Energy Costs in Germany and Europe - An Assessment Based on a (Total Real Unit) Energy Cost Accounting Framework

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Abstract

Affordable energy is one of the objectives of EU's energy policy. This goal has been challenged by many factors influencing energy prices and costs such as developments in global energy markets, the EU ETS and the promotion of renewables. Analysing energy costs (prices times quantity) instead of prices has the advantage of taking into account quantity adjustments. However, it does not allow for monitoring the burden which energy costs pose on firms. For this purpose, both the European Commission and the Energy Expert Commission of the German Government recommend using real unit energy costs, defined as energy costs as fraction of value added. We develop an input-output based (real unit) energy cost accounting framework and study the trends in Germany and the EU between 1995 and 2011. We find that many of the unveiled developments are not adequately represented in the political debate, especially with regard to indirect costs (via energy embodied in intermediate inputs), which are more difficult to assess. Indirect energy costs are on the rise, are larger than direct costs in many industries, are increasingly imported and amplify the asymmetric impacts of legal exceptions available to energy-intensive industries.

JEL Classification

O14, Q48

Keywords

Direct energy costs; Indirect energy costs; Energy costs of intermediate consumption; Real unit energy costs; Energy cost analysis; Input-output based (total real unit) energy cost accounting

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Highlights

- Indirect energy costs are increasingly imported into the EU.
- Total energy costs in the EU are large and in the magnitude of French GDP.
- The burden of energy costs is rising in the EU, but Germany remains below average.
- Petroleum products drove costs more than electricity, gas, steam and hot water.
- Costs of Germany's promotion of renewable electricity has surpassed costs of coal.

1 Introduction

Affordable energy is one of the main objectives of EU's energy policy. Explicit reference to this goal can already be found in the directives on the liberalisation of European Union's (EU) electricity and gas markets in 1996/1998, 2003 and 2009 and are now reiterated in Germany's and in EU's future long-term 2020, 2030 and 2050 energy strategies (BMWi/BMU [2010]; European Commission [2010, 2011, 2014a]). Factors that have been challenging accomplishing this goal have been, for example, the developments in global energy markets, the EU Emissions Trading System (EU ETS) and the promotion of renewable energy sources. The latter aspect is of particular current interest because Germany and the European Union have given long term commitments to the decarbonisation of their energy system by 2050. This shift towards sustainability will require additional investments and subsidies in the trillions and will, as a result, affect energy prices. In Germany, the EEG surcharge, the mechanism which finances the promotion of renewable electricity generation under Germany's Renewable Energy Act (Erneuerbares Energien Gesetz, EEG), is already a significant electricity price component. In order to draw conclusions about how these factors affect energy affordability and competitiveness, the relationship between energy prices, energy costs and competitiveness must be thoroughly understood and analysed.

To this end, we develop an input-output based (total real unit) energy cost accounting framework and use it to reveal major trends in Germany and the EU between 1995 and 2011. This study is geared towards energy costs rather than energy prices, because costs factor in the quantities of energy consumed and therefore possible demand adjustments. In addition, our study is limited to energy costs that accompany intermediate consumption rather than final consumption, because firms are primarily exposed to international competition. In this context, we focus on the burden of energy costs on firms. Both the European Commission [2014b] and the Energy Expert Commission of the German Government [Löschel et al., 2014, 2015a, Germeshausen and Löschel, 2015] recommend using real unit energy costs as appropriate indicator for assessing this burden. Real unit energy costs are (direct) energy costs as percentage of value added and measure the amount of money spent on energy to obtain one unit of value added. In this sense, the indicator measures the energy requirement in euros to produce one euro of value added. Hence it is a proxy for competitiveness. Real unit energy costs allow for meaningful trans-national and trans-sectoral comparisons. However, real unit energy costs alone do not take into account indirect energy costs which are embodied in non-energy intermediate inputs.

During the last three years, real unit energy costs have become widespread in European energy policy (see also [European Commission, 2016, 2014c,d]), but have only been used to compare direct energy costs in different sectors and countries. The indicator was also used in several peer-reviewed studies. For example, Sato and Dechezleprêtre [2015] used direct real unit energy costs in order to divide EU sectors into energy intensive and non-energy intensive. Their results give support to the notion that trade impacts of carbon pricing depend on sectoral energy intensities. Similarly, Fitz Gerald et al. [2009] used direct real unit energy costs to exemplify the idea of vulnerability of EU sectors to the introduction of an energy or carbon tax.

By now, no study systematically analysed total (that is direct and indirect) real unit energy cost trends over time, nor did any study shed light on the underlying drivers. Hence, we greatly extent in this paper previous analyses. We find that indirect energy costs are an increasingly important part of total energy costs. Taking indirect costs into account, total energy costs in the European Union are large and in the magnitude of French GDP. The burden of energy costs is rising in the EU, but Germany remains below average. We also analyse the underlying factors of the evolution of energy costs: Indirect energy costs are mainly imported into the

EU and petroleum products drove costs more than electricity, gas, steam and hot water. The promotion of renewable electricity has become a significant cost factor for companies, even though Germany's energy transition in the electricity sector seems not to be a predominant driver for energy costs in Germany. Economy-wide costs of Germany's promotion of renewable electricity has surpassed the costs of coal. Value added generation contributed to the fact, that the burden of total energy costs on firms increased less in Germany's secondary sector than in the European Union.

The remainder of this paper is structured as follows: Section 2 provides a description of the methodology and data used in our analysis. In Section 3, we will present the results. Finally, Section 4 derives some policy implications and concludes.

2 Methodology and data

We propose a framework for input-output based (total real unit) energy cost accounting which is fully compatible with the definitions in the System of National Accounts of the United Nations (2008 SNA) and the European System of National and Regional Accounts (ESA 2010). All necessary aggregates are shown in Figure 1 and can also be found in standard national input-output tables compiled by statistical offices.

<< Insert Figure 1 about here >>

The output of an industrial branch is the total monetary value of all goods produced by the industry during an accounting period (as the sum of all firms in that particular sector). The production of output requires intermediate inputs which consist of goods and services which are either transformed or used up by the production process. Value added is consequently the difference between output and the monetary value of all intermediate inputs, generated by the factors of production, i.e. labour and capital.

Direct energy costs are related to energy products, which are used as intermediate inputs. Costs associated with the consumption of energy for non-energy purposes, such as chemical feedstocks, lubrication of machinery, etc. are also part of direct energy costs. Indirect energy costs are those embedded in non-energy intermediate inputs. They reflect the energy products which were used at earlier stages of the value chain.[1] Because they are potentially important, they should be quantified and regarded in (total real unit) energy cost analysis. As mentioned above, real unit energy costs are calculated as energy costs per value added. According to the aggregate used in the numerator we distinguish between (direct) real unit energy costs, indirect real unit energy costs and total real unit energy costs.

All our calculations in this study are based on data of the World Input-Output Database (WIOD; Timmer et al. [2015]). WIOD provides international supply and use tables and (inter-country) world input-output tables covering the period from 1995 to 2011. World input-output tables give a comprehensive summary of all transactions in the global economy between industries (and also final users) across countries. Amongst others, these tables report (direct) energy costs, distinguishing four different energy product groups, the output and the value added of 35 industries in 40 countries (EU-27 and 13 major other countries). Output and value added are also available for the residual region (rest of the world). Related papers using the WIOD database analyse e.g. the development of energy intensity (Löschel et al. [2015b]), material use

[1] Figure 1 applies also to earlier stages of the value chain.

(Pothen and Schymura [2015]), natural resource footprints (Wu et al. [2016]) or the impacts of international trade and structural change on the environment (Löschel et al. [2013]).

Energy cost analyses, making use of national input-output tables and taking into account both direct and indirect costs, were conducted for more than 40 years (e.g. Chapman [1974]). Early studies focused primarily on the US economy and on products delivered to final demand (e.g. Herendeen [1974]). Subsequently, total energy cost calculations were also performed for the German [Denton, 1975] and other European economies, but never to the entire European Union. Since the first papers, several new methodological considerations and extensions have been proposed (e.g. Costanza [1980]). However, we are not aware of any study which solely focuses on real unit energy costs, i.e. energy costs of intermediate consumption as percentage of value added. As mentioned above, our framework also includes indirect effects and allows for calculating a comprehensive indicator for the assessment of the burden of energy costs on firms, to which we refer to as total real unit energy costs:

$$TRUEC_{r,s,t} = DRUEC_{r,s,t} + IRUEC_{r,s,t} \tag{1}$$

where *TRUEC*, *DRUEC* and *IRUEC* are total, direct and indirect real unit energy costs of sector s in region r in the year t, and with $r \in [1, \ldots, 41]$, $s \in [1, \ldots, 35]$ and $t \in [1995, \ldots, 2011]$.

This can also be written as:

$$TRUEC_{r,s,t} = \frac{TEC_{r,s,t}}{VA_{r,s,t}} = \frac{DEC_{r,s,t} + IEC_{r,s,t}}{VA_{r,s,t}} \tag{2}$$

where *TEC*, *DEC* and *IEC* refer to total, direct and indirect energy costs, and *VA* to value added.

