas supply sector, while Australia was a loser due to the negative effect of the fall in the demand for coal.

Finally and in conclusion, our results support a relatively positive impact on employment from historical deployment of renewables and gas in the EU. Given our findings, the forward

looking estimates for the EU (Ragwitz et al. 2009) and (Cambridge Econometrics 2013) do not appear to be overly optimistic. Of course a direct comparison is not possible as the changes being compared are different, but an overall picture of a small gain in employment from the technology shifts involved in moving to a lower carbon future is probably right.

## 7 REFERENCES:

- Alberici, S., S. Boeve, P. van Breevoort, Y. Deng, S. Förster, A. Gardiner, V. van Gastel, et al. 2014. "Subsidies and Costs of EU Energy. Final Report." Ecofys by order of: European Commission.
- Arto, Iñaki, and Erik Dietzenbacher. 2014. "Drivers of the Growth in Global Greenhouse Gas Emissions." *Environmental Science & Technology* 48 (10): 5388-94. doi:10.1021/es5005347.
- Arto, Iñaki, José Manuel Rueda-Cantuche, Antonio F. Amores, Erik Dietzenbacher, Nuno Sousa, Letizia Montinari, and Anil Markandya. 2015. *EU Exports to the World: Effects on Employment and Income*. Luxembourg: Publication Office of the European Union.
- Böhringer, Christoph, Andreas Keller, and Edwin van der Werf. 2013. "Are Green Hopes Too Rosy? Employment and Welfare Impacts of Renewable Energy Promotion." *Energy Economics* 36 (March): 277-85. doi:10.1016/j.eneco.2012.08.029.
- Cai, Wenjia, Yaqian Mu, Can Wang, and Jining Chen. 2014. "Distributional Employment Impacts of Renewable and New energy-A Case Study of China." *Renewable and Sustainable Energy Reviews* 39 (November): 1155-63. doi:10.1016/j.rser.2014.07.136.
- Cambridge Econometrics. 2013. "Employment Effects of Selected Scenarios from the Energy Roadmap 2050. Final Report for the European Commission (DG Energy)." Cambridge Econometrics.
- Cameron, Lachlan, and Bob van der Zwaan. 2015. "Employment Factors for Wind and Solar Energy Technologies: A Literature Review." *Renewable and Sustainable Energy Reviews* 45 (May): 160-72. doi:10.1016/j.rser.2015.01.001.
- Dietzenbacher, Erik, Bart Los, Robert Stehrer, Marcel Timmer, and Gaaitzen de Vries. 2013. "The Construction of World Input-Output Tables in the WIOD Project." *Economic Systems Research* 25 (1): 71-98. doi:10.1080/09535314.2012.761180.
- Drummond, P. 2013. "Country Report: The European Union. Contribution to CECILIA2050 Deliverable 1.2: Review of the Existing Instrument Mix at EU Level and in Selected Member States." London, UK: University College London.
- Duscha, V., M. Ragwitz, B. Breitschopf, W. Schade, R. Walz, M. Pfaff, E. de Visser, et al. 2014. "Employment and Growth Effects of Sustainable Energies in the European Union. Final Report." Karlsruhe, Germany: Fraunhofer-ISI.

