Part I

Energy Costs and Competitiveness

OVERVIEW

This part analyses energy cost competitiveness. The cost of energy has emerged as an important dimension of international competitiveness of European industries, in particular in light of the "shale gas revolution" taking place in the US. Energy matters for the competitiveness of our economies as it affects the production costs of industries and services and the purchasing power of households.

Chapter 1 introduces the concept of Unit Energy Costs (UEC). Similarly to Unit Labour Costs, the UEC indicator measures the energy cost per one unit of value added, in a given sector or in an aggregation thereof. This indicator enables to compare the relative importance of energy inputs – or in other words the sensitivity to energy price shocks - of a given sector over time. The UEC indicator brings together two key components of energy competitiveness: the value of energy inputs and energy intensity.

Chapter 2 analyses the impacts of the development of shale gas, always through the same integrated approach, i.e. observing the parallel evolution of energy intensity and energy prices in the EU and in the US. It discusses how the introduction of shale gas has affected the US and EU energy sectors, the development in the EU-US energy price-gap and in the trade balances for the EU and US in terms of energy trade, of current accounts and trade of goods.

1. UNIT ENERGY COSTS IN EUROPE AND THE WORLD

1.1. INTRODUCTION

Energy is a key input in many production processes. For this reason, its costs represent a competitiveness factor for manufacturing industry, with the intensity of use next to the energy price as the major drivers. However, another equally important factor is the intensity of its use. In order to provide a more comprehensive assessment of the role that energy plays in determining industrial competitiveness, these factors shall be looked at in combination, the same as it is done for other inputs such as capital and labour.

The objective of this chapter is to assess energy cost competitiveness using unit energy cost indicators. Section 1.2 describes the concept and methodology used to build these indicators. Section 1.3 provides an international comparison of unit energy costs in Europe and other parts of the world. Section 1.4 focuses on sectoral developments while section 1.5 assesses Member States unit energy costs development. Conclusions are presented in section 1.6.

1.2. ASSESSING UNIT ENERGY COSTS

1.2.1. Introductory remarks on the role of energy in the production process

Energy is a key aspect of competeviness. This follows from the energy's essential role in the production process of goods and services. Hence, an economic analysis of energy cost competeviness cannot limit itself to energy prices but needs to consider indicators which inform on how energy prices and energy use affect production decisions. Energy costs, energy productivity and energy intensity are such indicators which can be analysed.

The role of energy in production can be empirically analysed by using analytical frameworks firmly based on economic theory. Often, the production function is employed in such analysis, as it expresses in a mathematical form how the output of the production process is related to the production inputs. Two basic assessment methods rely on the production function concept, namely growth accounting and econometric studies on the production function. Decomposition based on the input-output method has a close relation to both methods.

As regards the first method, growth accounting is an empirical method which allows the identification of the sources of growth of output. Under the conventional assumptions of constant returns to scale and production input prices equal to their marginal productivity, it is possible to derive from a further unspecified production function that output growth is a weighted average of the growth of the production inputs with the cost shares of the various inputs as weights plus a remainder term called "multi-factor productivity" generally associated with technical progress. However, growth accounting as a method cannot be used to analyse the causes of changes in energy costs, intensity and productivity.

Growth accounting is more complicated at industry level than at macroeconomic level since intermediate deliveries between industries and also within a given industry serve both as input and output, rendering it more difficult to link the industry "multi-factor productivity" terms to economy-wide measures of productivity (Hulten 2009). For a growth accounting analysis at macro level, production output can be expressed in value added ([2]) since the costs of intermediate inputs cancel out against the gross income of delivering these inputs in the derivation of GDP (which thus equals GDI). At industry level, however, the intermediate deliveries do not cancel out, so one can argue in favour of gross production rather than value added as the appropriate output variable. For instance, O'Mahony and Timmer (2009) present as basis for industry-level growth accounting the so-called KLEMS production function which has gross production as output variable and capital (K), labour (L), energy (E), materials (M) and services (S) as production inputs. The contribution to overall growth by each production and intermediate factor is given by the product of its share in total cost and its growth rate. As observed by Hulten (2009), the weights for the primary