WIOD provides data on direct energy costs and value added. However, indirect energy costs have to be computed separately. We choose an iterative approach in two rounds.[2] The first round yields:

$$IEC^{1st}_{r,s,t} = \sum_{rr} \sum_{ss} \left[a_{rr,ss,r,s,t} \times dec_{rr,ss,t} \right] \times GO_{r,s,t} \tag{3}$$

where

[2]This technique allows for a stepwise calculation of indirect energy costs. Thereby, it is also possible to stepwise trace indirect energy costs back to their sectoral and regional origin, which allows further detailed analysis along the value chain, see Section 3.2.2. However, with each additional round, this technique also requires exponentially growing computing time.

$IEC^{1st}_{r,s,t}$	are indirect energy costs of sector s in region r in the year t in the first round,
$a_{rr,ss,r,s,t}$	is the share of intermediate inputs from sector ss in region rr in gross output of sector s in region r in the year t,
$dec_{rr,ss,t}$	is the share of direct energy costs of sector ss in region rr in gross output of sector ss in region rr in the year t and
$GO_{r,s,t}$	is the gross output of sector s in region r in the year t.
rr and ss	denote the delivering regions and sectors, whereas
r and s	denote the receiving regions and sectors.

The second round is calculated accordingly:

$$IEC^{2nd}_{r,s,t} = \left[\sum_{rr} \sum_{ss} \left[\sum_{rrr} \sum_{sss} \left[a_{rrr,sss,rr,ss,t} \times dec_{rrr,sss,t} \right] \right] \times a_{rr,ss,r,s,t} \right] \times GO_{r,s,t} \tag{4}$$

Adding the results of the two rounds yields the total indirect energy costs:

$$IEC_{r,s,t} = IEC^{1st}_{r,s,t} + IEC^{2nd}_{r,s,t} \tag{5}$$

Because WIOD does not provide sectoral shares of direct energy costs in gross output for the residual region (rest of the world), we assume that energy cost intensities in this region are about the average of the EU-27 and the other 13 countries in the database, i.e. the sectoral generation of one unit output in the rest of the world requires the same energy costs as the average of the other 40 countries.

While WIOD allows us to report direct energy costs both at basic prices and at purchasers' prices, indirect energy costs can only be calculated at basic prices. This is due to the fact that WIOD does not provide sufficient information on taxes less subsidies on products and international transport margins. This also means that all indirect energy cost values in this study are at the lower end of the possible range.

3 Results and discussion

In 2011 the total energy costs in the EU-27 amounted to 1,908 billion euros. This is somewhere between the GDP of the United Kingdom and France. Most of the costs incurred in the secondary sector (1,287 billion euros) and in the tertiary sector (574 billion euros). Only 47 billion euros incurred in the primary sector. Germany's share in Europe's total energy costs is about 15 % (see Figure 2).

During the period from 1995 to 2011 total real unit energy costs have risen in the EU-27 and in Germany, but different phases can be identified. First, between 1995 and 2002 the indicator remained unchanged in both regions. Then, between 2002 and 2008, the burden of energy costs increased from 8.5 % to 14.2 % in Germany and from 11.0 % to 16.8 % in Europe, reaching their highest values in the record. After 2008 total real unit energy costs decreased sharply during the financial crisis and rose again afterwards.

Real unit energy costs in Germany stayed below the European average throughout the entire time period, but increased (relatively) more in Germany (plus 58 % compared to plus 50 %). However, in recent years, after 2002, the development in Germany was more favourable than in the European Community. Especially after the financial crisis the gap widened and reached its maximum in 2011 (4.4 percentage points).

<< Insert Figure 2 about here >>

The remainder of this paper will shed light on the most important underlying sectoral ratios and developments by presenting energy costs in the year 2011 and then trends in real unit energy costs. Due to their relevance, this paper focuses on the secondary and tertiary sector.[3] We pick a set of sixteen industries for a detailed investigation. These industries comprise all energy sectors (two) and transport sectors (three) available in the WIOD, and also the six most important industrial non-energy sectors and the five most important non-transport service sectors with regard to output in Germany 2011. Each industry is compared to their European counterpart.

3.1 Total energy costs

Energy sectors, industrial non-energy sectors, transport sectors and non-transport service sectors have different energy cost structures. This is shown in Figure 3 for the case of Germany in the year 2011.

<< Insert Figure 3 about here >>

Energy sectors are dominated by direct energy costs, because refineries and electricity suppliers use primary energy carriers for the generation of secondary energy. However, in the other considered German industrial non-energy sectors it is indirect energy costs that are generally more relevant to firms. Here, sectoral direct energy costs are between 2 and 8 billion euros. The range (maximum value minus minimum value) of indirect energy costs is about the same but indirect costs are at a higher level, namely between 5 and 11 billion euros. In some sectors, like machinery and transport equipment, indirect energy costs are more than three times the size of direct energy costs. A similar picture can be found in service sectors, where direct energy costs outweigh indirect energy costs in transport sectors but not in the other considered non-transport service sectors like financial intermediation and real estate activities.

The ratio of indirect to direct energy costs is higher in industrial sectors than in service sectors. This is due to the fact that generally more energy costs are embedded in the (physical) inputs required for the manufacturing of industrial goods than in the inputs needed for the production of services. In the same way, the level of total energy costs is lower in service sectors than in industrial sectors. While costs for primary energy carriers such as coal, natural gas and crude oil are relevant to industrial sectors in general and to energy sectors in particular, service sectors rely almost exclusively on secondary energy carriers. For example, refined petroleum products are key for transport sectors, especially for air transport, where virtually 100 % of direct and 65 % of indirect energy costs are caused by these products.

[3]Within secondary sectors it is appropriate to distinguish between energy sectors and industrial non-energy sectors. The primary activity of the first is the production of energy, whereas all other sectors are primarily consumers of energy. Also, within the tertiary sectors it is useful to separate transport sectors from non-transport service sectors, since transport services heavily rely on fuels.

<< Insert Table 1 about here >>

3.2 Total real unit energy costs

In the following, energy costs time series are related to their respective value added. Most notably, total real unit energy cost growth was less pronounced in Germany's secondary sector than in the European average (see Table 2). Here, the indicator increased by 77 % in Germany compared to 85 % in the Community. This finding contradicts the general perception in Germany, that domestic manufacturing industries are particularly affected (negatively) by national energy policy decisions. Furthermore, discussions surrounding energy costs and international competitive pressures largely centre on manufacturing industries. On the other hand, real unit energy costs in Germany's service sectors increased relatively to the EU-27.

The finding for the total economy (see Figure 2) can also be observed at the level of the sixteen single sectors under discussion in this paper: in most sectors, both industrial and service, the burden of energy costs remained at a lower level in Germany compared to the EU in total. Exceptions are the refinery industry, water transport and air transport. The largest increases of total real unit energy costs can be found in the refining industry and in air transport. This indicates that crude oil and petroleum products were key drivers of the changes. In the year 2011, total real unit energy costs in industrial non-energy sectors in Germany and in the EU were 10 % or higher. On the other side, in non-transport service sectors, in no case they exceeded 5 %. Thus, value added generation in non-transport service sectors clearly depends less on energy inputs than in industrial branches, where the generation of 1 euro value added requires at least 10 cents of total energy costs.

<< Insert Table 2 about here >>

Up to this point, this study has focused on absolute figures and cost ratios in the year 2011 and aggregated trends of total real unit energy costs over time. The following five subsections are concerned with the analysis of the underlying factors of this evolution.

3.2.1 The role of direct and indirect energy costs

Equations 1 and 2 can be rearranged to:

$$TRUEC_{r,s,t} = DRUEC_{r,s,t} + IRUEC_{r,s,t} = \frac{DEC_{r,s,t}}{VA_{r,s,t}} + \frac{IEC_{r,s,t}}{VA_{r,s,t}} \tag{6}$$

Figure 4 displays the results. In sectors which require large amounts of energy inputs, i.e. energy sectors and transport sectors, direct energy costs were the main drivers of total real unit energy costs over time in Germany and Europe. Even though indirect energy costs also rose in these sectors, their contribution remains of secondary importance.

In contrast, indirect energy costs were the key drivers in the other sectors. Interestingly, this observation is valid both for industrial non-energy sectors and also for non-transport service sectors. In most sectors indirect real unit energy costs outgrew direct real unit energy costs. In this, we observe two distinct trends, because the growth rate of indirect real unit energy costs between 1995 and 2011 was well above 50 % in all industries (except for EU's construction

sector and Germany's and EU's real estate activities sector) whereas the growth rate of direct real unit energy costs always remained below the 50 % threshold (except for Germany's construction industry and EU's chemical industry). In the German machinery industry, electrical and optical equipment industry and real estate activities sector, direct real unit energy costs even decreased over the time period (minus 14 %, minus 3 % and minus 17 %), while indirect real unit energy costs increased (plus 77 %, plus 75 % and plus 2 %).