- European Commission. 2008. “20 20 by 2020. Europe’s Climate Change Opportunity.” COM/2014/30. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee of the Regions. European Commission.
- . 2011. “A Roadmap for Moving to a Competitive Low Carbon Economy in 2050. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. COM(2011) 112 Final.”
- . 2014a. “A Policy Framework for Climate and Energy in the Period from 2020 to 2030.” COM/2014/015. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee of the Regions. European Commission.
- . 2014b. “Energy Prices and Costs in Europe.” COM/2014/021. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee of the Regions. European Commission.
- Herreras Martínez, Sara, Janske van Eijck, Marcelo Pereira da Cunha, Joaquim J. M. Guilhoto, Arnaldo Walter, and Andre Faaij. 2013. “Analysis of Socio-Economic Impacts of Sustainable Sugarcane-ethanol Production by Means of Inter-Regional Input-Output Analysis: Demonstrated for Northeast Brazil.” *Renewable and Sustainable Energy Reviews* 28 (December): 290-316. doi:10.1016/j.rser.2013.07.050.
- Hienuki, Shunichi, Yuki Kudoh, and Hiroki Hondo. 2015. “Life Cycle Employment Effect of Geothermal Power Generation Using an Extended Input-output Model: The Case of Japan.” *Journal of Cleaner Production* 93 (April): 203-12. doi:10.1016/j.jclepro.2015.01.008.
- International Energy Agency. 2014. <http://www.iea.org>.
- Jenner, Steffen, Felix Groba, and Joe Indvik. 2013. “Assessing the Strength and Effectiveness of Renewable Electricity Feed-in Tariffs in European Union Countries.” *Energy Policy*, Special Section: Transition Pathways to a Low Carbon Economy, 52 (January): 385-401. doi:10.1016/j.enpol.2012.09.046.
- Lehr, Ulrike, Joachim Nitsch, Marlene Kratzat, Christian Lutz, and Dietmar Edler. 2008. “Renewable Energy and Employment in Germany.” *Energy Policy* 36 (1): 108-17. doi:10.1016/j.enpol.2007.09.004.
- Madlener, Reinhard, and Martin Koller. 2007. “Economic and CO<sub>2</sub> Mitigation Impacts of Promoting Biomass Heating Systems: An Input-output Study for Vorarlberg, Austria.” *Energy Policy* 35 (12): 6021-35. doi:10.1016/j.enpol.2007.08.023.