([2]) This chapter uses gross value added at basic prices. The National Accounts define it as the output at basic prices (i.e. the sales revenues of the products without the taxes and subsidies) minus the costs of the products used up in the production process, valued at purchaser prices (i.e. without VAT) production factors, capital and labour, are smaller than is the case for a "value added" production function, since industry gross output is bigger than industry value added. Hulten (2009) also notes that the gross output approach is sensitive to the degree of vertical integration of an industry, as a vertical merger of an industry with some of its suppliers could lead to the statistical elimination of intermediate flows. The same reasoning applies when an industry decides to outsource some energy-intensive parts of the production process either within the same industry or to other industries in the same country or to low-energy cost countries. While Hulten (2009) observes that the gross production approach is tainted by statistical problems regarding intermediate deliveries, he recalls that the choice between value added or gross output should take account of the specification of technical change. Hence, he cautions against the use of value added as industrial output variable since "it implies (improbably) that efficiency-enhancing improvements in technology exclude material and energy" (ibidem, p28).

The second method using the production function concerns direct econometric estimation of the production function (or, relatedly, the cost function) at industry level. This allows for estimating the output, substitution and price elasticity for the different input factors such as energy. The economics literature provides a wide array of studies varying considerably in aggregation level, in the coverage of sectors, countries and time period; and estimation method. Also the standard assumptions of constant returns to scale and competitive pricing (i.e. the absence of mark-ups) can be relaxed (Ecorys & CE, 2011, ch.4) Often the production function used has the shape of a translog function and mostly gross production is the output variable of choice, but value added is occasionally used as well, mostly for data availability and data quality reasons. For example, Krishnapillai and Thompson (2012) estimate for the US a production function for industrial value added, distinguishing capital, labour and electricity as production inputs; the estimated price elasticity suggest that electricity, capital and labour are substitutes.

The analytical framework underlying the input-output-table allows for a rigorous analysis of differences in industrial cost structures either over time or over countries / branches of industry. The point of departure is total gross production at industry level. One can directly relate the change in output to the corresponding changes in the cost shares of the various primary and intermediate inputs (up to the desired level of aggregation), such as for energy as a whole. However, this leaves out the indirect effects underlying the changes of the intermediate inputs. More formal decomposition methods allow for assessing the relative role of changes in input prices and input quantities in the overall change of sectoral costs. Fujikawa et al. (1995) compare the cost structure for industry sectors in Japan and US; they derive from the price version of the input-output model a decomposition of cost differences into a primary input price component, a primary input technology component and an intermediate input technology component, all three of which can be further divided into a direct and indirect component (i.e. following from deliveries from other sectors). The role of energy in relative productivity developments between countries has been studied with such decomposition methods, among others by Jorgenson and Kuroda (1992).

In addition to these elaborated analytical methods, one can also directly compare (unit) energy cost levels and developments over time and /or between countries outside of the input-output framework, hence without any restrictive assumption on the relation between output and the defined inputs. This allows much more freedom in choosing the output indicator, gross production, value added or even other indicators. These statistical decomposition exercises tend not to be reported in the economics literature, unless it involves an innovation in method. Among others, the US Department of Energy (2003) decomposes the index of energy use into the multiplicative relation of an activity index, an index on structure (changes in the composition of the economy or sector at hand) and an index of energy intensity or productivity. This index approach only accounts for changes relative to a base year and not for difference in levels (in the base year). One of the advantages is that one can choose for each of the (sub)-sectors / activities in the sector under study the best output variable possible.

Box I.1.1: Real Unit Energy Cost (RUEC), Nominal Unit Energy cost (NUEC), Energy Prices and Energy Intensity

RUEC is calculated as the ratio of energy costs in current prices (for the four category of energy inputs described in Appendix 1) over value added in current prices. NUEC in turn is defined as the ratio of energy costs in current prices over value added in constant prices (reference year 2005). Keeping both the numerator and the denominator in current prices in the RUEC cancels out the price dimension from the ratio, while keeping the numerator in current and the denominator in constant prices in the NUEC allows to capture the evolution of sectoral price developments. All data used for the analysis are expressed in USD to allow a global comparison.

The RUEC indicator can be decomposed in **two sub-indicators**: the *energy intensity* (the ratio of quantity of energy inputs used in calorific terms per unit of value added in constant prices) and the *average real energy price over different energy sources* (the monetary value paid by manufactures per unit of energy inputs deflated with the sectoral value added deflator). This price should be interpreted as an implicit unit value of 1 calorific unit of energy used relative to the sectoral deflator. As this price is an average unit price over all the different energy sources used by the sector, it is sensitive to the energy mix of the sector. The decomposition of RUEC can be illustrated as following:

$$RUEC = \frac{EC}{VA_{current}} = \frac{EC}{VA_{const} * P_{VA}} = \underbrace{\frac{EC}{Q_E * P_{VA}}}_{\boxed{\text{real energy price}}} * \underbrace{\frac{Q_E}{VA_{const}}}_{\boxed{\text{energy intensity}}}$$

where EC is the monetary value of energy costs in current prices, Q_e is the calorific value of energy inputs, $VA_{current}$ and VA_{const} are the value added in current and constant prices respectively and P_{VA} is the value added deflator.