<< Insert Figure 4 about here >>

What are the causes for this shift towards indirect costs? One explanation might be found in the so-called pollution haven hypothesis (see e.g. Copeland and Taylor [2004]; Levinson and Taylor [2008]), which postulates that regulatory stringency in developed countries shifts polluting industries to the developing world. Following the carbon leakage logic, it might be argued that the EU ETS or other environmental regulations induce significant additional costs for industries which finally relocate production from Europe into regions with less ambitious climate policies or lower energy prices. Energy (cost) intensive products may then be imported as intermediate inputs into domestic industrial sectors. However, empirical support for this hypothesis is limited (see e.g. Cave and Blomquist [2008]; Sato and Dechezleprêtre [2015]).

In order to find a more convincing reason it is necessary to trace the origin of the costs, which is done in the next section. The focus here will be on the industrial sector, because it provides the most interesting results.

3.2.2 Digging deeper: where do indirect energy costs in industrial sectors come from?

We separate indirect real unit energy costs into domestic and imported fractions:

$$IRUEC_{r,s,t} = IRUEC^{DOM}_{r,s,t} + IRUEC^{IMP}_{r,s,t} = \frac{IEC^{DOM}_{r,s,t}}{VA_{r,s,t}} + \frac{IEC^{IMP}_{r,s,t}}{VA_{r,s,t}} \tag{7}$$

where the superscript *DOM* denotes domestic and *IMP* denotes imported.

The results are displayed in Figure 5. In the case of Germany imported indirect energy costs gained in importance relative to domestic indirect energy costs. Imported indirect real unit energy costs rose between 171 % in the machinery industry and 302 % in the chemical industry, while domestic indirect real unit energy costs grew between 7 % in the chemical industry and 73 % in the transport equipment industry. In 1995 the burden from imported inputs was lower than that from domestic inputs in each of the six industrial non-energy sectors chosen in this study. By 2011, however, imported indirect real unit energy costs were larger in the chemical industry, in the metal industry and in the electrical and optical equipment industry.

Similarly, imported indirect real unit energy costs increased more than domestic indirect real unit energy costs in the EU-27. In the construction industry and in the chemical industry, where both the smallest and the largest growth rates occurred, the burden from imports rose by 140 % and 334 % and that from domestic inputs by only 23 % and 79 %, respectively. Despite of these changes, the burden of the latter is still at a higher level.

<< Insert Figure 5 about here >>

The level differences between Germany and the European Union can be explained by the shares of domestic and imported indirect energy costs in total indirect energy costs (see Table 3). In Germany, the share of domestic indirect energy costs has decreased from 68 % in 1995 to 47 % in 2011, i.e. most of indirect energy costs in Germany's secondary sector are now imported from abroad. In contrast, the share of domestic indirect energy costs in the EU-27 remained high (81 % in 2011). However, imported indirect energy costs in Germany include imports from other EU countries, where most of Germany's imported indirect energy costs come from. European countries and their economies are highly interdependent and a large share of indirect energy costs circulates within the Community.

Looking beyond the European border, Brazil, China, India and Korea more than doubled their shares in Germany's and the EU's total indirect energy costs. It should be noted, that China's share in Germany's total indirect energy costs climbed from 0.6 % in 1995 to 5.2 % in 2011 (and in the European average from 0.5 % to 3.7 %), finally resulting in 3.4 billion euros of imported indirect energy costs (10.9 billion euros in the Community). This development reflects the general shift of the global economy to countries with a higher energy intensity, where China accounts for most of this development [Voigt et al., 2014].

<< Insert Table 3 about here >>

3.2.3 The role of primary and secondary energy products

Total real unit energy costs can be split into their energy product-specific components:

$$\begin{aligned} TRUEC_{r,s,t} &= TRUEC^{CPA10}_{r,s,t} + TRUEC^{CPA11}_{r,s,t} + TRUEC^{CPA23}_{r,s,t} + TRUEC^{CPA40}_{r,s,t} \\ &= \frac{TEC^{CPA10}_{r,s,t}}{VA_{r,s,t}} + \frac{TEC^{CPA11}_{r,s,t}}{VA_{r,s,t}} + \frac{TEC^{CPA23}_{r,s,t}}{VA_{r,s,t}} + \frac{TEC^{CPA40}_{r,s,t}}{VA_{r,s,t}} \end{aligned} \tag{8}$$

where the superscript *CPA10* refers to the energy product group coal and lignite, *CPA11* to crude petroleum and natural gas, *CPA23* to coke and refined petroleum products and *CPA40* to electrical energy, gas, steam and hot water.[4]

Primary energy products are predominantly used in energy sectors for secondary energy generation, where they cause considerable direct energy costs. Crude petroleum and natural gas alone accounted for 70 % of direct real unit energy costs in Germany's refining industry in the year 2011, and in Europe even for 76 %. Since 1995 direct real unit energy costs of crude petroleum and natural gas almost doubled in this industry in Germany, and almost tripled in Europe.

In the same way, primary energy carriers (including coal and lignite), accounted for 21 % and 42 % of direct real unit energy costs in Germany's and EU's electricity, gas and water supply sector. However, the industry is dominated by costs for (secondary) electrical energy, gas,

[4]Abbreviations stem from the statistical classification of products by activity (CPA) which are designed to categorise products that have common characteristics. *CPA10* also includes peat, *CPA11* also includes services incidental to oil and gas extraction excluding surveying and *CPA23* also includes nuclear fuels.

steam and hot water. The reason for this finding is that this sector comprises activities related to transmission, distribution and trade of electricity and gas, the manufacture of gas and the collection, treatment and supply of water.

Apart from the energy sectors, primary energy carriers are of minor importance as direct inputs. Their indirect costs are slightly larger, especially in the secondary sector. This is partly due to imports from outside the EU, particularly China. However, in sum, their contribution remains low. Because the major part of the economy relies rather on secondary energy products, we limit ourselves in the following to coke and refined petroleum products on the one hand and electricity, gas, steam and hot water (district heating) on the other hand. Figure 6 shows their respective trends.

<< Insert Figure 6 about here >>

As indicated above, the demand for petroleum products is key for understanding the observed rise of total real unit energy costs between 1995 and 2011. When comparing sectoral total real unit energy costs of coke and petroleum products with those of electricity, gas, steam and hot water, it is clearly visible that the first had a far stronger upward momentum. This is true for all industries apart from the electricity, gas and water supply sector. In general, at the beginning of the period, the total cost burden of petroleum products was smaller than that of electricity, etc. in industrial non-energy and non-transport service sectors. This gap was reduced over time and in some industries the situation even reversed by the end of the period.

For many industrial branches growth rates of petroleum-based total real unit energy costs have been larger than 100 % (e.g. in Germany's and in EU's chemical industry and electrical and optical equipment industry). In Germany's transport equipment sector and in Germany's and EU's air transport sector costs more than tripled. The oil price surge between 2003 and 2008 increased both prices for crude oil and refined petroleum products leading to higher direct and indirect real unit energy costs. During the economic crisis at the end of the last decade oil prices plummeted, but recovered afterwards, which is likewise visible in the data.

Opposed to the upward trends of refinery products, total real unit energy costs of electricity, gas, steam and hot water grew moderately. In some sectors the burden even decreased between 1995 and 2011 (e.g. in Germany's inland transport and real estate sectors and in EU's construction and water transport sectors).

Comparing the regions, the total cost burden of electricity, etc. is generally lower in Germany's non-transport service sectors than in the EU. It is also at a lower level in the electricity, gas and water supply industry, even though the larger increase took place in Germany (by a factor of about 10). And most remarkably, total real unit energy costs of electricity, etc. in the industrial non-energy sectors are not only at a lower level in Germany, but also the increases since the year 2000 had been smaller.[5]

The latter finding is contrary to what could have been expected in the light of Germany's energy transition (Energiewende). Electricity generation from renewable energy sources has experienced an uptake since the Renewable Energy Act came into force in the year 2000. The purpose of the Act is to facilitate a sustainable energy supply and to promote the further development of technologies for renewable electricity generation. It gives priority to the purchase and transmission of such electricity by the grid system operators and guarantees fixed feed-in

[5]Except for the German construction industry, which has gone through a crisis (see Section 3.2.5).

tariffs to the producers. The additional costs are passed through to (non-privileged) consumers via a surcharge (EEG Umlage) as part of the electricity price. However, in order to maintain international and intermodal competitiveness, allowances are available to electricity-intensive undertakings under the Renewable Energy Act. In addition, also other privileges and exemptions with regard to taxes, grid charges, etc. do exist for large consumers of electricity. All of this contributed to the relatively favourable development in Germany's industrial non-energy sectors.

Thus, the results do not indicate that Germany's energy transition in the electricity sector was a major driver of total real unit energy costs. Unfortunately, this finding is confounded by the fact, that WIOD's supply and use tables only provide data for aggregated energy products (electrical energy, gas, steam and hot water in sum, instead of renewable electrical energy alone). So the question remains: how large is the impact of Germany's promoted renewable electricity generation on electricity prices and consequently on (real unit) energy costs? The next section sheds light on this topic using a simple case study. For the sake of comparability with the results presented above, the case study focuses on the year 2011 (not later) and on intermediate consumption.