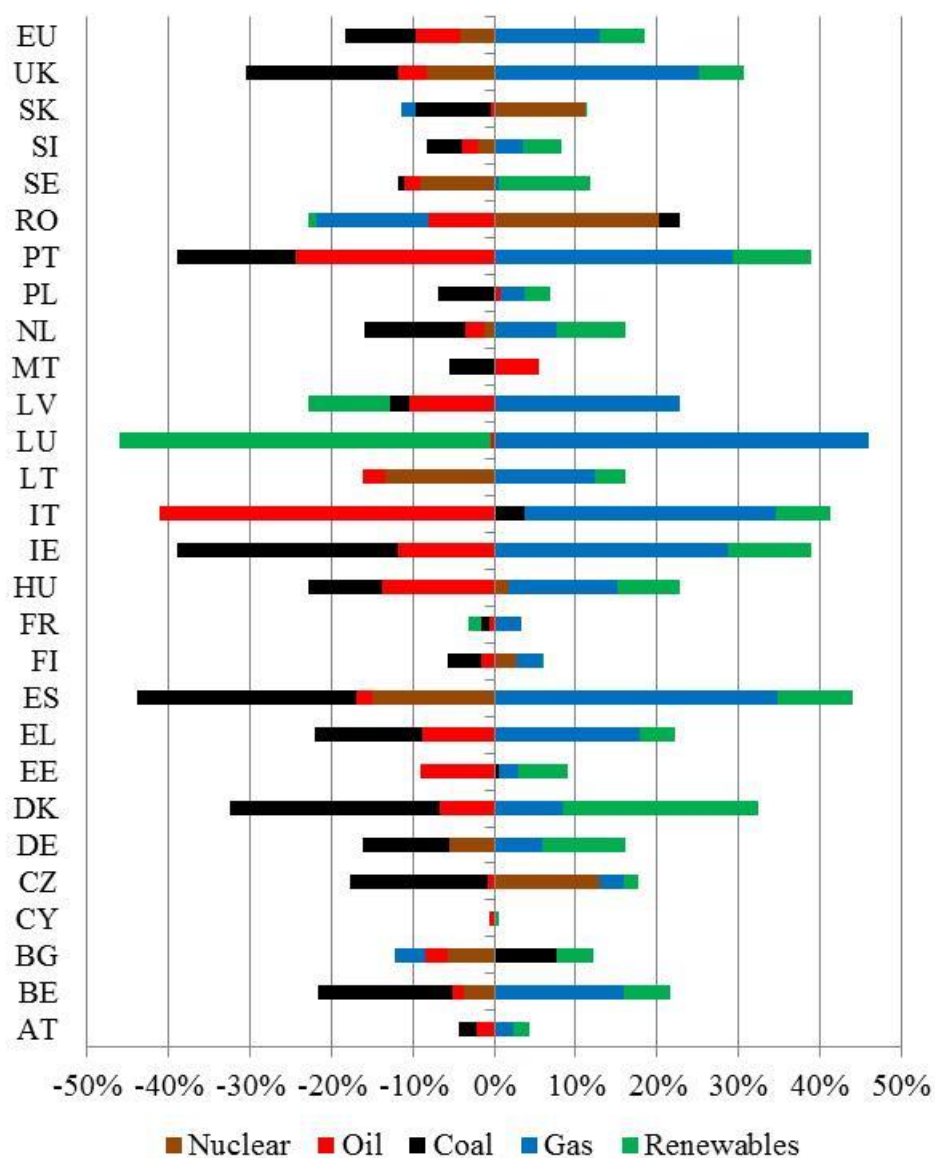
- Markaki, M., A. Belegri-Roboli, P. Michaelides, S. Mirasgedis, and D. P. Lalas. 2013. "The Impact of Clean Energy Investments on the Greek Economy: An Input-output Analysis (2010-2020)." *Energy Policy* 57 (June): 263-75. doi:10.1016/j.enpol.2013.01.047.
- Mathiesen, Brian Vad, Henrik Lund, and Kenneth Karlsson. 2011. "100% Renewable Energy Systems, Climate Mitigation and Economic Growth." *Applied Energy*, The 5th Dubrovnik Conference on Sustainable Development of Energy, Water and Environment Systems, held in Dubrovnik September/October 2009, 88 (2): 488-501. doi:10.1016/j.apenergy.2010.03.001.
- Mirasgedis, S., C. Tourkolias, E. Pavlakis, and D. Diakoulaki. 2014. "A Methodological Framework for Assessing the Employment Effects Associated with Energy Efficiency Interventions in Buildings." *Energy and Buildings* 82 (October): 275-86. doi:10.1016/j.enbuild.2014.07.027.
- Moreno, Blanca, and Ana Jesús López. 2008. "The Effect of Renewable Energy on Employment. The Case of Asturias (Spain)." *Renewable and Sustainable Energy Reviews* 12 (3): 732-51. doi:10.1016/j.rser.2006.10.011.
- Mundaca, Luis, Rocio Román, and José M. Cansino. 2015. "Towards a Green Energy Economy? A Macroeconomic-Climate Evaluation of Sweden's CO<sub>2</sub> Emissions." *Applied Energy* 148 (June): 196-209. doi:10.1016/j.apenergy.2015.03.029.
- Murray, Joy, and Manfred Lenzen. 2013. "The Sustainability Practitioner's Guide to Multi-Regional Input-Output Analysis." *Common Ground, Champaign, IL*. [http://pub.iges.or.jp/modules/envirolib/upload/4229/attach/Sustainability\\_Practitioners\\_Guide\\_E-Book\\_rev\\_Ch16.pdf](http://pub.iges.or.jp/modules/envirolib/upload/4229/attach/Sustainability_Practitioners_Guide_E-Book_rev_Ch16.pdf).
- Neuwahl, Frederik, Andreas Löschel, Ignazio Mongelli, and Luis Delgado. 2008. "Employment Impacts of EU Biofuels Policy: Combining Bottom-up Technology Information and Sectoral Market Simulations in an Input-output Framework." *Ecological Economics* 68 (1-2): 447-60. doi:10.1016/j.ecolecon.2008.04.018.
- Ortega, Margarita, Pablo del Río, Pablo Ruiz, and Christian Thiel. 2015. "Employment Effects of Renewable Electricity Deployment. A Novel Methodology." *Energy* 91 (November): 940-51. doi:10.1016/j.energy.2015.08.061.
- O'Sullivan, M., Dietmar Edler, P. Bickel, U. Lehr, F. Peter, and F. Sakowski. 2014. "Gross Employment from Renewable Energy in Germany in 2013. A First Estimate." Research project commissioned by the Federal Ministry for Economic Affairs and Energy.
- Qi, Tianyu, Li Zhou, Xiliang Zhang, and Xiangkun Ren. 2012. "Regional Economic Output and Employment Impact of Coal-to-Liquids (CTL) Industry in China: An Input-output