Finally the relation that links RUEC with NUEC can be expressed as follows:

$$NUEC = \frac{EC}{VA_{const}} * s = \frac{EC}{VA_{current} * \frac{1}{P_{VA}}} * s = \underbrace{\frac{EC}{VA_{current}}}_{\boxed{\text{RUEC}}} * \underbrace{s * P_{VA}}_{\boxed{\text{nominal effect}}}$$

where EC is energy cost and s is the exchange rate.

This shows that the nominal effect is the combination of the nominal exchange rate and the domestic sectoral inflation. This nominal effect may add, compensate or offset the energy-related effects. This means for example that a country experiencing an increase in RUEC may succeed in partially or fully compensating this through currency depreciation or internal deflation. Conversely currency appreciation or domestic inflation may add additional pressure to its energy price developments.

Due to the potential problems with sectoral purchasing power parities (PPP), we use market exchange rates. This calls for caution when interpreting levels of NUEC, energy intensities and energy prices due to the

(Continued on the next page)

Box (continued)

problem of different purchasing power in non-tradable sectors. Therefore NUEC is only presented in changes, but the levels of energy prices and energy intensities are important source of information that we analyse. As the focus is on the manufacturing sector, the issue of PPPs is less problematic due to the lower share of non-tradable inputs. In addition, it is a concern only when comparing countries with significantly different per capita income levels, therefore comparing EU, US and Japan should not represent a major problem. Caution is necessary though when comparing levels of energy prices and intensities of countries with significantly different income levels.

Finally, the NUEC indicator is expressed in US dollars, and its change is compared among countries. An alternative way of presentation would be to compute real exchange rate indices by taking ratios of NUECs of different countries, or real effective exchange rate indices by using a weighted average of countries as the denominator of the ratio.

In this chapter, the approach proposed uses the input-output table as a starting point but it is not based on input-output-analysis. Compared to the range of methods presented above, the decomposition of energy costs proposed here is relatively straightforward. The comparison is between many countries whereas the literature, as reviewed above, tends to focus on a single or only a few countries. Because of the lack of clear guidance from the literature whether to use value added or gross production and for reasons of data availability and quality, the unit energy cost concept used here has followed the convention of using value added as benchmark (Box I.1.1). This seems fairly unproblematic since this decomposition is statistical and not embedded in a theoretical framework. Moreover, such a convention underlines the direct analogy with the study of unit labour costs and its split labour costs per worker and labour productivity. However, the analogy should be handled with care as energy is an intermediate input and not a primary production factor.

1.2.2. Unit Energy Costs: Concept and Methodology

This section introduces the concept of **Unit Energy Costs (UEC).** Similarly to Unit Labour Costs, the UEC indicator measures the energy cost per 1 unit of value added, in a given sector or in an aggregation thereof. This indicator enables to compare the relative importance of energy inputs – or in other words the sensitivity to energy price shocks - of a given sector over time ([3]). The analysis focuses on the manufacturing sector and 14 subsectors of manufacturing as these sectors are characterised by a relatively higher use of energy than others. Services are not analysed due to their low energy intensity([4]).

As Unit Labour Costs combine wages and labour productivity, the UEC indicator brings together two key components of competitiveness: the value of energy inputs and energy intensity, which is the reciprocal of energy productivity. In addition, in order to differentiate between pure energy-related effects and macroeconomic developments such as fluctuations in the exchange rate and inflation differentials, a distinction is made between Real Unit Energy Cost (RUEC) measuring the energy-related effect and Nominal Unit Energy Cost (NUEC) which incorporates both components (See Box I.1.1 for more details). The RUEC can then be decomposed into the real price of energy inputs – deflated with the value added deflator, hence helping to measure energy inflation above the inflation of the given sector – and energy intensity.

To summarize the different factors of NUEC:

NUEC = RUEC * nominal effect = real energy price * energy intensity * nominal effect

While the nominal effect is important from an international competitiveness perspective as businesses make their decisions on the basis of nominal values, the nominal effect of this decomposition is determined by factors that are not related to energy markets such as monetary policy, inflation expectations, financial market and labour market developments and exchange rate evolution. This analysis focuses on the energy-related effects,

([3]) See the description of the data used in Appendix 1.