3.2.4 Digging deeper: how large is the impact of Germany's promoted renewable electricity generation on electricity prices and on (real unit) energy costs?

In order to answer the question on the impact of Germany's promotion of renewable electricity generation on electricity prices and on (real unit) energy costs, we must look at the total real unit energy costs of a subset of the aggregated WIOD energy product group: electrical energy, gas, steam and hot water ($CPA40$):

$$TRUEC^{RE}_{r,s,t} \subset TRUEC^{CPA40}_{r,s,t} \tag{9}$$

where the superscript RE refers to promoted renewable energy under the German Renewable Energy Act. Thus, total real unit energy costs of Germany's promoted renewable electricity generation in the year 2011 are:

$$TRUEC^{RE}_{r,s,2011} = \frac{DEC^{RE}_{r,s,2011} + IEC^{RE}_{r,s,2011}}{VA_{r,s,2011}} \tag{10}$$

In this case study, direct energy costs will take into account three cost components (price-quantity combinations):

$$DEC^{RE}_{GER,s,2011} = DEC^{EEG,PC}_{GER,s,2011} + DEC^{EEG,NPC}_{GER,s,2011} - DNS^{MOE}_{GER,s,2011} \tag{11}$$

$DEC^{EEG,PC}_{GER,s,2011}$ are direct energy costs incurred by Germany's industry s in the year 2011 due to the reduced EEG surcharge which privileged consumers (PC) under the EEG Special Equalisation Scheme had to pay (0.05 ct/kWh). The total amount of electricity consumed under the EEG Special Equalisation Scheme is known (85 TWh; Netztransparenz.de [2012]). For the

sectoral breakdown the shares reported in the application procedure for companies wishing to take advantage of the reduction in the coming year are used [BMU, 2011]. Thus, $DEC^{EEG,PC}_{GER,s,2011}$ equals price (0.05 ct/kWh) times sectoral quantity of electricity consumed by privileged consumers.

$DEC^{EEG,NPC}_{GER,s,2011}$ are direct energy costs incurred by Germany's industry s in the year 2011 due to the EEG surcharge which non-privileged consumers (NPC) had to pay. In the year 2011, the EEG surcharge amounted to 3.53 ct/kWh. Starting from WIOD's sectoral electricity consumption data in 2009 we use sectoral consumption growth rates provided by Eurostat [2016a] to extrapolate the sectoral electricity consumption in 2011 and correct for electricity autoproduction [Destatis, 2012]. Based on this we calculate the sectoral shares of the total electricity consumption. The amount of (privileged and non-privileged) EEG (462 TWh) electricity consumed is then allocated between the sectors using those shares. As a final step, the calculated sectoral quantities are reduced by the sectoral quantities under the EEG Special Equalisation Scheme. Thus, non-privileged quantity times the non-privileged price of 3.53 ct/kWh yields $DEC^{EEG,NPC}_{GER,s,2011}$.

$DNS^{MOE}_{GER,s,2011}$ are direct net savings in Germany's industry s in the year 2011 due to the so called merit order effect (MOE), which describes the depressing effect of the generation of renewable electricity, with grid priority and low marginal costs, on the wholesale price of electricity. The merit order effect is widely accepted, but the size of the effect is under discussion. Four studies calculated the effect in the year 2011 for Germany: Sensfuß [2013] estimated that the merit order effect of renewable electricity generation was 0.87 ct/kWh. The remaining studies consider only wind and photovoltaics. Würzburg et al. [2013] estimated a reduction of the electricity price of 0.76 ct/kWh between mid-2010 and mid-2012. Cludius et al. [2014] computed 0.77 ct/kWh. Finally, Dillig et al. [2016] revealed a high effect on the electricity market price of 3.23 ct/kWh due to a lack of non-renewable power capacities. No other study before or afterwards reported such a strong effect. In this case study we will use the median value (0.82 ct/kWh) of the mentioned four studies and assume that this price reduction is passed on to all consumers of electricity. Thus, $DNS^{MOE}_{GER,s,2011}$ equals price savings (0.82 ct/kWh) times sectoral quantity of electricity consumed by privileged and non-privileged consumers.

Of course, further cost components are conceivable in this context, such as from additional back-up capacities for coping with the volatility of renewable generation and additional grid charges (the latter declined between 2006 and 2011), but these are presumably of limited importance to the assessment and for drawing the intended general conclusions from this case study. Also with regard to those cost components, energy-intensive companies are often exempted.

Finally, in order to assess $IEC^{RE}_{r,s,2011}$ it is necessary to use the share of $DEC^{RE}_{GER,s,2011}$ in gross output of Germany's sector s in the year 2011 in equations 3 and 4 accordingly. The results are reported in Table 4 and Table 5.

Apart from private households in Germany, which bear a large part of the costs of promoted renewable electricity generation, also German companies are facing additional costs. In the total economy, attributable direct energy costs amounted to 6.5 billion euros, indirect energy costs amounted to 2.7 billion euros (see Table 4). This are, expressed as percentage of value added, 0.27 and 0.12 %. Or stated differently, about 3.2 % of total energy costs in Germany can be attributed to the promotion of renewable electricity.

<< Insert Table 4 about here >>

Even though total real unit energy costs of electrical energy, gas, steam and hot water did not indicate that Germany's energy transition in the electricity sector was a predominant driver for energy costs (see Section 3.2.3), this case study reveals that the promotion of renewable electricity has (already) become a significant cost factor for companies. The costs for the promotion of renewables are larger than the costs attributable to coal and lignite. In the year 2011, direct energy costs of coal and lignite amounted to only 6.3 billion euros in Germany. And most of the amount was paid by just two industrial branches, the electricity generating and petroleum refining sectors. In addition, the indirect energy costs of coal and lignite amounted to 4.7 billion euros. But when compared to the indirect cost figure of renewables, one must bear in mind, that the figure for coal and lignite includes imported costs from outside Germany. Without those imported costs, the indirect energy costs of coal and lignite were only about 1.8 billion euros. This switch in importance between promoted renewables on the one hand and traditional coal and lignite on the other hand must have happened about the time of the reference year chosen in this case study. Total real unit energy costs of promoted renewable electricity increased from approximately zero before the year 2000 to 0.39 % in 2011. In contrast, total real unit energy costs of coal and lignite remained relatively stable and moved from 0.36 % in the year 2000 to 0.34 % in 2011 (if imported indirect energy costs are excluded).

Once more, the effects of indirect energy costs must be highlighted. At the regional level, 1 euro of direct costs attributable to the German promotion of renewable electricity caused about 42 cents of indirect energy costs in Germany and about 12 cents in the rest of the EU-27. In total, 774 million euros of indirect energy costs were exported from Germany into the rest of the Community because of the domestic promotion in the year 2011. This is remarkable given the early stage on the long way to a decarbonised energy system, which of course is not limited to the electricity sector.

In addition, we also look at the sectoral level. In absolute terms, most of the direct and indirect energy costs are born by the secondary sector. But when looking at the shares of direct energy costs of promoted renewable electricity in direct energy costs of the total product group electrical energy, gas, steam and hot water, these are below average in the German secondary sector (compare figures in Table 4 and Table 5). This is also true for resulting indirect energy costs in Germany. This implies that the asymmetric direct impacts of allowances available to electro-intensive undertakings in the secondary sector are amplified by the resulting indirect effects. However, this effect is not visible in the EU-27 aggregate because of the relatively high export shares of the secondary sector.

<< Insert Table 5 about here >>

3.2.5 The role of labour and capital (factors of production)

Finally, as total real unit energy costs are defined as percentage of value added, we need to discuss the role of the denominator of the indicator and the corresponding factors of production, labour and capital:

$$TRUEC_{r,s,t} = \frac{TEC_{r,s,t}}{VA^{LAB}_{r,s,t} + VA^{CAP}_{r,s,t}} \tag{12}$$

where the superscript LAB refers to labour and CAP to capital.

Due to the inverse relationship between the aggregates, total real unit energy costs decrease if one of the value added components increases and vice versa, all else being equal. The trends in value added by labour and by capital are shown in Figure 7.[6]

Many industries expanded their value added figures between 1995 and 2011 and in this way increased their contribution to overall GDP and their importance. Considerable increases can be found in Germany's electrical and optical equipment sector and also in Germany's and EU's renting of machinery and equipment sector. However, in our chosen set of sixteen industrial branches, value added generation outperformed total energy costs only in one case, in Germany's real estate sector, where total real unit energy costs could be reduced by 6 % (see also Table 2).