- Analysis.” *Energy, Energy and Exergy Modelling of Advance Energy Systems*, 46 (1): 259-63. doi:10.1016/j.energy.2012.08.024.
- Rafaj, Peter, Markus Amann, José Siri, and Henning Wuester. 2013. “Changes in European Greenhouse Gas and Air Pollutant Emissions 1960-2010: Decomposition of Determining Factors.” *Climatic Change* 124 (3): 477-504. doi:10.1007/s10584-013-0826-0.
- Ragwitz, M., W. Schade, B. Breischopf, R. Walz, N. Helfrich, M. Rathmann, G. Resch, et al. 2009. “EmployRES - The Impact of Renewable Energy Policy on Economic Growth and Employment in the European Union, Final Report.” European Commission, DG Energy and Transport.
- Renner, M., S. Sweeney, and J. Kubit. 2008. “Green Jobs: Towards Decent Work in a Sustainable, Low-Carbon World.” Nairobi, Kenya: United Nations Environment Programme.
- Silalertruksa, Thapat, Shabbir H. Gheewala, Katja Hünecke, and Uwe R. Fritsche. 2012. “Biofuels and Employment Effects: Implications for Socio-Economic Development in Thailand.” *Biomass and Bioenergy*, International Conference on Lignocellulosic ethanol, 46 (November): 409-18. doi:10.1016/j.biombioe.2012.07.019.
- Su, Bin, and B. W. Ang. 2015. “Multiplicative Decomposition of Aggregate Carbon Intensity Change Using Input-output Analysis.” *Applied Energy* 154 (September): 13-20. doi:10.1016/j.apenergy.2015.04.101.
- Timmer, Marcel. 2012. “The World Input-Output Database (WIOD): Contents, Sources and Methods.” WIOD Background document available at [www.wiod.org](http://www.wiod.org).
- Tourkolias, C., and S. Mirasgedis. 2011. “Quantification and Monetization of Employment Benefits Associated with Renewable Energy Technologies in Greece.” *Renewable and Sustainable Energy Reviews* 15 (6): 2876-86. doi:10.1016/j.rser.2011.02.027.
- UNEP. 2008. “UNEP Background Paper on Green Jobs.” Nairobi, Kenya: United Nations Environment Programme.
- Walz, Rainer, and Wolfgang Eichhammer. 2012. “Benchmarking Green Innovation.” *Mineral Economics* 24 (2-3): 79-101. doi:10.1007/s13563-012-0016-y.
- Walz, Rainer, and Frank Marscheider-Weidemann. 2011. “Technology-Specific Absorptive Capacities for Green Technologies in Newly Industrialising Countries.” *International Journal of Technology and Globalisation* 5 (3-4): 212-29. doi:10.1504/IJTG.2011.039765.

Wei, Max, Shana Patadia, and Daniel M. Kammen. 2010. "Putting Renewables and Energy Efficiency to Work: How Many Jobs Can the Clean Energy Industry Generate in the US?" *Energy Policy* 38 (2): 919-31. doi:10.1016/j.enpol.2009.10.044.

Ziegelmann, Arko, Markus Mohr, and Hermann Unger. 2000. "Net Employment Effects of an Extension of Renewable-Energy Systems in the Federal Republic of Germany." *Applied Energy* 65 (1-4): 329-38. doi:10.1016/S0306-2619(99)00072-0.

## 8 APPENDIX



Source: International Energy Agency

Note: the change has been calculated as the difference between the share of each technology in the electricity and heat generation mix in 2009 minus the share in 1995

Figure A.1: Change in the electricity and heat generation mix in the EU, 1995 and 2009 (%)



Table A.1: Total impacts on employment by sector and EU member states (Thousands jobs)