([4]) Transport services are characterised by high energy intensity, but they are not included in the analysis.

therefore it concentrates on the RUEC while the NUEC is presented only to illustrate how nominal developments complemented the pure energy effect.

The RUEC and NUEC indicators should be interpreted in comparison among different countries. While the level of RUEC indicates the importance of energy inputs and sensitivity to energy price shocks, an increase that is greater than in other countries can signal an increased vulnerability of this sector to energy costs, but it could also reflect a restructuring of production towards more energy intensive production processes. Therefore, it is necessary to analyse the level and evolution of the price of energy inputs and energy intensity as well. Moreover, to address the issue of potential restructuring on changes in the RUEC, a shift share analysis is carried out, which is a common method to disentangle the effects of restructuring from the growth of an aggregate indicator (see below).

1.3. UNIT ENERGY COSTS: AN INTERNATIONAL COMPARISON

This section analyses the developments of energy costs and their drivers for the manufacturing sector in a global comparison.

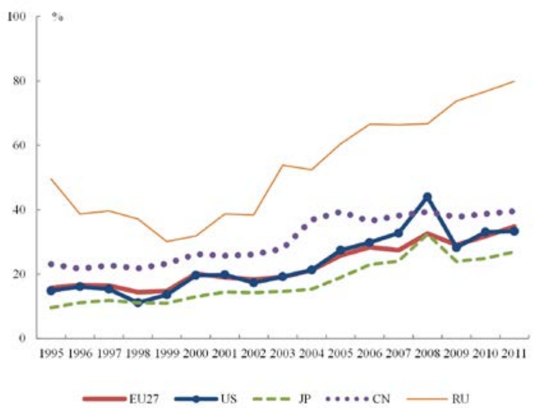
1.3.1. Real Unit Energy Costs

As mentioned above the level of Real Unit Energy Cost measures the amount of money spent on energy sources needed to obtain 1 unit of value added. Their evolution thus combines the energy component of the sector's inflation and the energy intensity of the sector.

Compared to its main economic partners, the EU manufacturing industry had in 2011 the third lowest RUEC in terms of value added after Japan while the US, after the hike of 2008, falls back to the just below the level of the EU in 2011 *(Graph* I.1.1). China, Russia and other major economies such as Brazil and Indonesia show substantially higher values than the EU ([5]).

The evolution and levels of energy costs over value added, and energy costs over gross output in manufacturing are broadly similar across developed countries such as the EU, US and Japan. This prominent feature is to a large extent explained by the industrial specialisation pattern towards high valued added sectors. By contrast, this is not the case for developing countries. A part of this difference can be explained by the fact that countries such as Russia, China or India and Brazil have more energy intensive production structures, specialized in sectors where energy inputs play a comparatively bigger role. Moreover, these production processes are often characterized by lower value added. This is confirmed when looking at the difference between the energy costs as a percentage of value added (RUEC) and as a share of gross output *(Graph* I.1.2). For the EU, Japan and the US, the RUEC are around three times higher than the share of energy costs in gross output. For countries such as China, India and Brazil the RUEC are four to five times higher, implying that the difference between gross output and value added for these countries is greater. The exception is Russia where the difference of RUEC and the share of energy costs in gross output is similar to that of the EU.

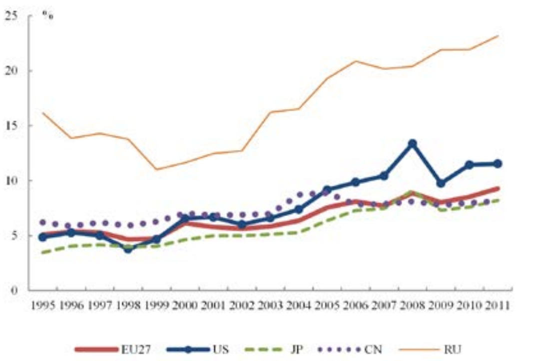
Graph I.1.1: **Real Unit Energy Costs as % of value added, manufacturing sector**



Source: Commission Services based on WIOD database.

([5]) Brazil and Indonesia (and the other world countries) are reported in Appendix 2.

Graph I.1.2: **Real Unit Energy Costs as % of gross output, manufacturing sector**



Source: Commission Services based on WIOD database.