On the other hand, prolonged or sudden contraction of value added may indicate a crisis, as the following three examples illustrate. After the boom following Germany's reunification, low investment activities led to a long-term economic decline in the national construction sector. Its share in Germany's total value added generation decreased from almost 7 % in 1995 to just under 4 % in 2006. Simultaneously, the number of employees went down about 1 million. Both effects are reflected in the contraction of the sector's value added by labour. Similarly, European petroleum refiners have been facing multiple structural challenges, ranging from declining demand for European oil products, to domestic overcapacities and capacity expansions in other world regions, to high prices of crude oil feedstock. Finally, also the financial crisis of 2009 can be identified in the data. The recession can be recognised most clearly in Germany's and Europe's industrial sectors, particularly with regard to value added by capital, which was more sensitive to the economic downturn. Even though the crisis caused a stronger contraction of capital compensation in Germany, the same is true for its recovery. In the first two examples, the contraction of value added augmented the effects of rising total energy costs. However, during the financial crisis, energy cost reductions were larger than contractions in value added, thus resulting in falling total real unit energy costs all across Europe.

<< Insert Figure 7 about here >>

As a general trend in the Community, the data documents a shift towards the tertiary sector. Value added growth rates in service sectors were higher than in industrial sectors. This is a sign of the gradual deindustrialisation of the European economy. It should be noted that German industrial sectors outperformed the European average. Therefore, value added generation contributed to the fact, that the burden of total energy costs on firms increased less in Germany's secondary sector than in the European Union.

4 Conclusions

In this study, we proposed an input-output based (total real unit) energy cost accounting framework which helped us compare the burden of energy costs on firms in Germany and Europe and reveal many developments which are not adequately represented in the political debate, especially with regard to indirect energy costs.

The first policy implication refers to the findings in Sections 3.1 and 3.2.1, that indirect energy costs are more important to many industrial branches than direct energy costs. This implies

[6] We use additional Eurostat [2016b] (general) GDP deflators for the years 2010-2011, because WIOD only provides (sectoral) deflators for the years 1995-2009.

that increases in energy prices do not only have a direct impact on energy-intensive industrial branches, but also an indirect impact on other sectors, which at a first glance do not seem to be affected. This is particularly true for industrial non-energy sectors where the ratio between indirect and direct energy costs is high. Our analysis reveals that indirect energy costs have become more important over time across most sectors, both in Germany and in Europe. This leads us to conclude that energy policy should not limit itself to monitor direct energy costs alone but should also take indirect energy costs into account.

Secondly, national energy policy should be aware of the transnational impacts of indirect energy costs. Decision-makers in policy recognise the importance of imported direct energy costs, especially with regard to primary energy carriers such as crude oil or natural gas which are, to a large extend, imported to Germany and the European Union. But decision-makers must also not underestimate the role of imported indirect energy costs. As discussed in Section 3.2.2, the majority of indirect energy costs in Germany's secondary sector are imported, not domestic. This implies that cost developments abroad are of national interest, because national companies benefit, to a certain extend, also from low energy costs of foreign suppliers and even international competitors.

Thirdly, even though the political debate (especially in Germany) is often centered on electricity, decision-makers should also observe closely the future developments on the market for crude oil and refined petroleum products. The emphasis on electricity is partly due to the fact that oil prices are primarily determined exogenously whereas prices for electricity are more influenced by domestic factors. The currently low oil price reinforces this tendency. Nevertheless, oil was and will remain important. As we found in Section 3.2.3, total real unit energy costs in Germany and in Europe between 1995 and 2011 have been strongly driven by petroleum-based energy carriers. The increase of total real unit energy costs between 2003 and 2008 can be related to the oil price shock. Furthermore, petroleum fuels will remain the dominant energy source in the transport sector for many years to come. Even if technological breakthroughs are achieved soon, a certain inertia of the transport sector is to be expected. Also, in many cases power-to-mobility concepts are still not competitive or need additional promotion. Accordingly, the German cabinet recently approved new incentives and tax exemptions to boost demand for electric cars (BMWi [2016]). This leads us to our next policy implication which regards the electricity sector.

The further promotion of renewable energy sources must be planned carefully in order to keep costs at an economically justifiable level and to avoid unequal burden-sharing between sectors. The share of renewables in gross electricity consumption reached 20.4 % in Germany in the year 2011. Because this share should exceed 80 % by 2050, a lot of costs occur in the future. The remaining reconstruction of the energy system, which is not confined to the electricity sector, may potentially be very expensive. In Section 3.2.4 we found that in 2011 already about 3.2 % of total energy cost in Germany's industries can be attributed to the promotion of renewable electricity. This figure has surpassed the corresponding share of coal. The EEG surcharge moved up from 3.53 ct/kWh in the year 2011 to 6.24 ct/kWh in the year 2014, whereas the share of renewables in gross electricity consumption only gained 7.0 percentage points. We also stressed, that indirect effects amplify the asymmetric impacts of legal exceptions available to energy-intensive industries. Consequently, non-privileged electricity consumers are affected negatively by exceptions in two ways. First, directly by paying normal EEG surcharges, and then indirectly, via relatively higher input costs. The extent to which the promotion of renewables is accompanied by unequal treatment and burden-sharing should be part of the future political debate.

In sum, the shift towards low carbon economies by promoting renewable energy, not just in Germany and in Europe, but all around the world, will induce additional direct energy costs. These will translate into additional indirect energy costs which in turn will (possibly asymmetrically) affect both domestic and foreign sectors and countries. Thus, promotion of renewable energies, which should be as cost-effective as possible, would require a truly global perspective. But of course, national energy policy will only have a limited influence on and interest in policy decisions in foreign countries. Nevertheless, it is advisable to design at least a more harmonised European approach. This is in line with the fact that a large portion of indirect energy costs is actually circulating within the Community.

Despite the benefits of cost analyses, the analysis of energy prices should not be discarded. Decision-makers in companies may very well be interested in the distinction between prices and quantities for good investment decisions. A new investment may have similar (expected) energy requirements and may also generate similar value added at different locations or in different countries. In such cases, energy prices can be crucial.

Finally, total real unit energy costs are a good starting point for gaining deeper insight into the relationship between energy costs and competitiveness. But more detailed analyses are mandatory. To this end, our proposed framework should be complemented by additional cost components (e.g. labour costs, taxes, etc.). Studies should also consider the possible cost pass-through to costumers. In this respect, the share of total real unit energy costs which can (not) be passed on to customers would be of special interest. Input-output analysis may be able to provide general information and allow for international comparisons. But aggregated input-output tables do not capture, inter alia, the heterogeneity within sectors. Thus, additional studies using micro data at the firm level should be conducted. This would add credibility to the evaluation of causal effects of energy costs on competitiveness.

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Tables

Table 1: Direct and indirect energy costs in Germany and in the European Union 2011.

Germany										
Sector	$DEC^{\cdots}$					$IEC^{\cdots}$				
	TOT	$CPA10$	$CPA11$	$CPA23$	$CPA40$	TOT	$CPA10$	$CPA11$	$CPA23$	$CPA40$
	Million euros									
Total economy	196,977	6,261	43,999	83,379	63,337	93,957	4,658	9,447	41,685	38,167
Primary sector	4,405	50	67	3,381	908	1,657	68	224	727	638
Secondary sector	135,598	6,164	42,053	40,686	46,694	64,596	3,774	7,700	25,753	27,370
Tertiary sector	56,974	48	1,879	39,312	15,735	27,704	815	1,524	15,205	10,160
Coke, refined petroleum and nuclear fuel	48,513	1,104	33,794	12,714	901	2,330	72	224	1,239	794
Electricity, gas and water supply	32,487	4,189	2,643	2,573	23,083	1,260	49	85	634	492
Chemicals and chemical products	11,125	150	1,711	6,692	2,572	6,520	233	1,327	2,947	2,013
Basic metals and fabricated metal	12,006	277	1,340	4,740	5,648	11,397	1,107	1,658	3,689	4,943
Machinery, not elsewhere classified	2,460	8	148	832	1,473	6,502	449	628	2,375	3,049
Electrical and optical equipment	2,520	4	136	954	1,427	5,232	330	527	1,995	2,381
Transport equipment	4,551	7	283	1,526	2,735	11,464	667	1,082	4,270	5,445
Construction	4,820	4	59	4,469	287	5,779	349	598	2,112	2,720
Inland transport	7,548	0	18	6,351	1,180	1,312	29	60	842	382
Water transport	2,802	2	79	2,705	16	1,070	8	24	853	184
Air transport	8,307	0	0	8,294	13	649	12	42	419	176
Financial intermediation	1,185	0	94	329	762	1,807	51	62	840	854
Real estate activities	721	0	5	163	553	1,281	58	55	605	563
Renting of machinery and equipment[1)]	3,997	0	167	2,723	1,106	3,348	122	175	1,630	1,421
Public administration and defence[2)]	5,073	41	319	3,193	1,521	2,110	76	114	1,084	836
Health and social work	4,130	0	261	1,560	2,310	2,959	110	457	1,259	1,132
European Union (EU-27)										
Sector	$DEC^{\cdots}$					$IEC^{\cdots}$				
	TOT	$CPA10$	$CPA11$	$CPA23$	$CPA40$	TOT	$CPA10$	$CPA11$	$CPA23$	$CPA40$
	Million euros									
Total economy	1,403,244	40,547	427,819	478,036	456,842	504,860	20,260	54,844	211,764	217,992
Primary sector	33,186	406	79	23,680	9,022	13,690	389	1,553	6,402	5,346
Secondary sector	989,158	39,425	425,296	219,772	304,665	298,202	15,354	36,939	114,894	131,015
Tertiary sector	380,900	715	2,444	234,585	143,156	192,969	4,517	16,353	90,468	81,630
Coke, refined petroleum and nuclear fuel	384,370	5,938	293,715	79,164	5,553	10,299	341	3,780	3,776	2,402
Electricity, gas and water supply	314,032	23,465	107,804	23,079	159,684	8,608	332	2,145	2,958	3,173
Chemicals and chemical products	69,694	869	7,116	42,005	19,704	32,278	1,032	6,382	14,287	10,576
Basic metals and fabricated metal	49,975	6,024	3,884	13,990	26,076	42,280	4,094	5,434	13,393	19,359
Machinery, not elsewhere classified	10,793	27	225	3,040	7,501	21,038	1,546	1,963	7,291	10,238
Electrical and optical equipment	9,085	88	210	2,648	6,139	19,333	1,190	1,861	7,163	9,118
Transport equipment	12,489	36	503	3,383	8,566	29,950	1,663	2,668	10,901	14,719
Construction	29,809	132	719	24,370	4,588	44,748	2,394	4,102	16,026	22,226
Inland transport	78,492	16	172	70,482	7,821	11,641	226	971	6,596	3,849
Water transport	11,596	2	79	11,293	222	4,049	45	258	2,811	935
Air transport	24,580	0	0	24,243	336	3,206	91	267	1,878	972
Financial intermediation	10,256	8	103	4,830	5,315	11,003	198	762	4,641	5,402
Real estate activities	16,632	208	24	2,894	13,506	9,946	454	936	3,836	4,718
Renting of machinery and equipment[1)]	30,620	9	220	18,382	12,010	28,009	609	2,285	12,354	12,761
Public administration and defence[2)]	27,554	213	348	11,966	15,027	11,927	407	1,065	4,919	5,536
Health and social work	23,375	27	283	7,951	15,114	19,993	519	3,039	7,940	8,495