Sector code	AUT	BEL	BGR	CYP	CZE	DEU	DNK	ESP	EST	FIN	FRA	GBR	GRC	HUN	IRL	ITA	LTU	LUX	LVA	MLT	NLD	POL	PRT	ROM	SVK	SVN	SWE	EU
c1	0.7	0.1	0.3	0.0	0.0	0.7	0.4	0.3	0.1	1.3	1.9	0.2	0.0	3.4	0.0	0.5	-0.6	0.0	0.6	0.0	0.6	5.0	-0.8	0.6	0.2	0.0	0.5	16.1
c2	0.5	0.0	0.1	0.0	-12.9	-10.8	0.0	-0.9	2.1	-0.6	1.0	-1.1	-0.1	0.3	-0.1	2.3	0.0	0.0	0.1	0.0	-0.5	-9.6	0.1	0.5	1.2	-0.2	-0.1	-28.5
c3	0.0	0.1	0.0	0.0	-0.1	0.1	0.0	0.2	0.0	-0.1	0.1	0.0	0.0	0.5	0.0	0.3	-0.1	0.0	0.2	0.0	0.1	1.4	0.0	0.0	0.1	0.0	0.1	2.8
c4	0.0	0.0	0.0	0.0	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.2	0.0	0.2	-0.4	0.0	0.1	0.0	0.0	0.5	-1.3	0.1	0.0	-0.1	0.0	-0.8
c5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.0	0.0
c6	0.6	0.1	0.0	0.0	0.0	0.6	0.1	-0.2	0.2	0.4	0.0	0.0	0.0	0.4	0.0	0.3	0.3	0.0	0.5	0.0	0.1	2.1	-1.2	0.2	0.4	0.0	0.6	5.3
c7	0.0	0.2	0.0	0.0	-0.2	0.7	0.1	0.2	0.0	-0.1	0.1	-1.3	0.0	0.8	0.0	0.9	-0.1	0.0	0.2	0.0	0.2	2.0	-0.6	0.0	0.3	0.0	0.2	3.5
c8	0.0	0.0	0.0	0.0	-0.1	0.0	0.0	0.0	0.0	0.0	0.4	-0.6	-0.1	0.0	-0.2	-2.2	-0.1	0.0	0.0	0.0	0.0	-0.1	-0.1	0.0	0.0	0.0	0.0	-3.0
c9	0.1	0.1	0.0	0.0	0.1	0.6	0.0	0.4	0.0	0.1	0.1	0.1	0.0	0.2	0.0	0.5	0.1	0.0	0.0	0.0	0.1	0.7	0.0	0.0	0.1	0.0	0.1	3.4
c10	0.1	0.0	0.0	0.0	-0.1	1.2	0.1	-0.1	0.0	0.1	1.2	-0.2	0.0	0.3	0.0	0.6	0.1	0.0	0.1	0.0	0.0	1.7	0.1	0.1	0.2	0.0	0.1	5.6
c11	0.0	0.1	0.0	0.0	-0.2	0.4	0.1	-0.7	0.0	0.1	-0.1	0.0	0.0	0.4	0.0	0.8	0.0	0.0	0.1	0.0	0.1	3.6	0.3	0.0	0.3	0.1	0.0	5.2
c12	0.2	0.3	0.1	0.0	-3.0	2.0	0.2	-6.3	0.2	1.1	-0.1	1.5	0.0	1.5	-0.1	1.4	0.2	0.0	0.1	0.0	0.4	2.8	0.0	0.3	0.0	0.1	0.3	3.1
c13	0.1	0.1	0.1	0.0	-0.2	2.5	0.2	0.0	0.1	0.7	0.6	0.8	-0.2	0.7	0.0	1.7	0.1	0.0	0.0	0.0	0.2	1.0	0.1	0.2	0.2	0.1	0.3	9.3
c14	0.9	0.1	0.2	0.0	1.3	9.7	0.2	0.0	0.1	0.2	1.1	0.4	0.2	1.1	0.0	2.8	0.1	0.0	0.2	0.0	0.2	3.6	0.3	2.0	1.1	0.3	0.3	26.5
c15	0.0	0.0	0.0	0.0	0.1	0.8	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.2	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.1	0.1	0.0	0.1	2.5
c16	0.1	0.1	0.0	0.0	-0.1	0.2	0.0	-0.8	0.0	0.1	0.2	-0.1	0.0	0.2	0.0	1.1	0.4	0.0	0.1	0.0	0.4	1.5	0.0	0.0	0.6	0.0	0.0	4.0
c17	11.0	1.5	1.2	0.0	-9.6	35.8	0.4	15.7	0.5	0.4	9.8	-4.0	1.3	3.7	2.2	1.3	-3.2	0.3	1.2	0.0	-0.4	-13.0	2.7	0.5	3.0	1.4	0.6	64.2