Notes: 1) And other business activities; 2) And compulsory social security; DEC = direct energy costs (at purchaser's prices); IEC = indirect energy costs (at basic prices); TOT = total; CPA10 = "coal and lignite; peat"; CPA11 = "crude petroleum and natural gas; services incidental to oil and gas extraction excluding surveying"; CPA23 = "coke, refined petroleum products and nuclear fuels"; CPA40 = "electrical energy, gas, steam and hot water".

Source: Own elaboration based on WIOD.

Table 2: Total real unit energy costs in Germany and in the European Union 1995 and 2011.

Sector	Germany			European Union (EU-27)		
	$TRUEC_{1995}$	$TRUEC_{2011}$	Rate of change	$TRUEC_{1995}$	$TRUEC_{2011}$	Rate of change
			Percent			Percent
Total economy	0.08	0.12	+58	0.11	0.17	+50
Primary sector	0.16	0.25	+54	0.12	0.22	+87
Secondary sector	0.16	0.29	+77	0.24	0.45	+85
Tertiary sector	0.04	0.05	+47	0.05	0.07	+31
Coke, refined petroleum and nuclear fuel	8.00	14.42	+80	3.98	10.76	+170
Electricity, gas and water supply	0.35	0.53	+52	0.72	1.16	+61
Chemicals and chemical products	0.22	0.33	+52	0.28	0.53	+90
Basic metals and fabricated metal	0.19	0.27	+41	0.23	0.34	+49
Machinery, not elsewhere classified	0.07	0.10	+37	0.10	0.14	+40
Electrical and optical equipment	0.07	0.10	+39	0.09	0.14	+59
Transport equipment	0.10	0.18	+85	0.14	0.21	+54
Construction	0.06	0.11	+70	0.09	0.11	+25
Inland transport	0.18	0.26	+44	0.23	0.34	+48
Water transport	0.18	0.46	+149	0.28	0.35	+24
Air transport	0.38	1.48	+286	0.27	0.83	+212
Financial intermediation	0.02	0.03	+50	0.03	0.03	+24
Real estate activities	0.01	0.01	-6	0.02	0.02	+32
Renting of machinery and equipment[1)]	0.02	0.02	+36	0.03	0.04	+26
Public administration and defence[2)]	0.04	0.05	+49	0.04	0.05	+25
Health and social work	0.03	0.04	+28	0.04	0.05	+27

Notes: 1) And other business activities; 2) And compulsory social security; TRUEC = total real unit energy costs.
Source: Own elaboration based on WIOD.

Table 3: Share of domestic and imported indirect energy costs of the secondary sector in Germany and in the European Union 1995 and 2011.

Origin		Germany			European Union (EU-27)		
		1995	2011	Rate of change	1995	2011	Rate of change
				Percent			
Domestic		67.96	46.78	-31	90.28	80.93	-10
Imported (from)	European Union (EU-27)	20.72	28.22	+36	-	-	-
	Brazil	0.43	1.14	+162	0.29	0.74	+157
	China	0.57	5.25	+825	0.47	3.66	+675
	India	0.34	0.80	+136	0.29	0.65	+126
	Japan	0.99	1.38	+40	0.72	0.83	+16
	Korea	0.34	0.83	+143	0.22	0.74	+239
	Russia	1.37	1.45	+6	1.10	1.39	+26
	United States of America	1.55	2.28	+47	1.52	2.19	+44
	Rest of the world	5.74	11.87	+107	5.12	8.87	+73
Total		100.00	100.00	-	100.00	100.00	-

Notes: - = not applicable.
Source: Own elaboration based on WIOD.

Table 4: (Real unit) energy costs of Germany's promoted renewable electricity generation in Germany and in the European Union 2011.

Region	Sector	DEC^{RE}	IEC^{RE}	$DRUEC^{RE}$	$IRUEC^{RE}$
		Million euros		Percent	
Germany	Total economy	6,482	2,720	0.27	0.12
	Primary sector	144	49	0.60	0.20
	Secondary sector	3,396	1,613	0.49	0.23
	Tertiary sector	2,942	1,058	0.18	0.06
European Union (EU-27)	Total economy	6,482	3,495	0.06	0.03
	Primary sector	144	66	0.07	0.03
	Secondary sector	3,396	2,168	0.12	0.08
	Tertiary sector	2,942	1,260	0.04	0.02

Notes: DEC = direct energy costs; IEC = indirect energy costs; DRUEC = direct real unit energy costs; IRUEC = indirect real unit energy costs; RE = attributable to Germany's promoted renewable electricity generation.
Source: Own elaboration based on WIOD, BMU [2011], Destatis [2012], Eurostat [2016a] and Netztransparenz.de [2012].

Table 5: Share of energy costs of Germany's renewable electricity generation in the energy costs of the (aggregated) energy product "electrical energy, gas, steam and hot water" in Germany and in the European Union 2011.

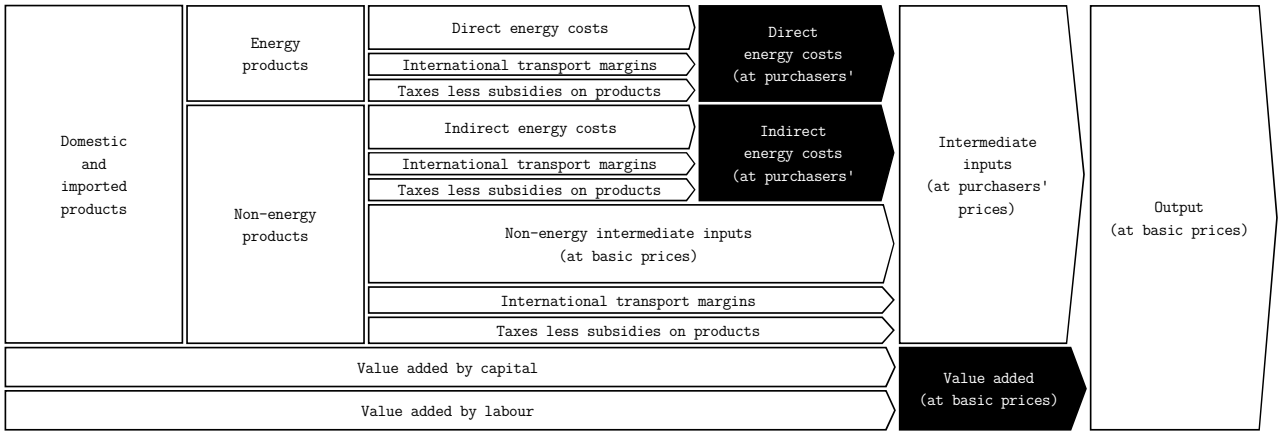
Sector	Germany		European Union (EU-27)	
	DEC^{RE} in DEC^{CPA40}	IEC^{RE} in IEC^{CPA40}	DEC^{RE} in DEC^{CPA40}	IEC^{RE} in IEC^{CPA40}
	Percent			
Total economy	10.23	7.13	1.42	1.60
Primary sector	15.87	7.62	1.60	1.23
Secondary sector	7.27	5.89	1.11	1.66
Tertiary sector	18.70	10.42	2.05	1.54

Notes: DEC = direct energy costs; IEC = indirect energy costs; RE = attributable to Germany's promoted renewable electricity generation; CPA40 = "electrical energy, gas, steam and hot water".