c18	1.3	1.2	0.2	0.0	-3.1	-1.4	1.5	-2.2	-0.2	2.9	-9.4	-0.7	-0.6	3.8	-0.4	-5.3	0.0	0.2	3.0	0.0	-0.5	44.7	4.1	0.1	4.5	0.5	0.2	44.5
c19	0.1	0.3	0.1	0.0	-1.2	2.3	0.1	4.3	0.2	0.2	-0.8	1.6	-0.2	2.4	0.4	0.9	-0.3	0.0	0.4	-0.3	1.1	1.8	0.2	0.0	0.6	0.0	0.2	14.3
c20	0.6	0.3	0.4	-0.3	-0.6	1.8	0.6	3.5	0.2	0.5	0.1	4.0	0.0	2.7	0.2	5.8	0.3	0.1	0.9	-0.3	3.1	10.9	-1.1	0.4	3.2	0.0	1.0	38.1
c21	0.6	-0.1	0.2	0.0	0.6	-1.1	1.0	10.0	0.6	1.1	-2.0	2.5	-0.3	10.8	-0.3	1.3	-2.0	0.1	1.5	0.0	1.7	7.8	-0.4	0.2	3.5	0.0	0.7	37.9
c22	0.1	0.6	0.0	0.0	0.5	0.0	0.2	-0.6	0.0	0.0	0.0	0.4	0.0	0.5	0.2	2.0	-0.4	0.0	0.1	0.2	0.8	0.3	0.3	0.1	1.1	0.0	0.5	6.9
c23	0.2	0.7	0.2	-0.1	6.7	9.6	0.1	0.6	0.2	-0.2	-1.6	0.8	-0.3	1.6	0.0	2.2	0.0	0.0	0.5	-0.1	0.2	10.6	2.2	0.4	3.2	0.0	0.4	38.2
c24	0.0	0.0	0.0	0.0	0.0	0.2	0.0	-0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.7
c25	0.0	0.0	0.0	0.0	0.0	0.1	0.0	-0.1	0.0	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.2
c26	0.5	0.1	0.1	0.0	-0.3	3.5	0.1	-0.3	0.1	0.0	0.3	0.2	0.0	0.2	0.0	1.3	0.0	0.0	0.1	0.0	0.2	-1.0	0.4	0.1	1.4	0.0	0.2	7.2
c27	0.2	0.7	0.2	0.0	0.2	0.4	0.4	4.6	0.1	-0.2	0.2	1.0	0.1	1.5	-0.1	2.6	-0.1	0.0	0.4	0.0	0.4	3.4	0.2	0.3	0.5	0.1	0.4	17.5
c28	-0.5	-0.2	0.1	0.0	0.5	-2.9	0.7	-6.4	0.2	0.1	0.6	-3.0	1.0	2.7	0.0	2.8	-0.5	0.0	0.3	0.0	0.6	4.2	0.7	0.1	0.0	0.0	0.5	1.4
c29	0.1	0.1	0.1	0.0	-0.3	0.6	0.1	-0.4	0.1	0.1	-0.1	-2.1	0.0	0.4	0.0	0.2	0.0	0.0	0.6	0.0	0.1	-1.7	0.0	0.0	0.7	0.0	0.2	-1.3
c30	2.3	9.2	0.1	0.0	1.7	28.3	2.7	13.4	0.8	-0.2	-3.6	12.0	0.0	9.7	0.6	18.5	0.7	0.5	2.5	0.0	21.8	22.0	3.2	0.6	7.0	0.1	5.1	159.0
c31	0.1	1.4	0.1	0.0	-0.3	2.2	0.0	1.7	0.0	0.0	-25.0	-0.1	0.0	1.4	0.0	0.0	-0.1	0.0	0.0	0.0	0.6	5.8	0.4	0.0	0.7	0.1	0.7	-10.3
c32	0.3	0.2	0.0	0.0	0.1	3.2	0.0	1.9	0.1	-0.1	1.9	-1.1	0.0	1.4	0.0	1.3	-1.0	0.0	0.4	0.0	0.8	1.4	0.1	0.0	0.5	0.1	0.2	11.5
c33	0.0	0.0	0.0	0.0	-0.2	0.0	0.0	-0.1	0.0	0.0	0.8	0.6	0.0	0.2	0.0	0.0	-0.2	0.0	0.1	0.0	0.4	1.2	0.0	0.0	0.2	0.0	0.2	3.4
c34	0.0	4.8	0.1	0.0	2.8	4.1	0.5	1.9	0.0	0.0	8.9	1.3	0.0	1.6	-3.9	4.1	-0.2	0.0	0.8	0.1	2.8	9.0	0.1	0.1	1.1	0.1	0.9	41.0
c35	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	19.9	22.0	4.0	-0.3	-18.0	95.1	9.8	39.7	6.0	7.7	-13.3	13.3	0.9	54.9	-1.7	50.5	-7.2	1.3	15.0	-0.3	35.8	124.2	10.0	7.2	36.0	2.9	14.3	529.5