Source: Own elaboration based on WIOD, BMU [2011], Destatis [2012], Eurostat [2016a] and Netztransparenz.de [2012].

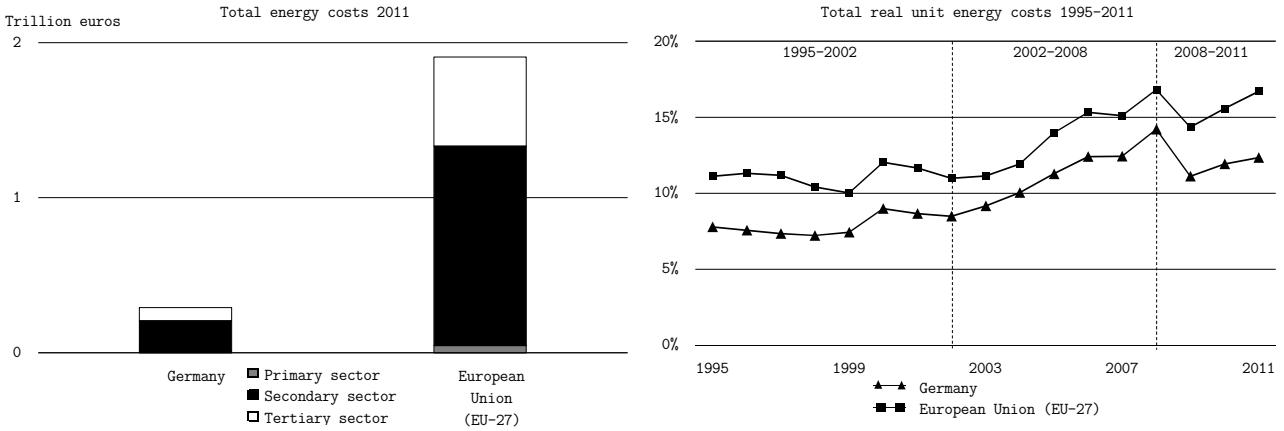
Figures

Figure 1: Main aggregates of input-output based (total real unit) energy cost accounting.



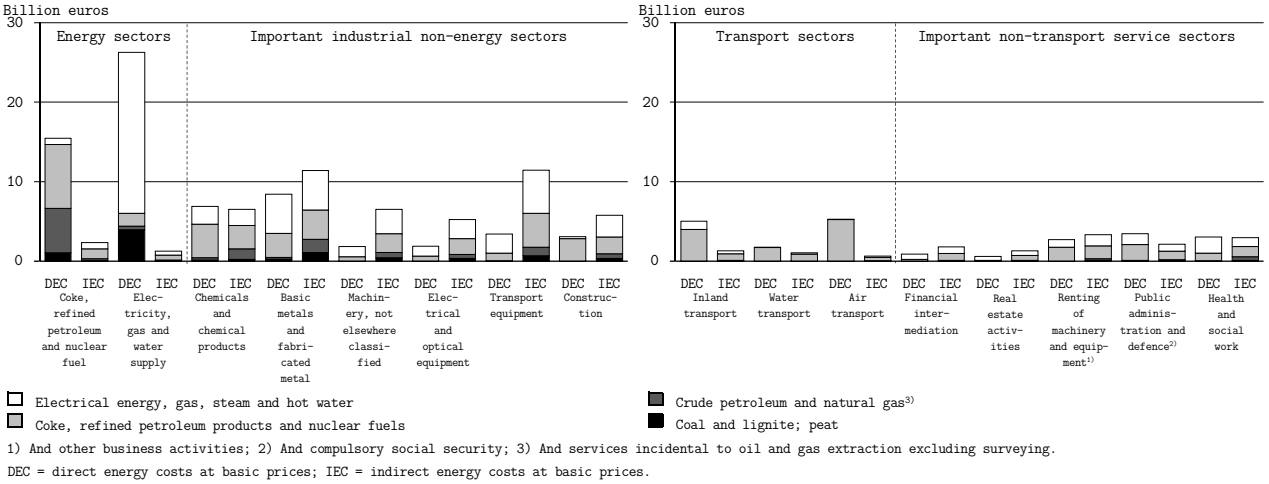
Source: Own elaboration.

Figure 2: Total energy costs 2011 and total real unit energy costs 1995-2011 in Germany and in the European Union.



Source: Own elaboration based on WIOD.

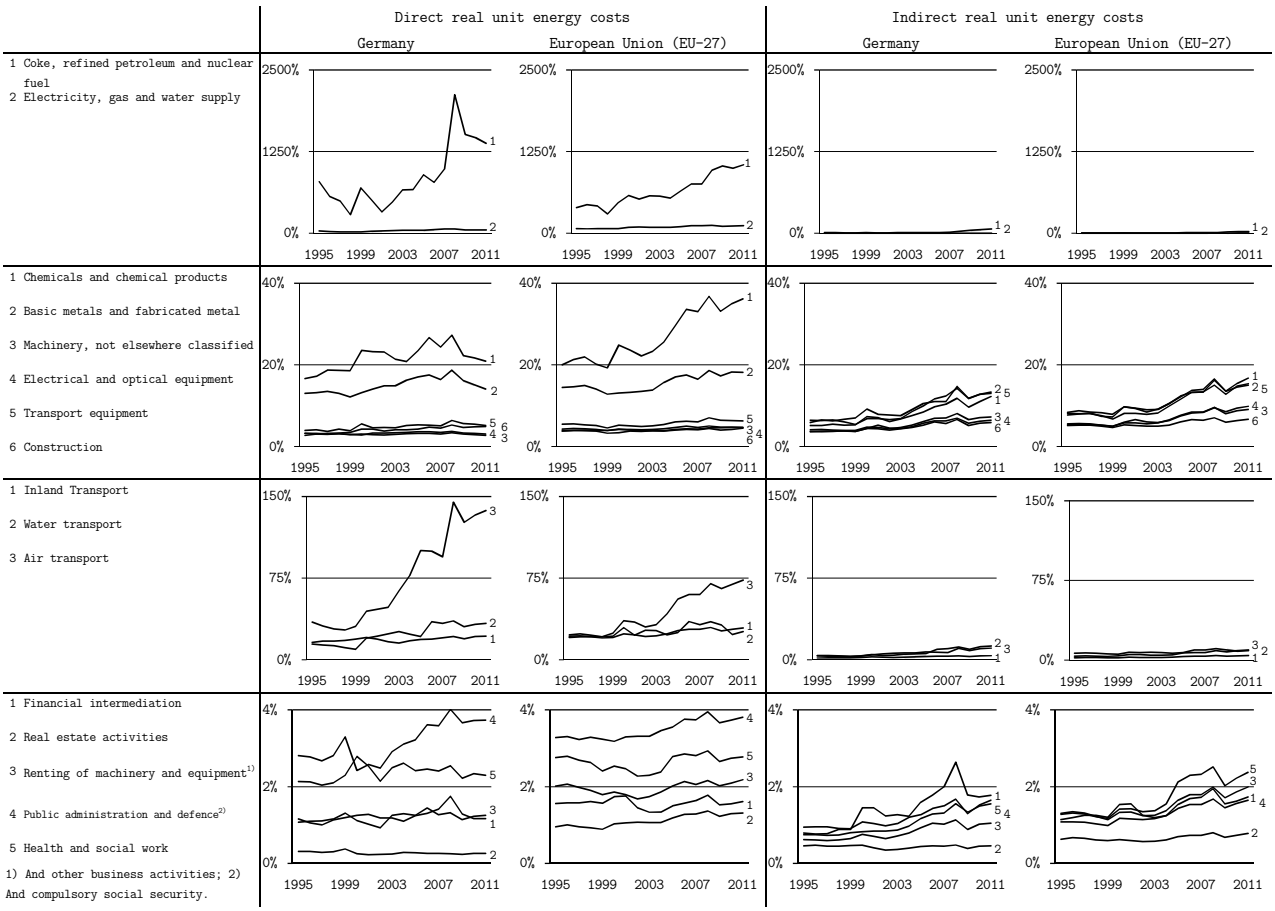
Figure 3: Direct and indirect energy costs in Germany 2011.



1) And other business activities; 2) And compulsory social security; 3) And services incidental to oil and gas extraction excluding surveying.
DEC = direct energy costs at basic prices; IEC = indirect energy costs at basic prices.

Source: Own elaboration based on WIOD.

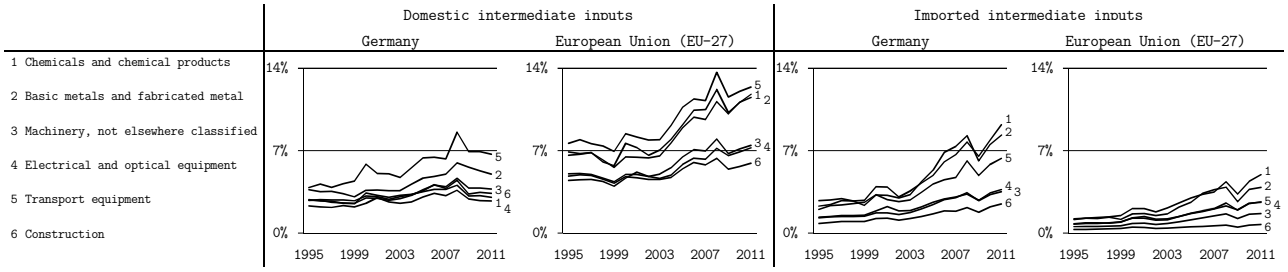
Figure 4: Direct and indirect real unit energy costs in Germany and in the European Union 1995-2011.



Notes: Real unit energy costs above 100 % mean that energy costs are larger than corresponding value added.

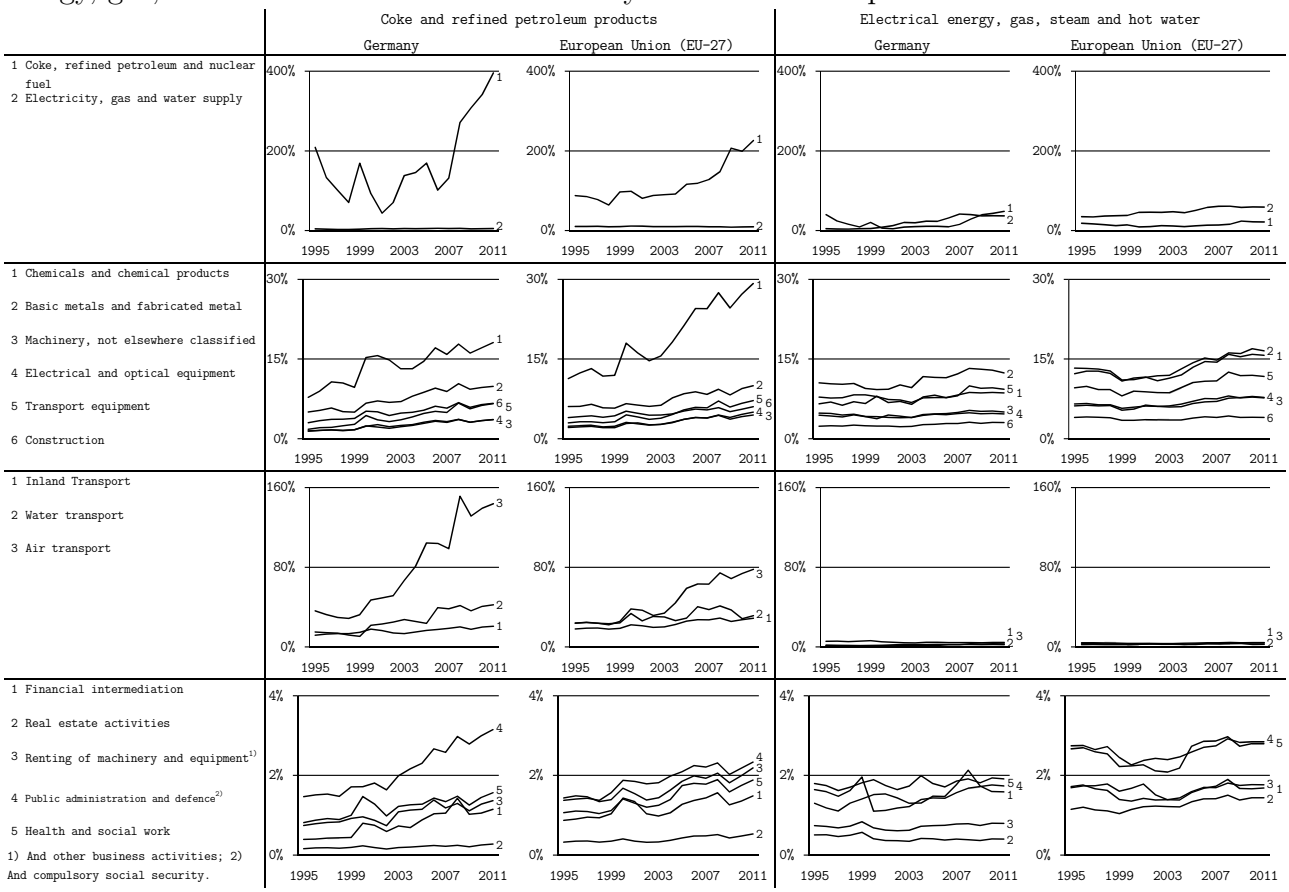
Source: Own elaboration based on WIOD.

Figure 5: Indirect real unit energy costs of domestic and imported intermediate inputs in Germany and in the European Union 1995-2011.



Source: Own elaboration based on WIOD.

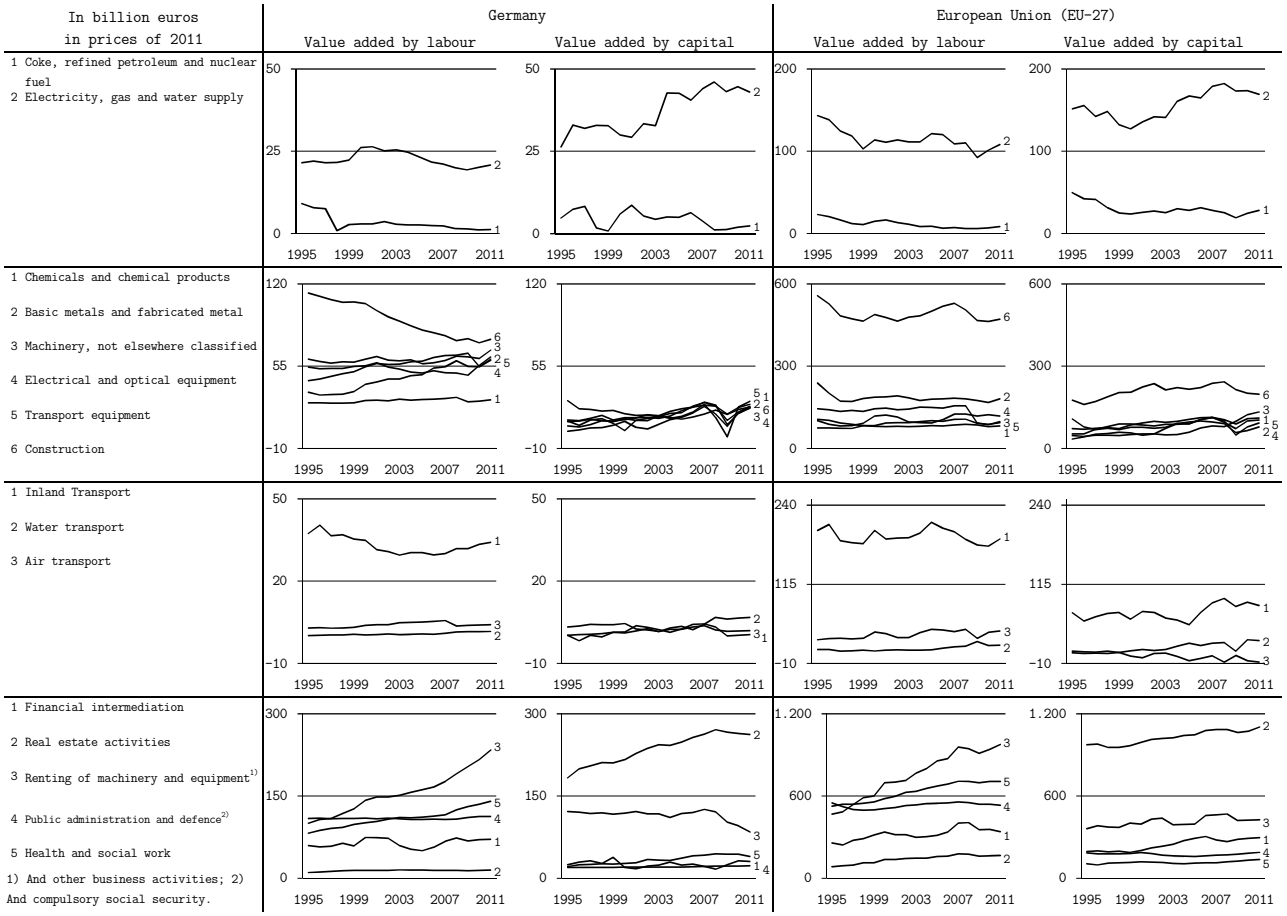
Figure 6: Total real unit energy costs of "coke and refined petroleum products" and "electrical energy, gas, steam and hot water" in Germany and in the European Union 1995-2011.



Notes: Real unit energy costs above 100 % mean that energy costs are larger than corresponding value added.

Source: Own elaboration based on WIOD.

Figure 7: Value added by labour and value added by capital in Germany and in the European Union 1995-2011.



Source: Own elaboration based on WIOD and Eurostat [2016b].