Table A.2: Total impacts on employment by sector in non-EU countries due to changes in the input structure of the EU electricity and gas sector between 1995 and 2009 (Thousands jobs)

Sector code	AUS	BRA	CAN	CHN	IND	IDN	JPN	KOR	MEX	RUS	TUR	TWN	USA	RoW	Total
c1	0.0	1.7	0.0	23.4	6.5	2.8	0.1	0.2	0.1	5.9	0.2	0.0	0.1	54.6	95.6
c2	-0.9	-0.3	-0.3	2.5	0.5	1.0	0.0	0.0	-0.5	9.5	0.0	0.0	-0.9	-2.1	8.6
c3	0.0	0.1	0.0	1.2	0.2	0.1	0.0	0.0	0.0	0.2	0.0	0.0	0.0	1.4	3.4
c4	0.0	0.0	0.0	2.6	0.2	0.1	0.0	0.0	0.0	0.7	0.1	0.0	0.0	-0.5	3.3
c5	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.4
c6	0.0	0.1	0.0	2.0	0.5	0.5	0.0	0.0	0.0	1.3	0.0	0.0	0.0	2.7	7.1
c7	0.0	0.1	0.0	3.2	0.2	0.1	0.1	0.1	0.0	1.0	0.0	0.0	0.1	3.0	7.8
c8	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	-2.5	-1.8
c9	0.0	0.0	0.0	2.1	0.3	0.1	0.1	0.1	0.0	1.0	0.0	0.1	0.1	1.8	5.7
c10	0.0	0.1	0.0	4.1	0.1	0.3	0.1	0.2	0.0	0.8	0.1	0.1	0.0	1.7	7.7
c11	0.0	0.0	0.0	1.1	0.3	0.0	0.0	0.1	0.0	0.7	0.1	0.0	0.0	0.9	3.2
c12	0.0	0.1	0.0	2.8	0.6	0.1	0.3	0.2	0.0	2.1	0.2	0.2	0.2	2.2	9.2
c13	0.0	0.0	0.0	2.5	0.3	0.0	0.1	0.1	0.0	2.7	0.2	0.1	0.3	1.7	8.2
c14	0.0	0.1	0.0	11.4	0.6	0.1	0.7	1.5	0.2	1.7	0.3	0.8	0.6	5.2	23.3
c15	0.0	0.0	0.0	1.0	0.2	0.1	0.1	0.1	0.0	1.6	0.1	0.0	0.1	0.7	4.1
c16	0.0	0.0	0.0	0.9	0.9	0.0	0.0	0.0	0.0	0.6	0.1	0.0	0.1	1.4	4.1
c17	0.0	0.8	1.0	1.5	0.1	0.0	0.1	0.0	0.1	7.4	0.0	0.0	0.1	7.9	19.1
c18	-0.1	-0.1	0.1	2.0	0.8	0.1	0.1	0.0	0.0	1.2	0.1	0.0	0.0	1.6	5.7
c19	-0.1	0.1	0.0	0.0	0.2	0.0	0.0	0.0	0.4	2.1	0.1	0.0	0.0	0.2	3.1
c20	0.0	0.1	0.1	3.6	0.4	0.8	0.3	0.5	0.3	61.8	0.2	0.2	0.4	34.4	102.9
c21	-0.1	0.6	0.2	6.5	1.9	0.4	0.1	0.3	0.4	7.3	0.1	0.2	0.1	4.4	22.4
c22	0.0	0.7	0.1	3.2	1.3	0.4	0.2	0.3	0.0	1.0	0.0	0.0	0.3	4.4	11.9
c23	-0.1	0.3	0.2	5.4	2.2	1.4	0.2	0.1	0.4	37.6	0.2	0.1	0.4	40.9	89.3
c24	0.0	0.0	0.0	2.1	0.0	0.6	0.1	0.2	0.1	0.2	0.2	0.2	0.0	0.6	4.2
c25	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.1	0.0	0.2	0.0	0.0	0.0	0.2	0.8
c26	0.0	0.1	0.0	0.4	0.0	0.3	0.1	0.1	0.1	1.7	0.1	0.2	0.3	0.8	4.2
c27	0.0	0.1	0.0	1.7	1.3	0.2	0.0	0.0	0.0	2.3	0.0	0.0	0.3	2.2	8.2
c28	-0.1	0.1	0.0	1.0	0.4	0.1	0.1	0.1	0.0	1.0	0.0	0.1	0.2	1.4	4.4
c29	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.1	0.0	1.4	0.0	0.0	0.0	0.4	2.2
c30	-0.1	1.5	0.2	1.6	5.5	0.0	0.7	1.3	0.0	7.2	0.1	0.5	5.6	16.9	40.8
c31	0.0	0.0	0.0	0.1	0.0	0.3	0.0	0.0	0.0	4.4	0.1	0.0	0.0	0.1	5.1
c32	0.0	0.0	0.0	0.5	0.1	0.1	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.6	1.5
c33	0.0	0.0	0.0	0.2	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.2	0.7
c34	0.0	2.1	0.2	74.2	21.6	1.7	0.4	0.5	0.0	3.3	0.1	0.1	0.7	22.5	127.4
c35	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.9
Total	-1.5	8.8	2.2	165.9	48.0	11.8	4.0	6.2	1.8	170.6	2.7	3.0	9.1	212.3	644.7

**Table A.3: Sector classification**

Sector code	Sector
c1	Agriculture, Hunting, Forestry and Fishing
c2	Mining and Quarrying
c3	Food, Beverages and Tobacco
c4	Textiles and Textile Products
c5	Leather, Leather and Footwear
c6	Wood and Products of Wood and Cork
c7	Pulp, Paper, Paper , Printing and Publishing
c8	Coke, Refined Petroleum and Nuclear Fuel
c9	Chemicals and Chemical Products
c10	Rubber and Plastics
c11	Other Non-Metallic Mineral
c12	Basic Metals and Fabricated Metal
c13	Machinery, Nec
c14	Electrical and Optical Equipment
c15	Transport Equipment
c16	Manufacturing, Nec; Recycling
c17	Electricity, Gas and Water Supply
c18	Construction
c19	Sale, Maintenance and Repair of Motor Vehicles and Motorcycles; Retail Sale of Fuel
c20	Wholesale Trade and Commission Trade, Except of Motor Vehicles and Motorcycles
c21	Retail Trade, Except of Motor Vehicles and Motorcycles; Repair of Household Goods
c22	Hotels and Restaurants
c23	Inland Transport
c24	Water Transport
c25	Air Transport
c26	Other Supporting and Auxiliary Transport Activities; Activities of Travel Agencies
c27	Post and Telecommunications
c28	Financial Intermediation
c29	Real Estate Activities
c30	Renting of Machinery and Other Business Activities
c31	Public Admin and Defence; Compulsory Social Security
c32	Education
c33	Health and Social Work
c34	Other Community, Social and Personal Services
c35	Private Households with Employed Persons