It is interesting to note that, since 2006-2007, real energy costs as a share of gross output in the US increased much more than in the EU and this evolution has been confirmed in 2010-2011. As the levels of RUEC expressed in terms of value added are similar, this may imply that the US are able to extract higher value added from their production than the EU.

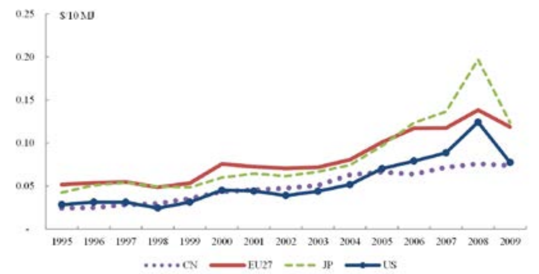
The EU's RUECs have steadily but slowly increased over time, a trend however that is also observed in the other major world economies. This signals the increasing importance of energy cost pressure on the manufacturing sector's value added on a global scale: for all the countries considered the energy costs have, as a matter of fact, increased proportionally more than the value added. If the refinery sector is excluded from the calculation of the RUEC (Appendix 3) the levels decrease substantially (more than halved) and the ranking of the countries changes with the US displaying the lowest level of RUEC, followed by the EU and Japan ([6]). This result indicates the importance of the refining sector in the US and it also highlights the fact that in the other industrial sectors, less dependent on oil, the RUEC level is higher in the EU than in the US. However even excluding the refinery sector, the EU RUEC remains among the lowest in the world.

1.3.2. The drivers of the Real Unit Energy Costs ([7])

The RUEC is decomposed into real energy prices and energy intensity.

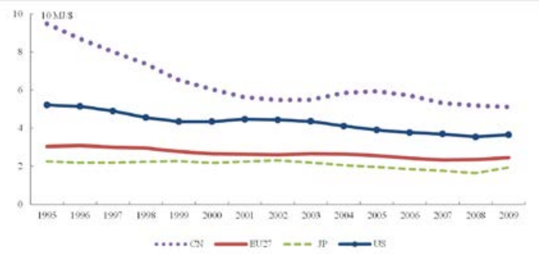
Japan and the EU are the two regions where the real energy prices are the highest in levels. However the evolution of real energy price has been similar for the four countries considered and it appears highly linked to the global oil price's fluctuation. With the oil price hike of 2008 however Japan and the US have registered a more severe increase in real energy prices than the EU and China signalling their greater sensitivity to oil prices.

Graph I.1.3: **Real Energy Price levels - Manufacturing**



Note: Energy prices deflated with value added deflator of the manufacturing sector (in 2005 USD)
Source: Commission Services based on WIOD, ESTAT and World Development Indicators databases.

Graph I.1.4: **Energy Intensity levels - Manufacturing**



Note: including feedstock
Source: Commission Services based on WIOD, ESTAT, OECD and World Development Indicators databases.

At the same time the EU and Japan have the lowest levels of energy intensity while the US

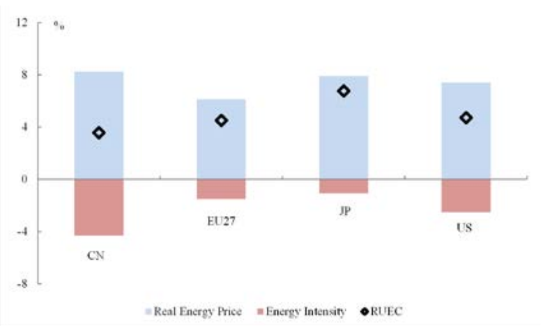
([6]) It is worth to note that excluding refineries from the manufacturing sector reduces the RUECs to levels of around 3-4% in gross output in the EU implying that energy costs play a smaller role in this segment of the economy.

([7]) Due to data limitation the assessment of Energy intensity and Real energy prices stops at 2009. Therefore to allow comparability the growth rates of RUEC have also been computed only up to 2009 (Graph I.1.5).

and China ([8]) **show considerably higher levels**. China and to a limited extent the US have been converging towards the European and Japanese levels. It is to note that graph I.1.4 shows energy intensity including feedstock. The level and trends of energy intensity would change if feedstock were excluded as shown in chapter 2 (graph I.2.10). Considering only final energy consumption, the catching up process of the US seems to have halted after 2009 while the EU performance keeps improving. The difference reveals another potential vulnerability for the EU industry, that is the cost pressure on EU industries stemming from the supply of energy sources to be used as raw material.

Graph I.1.5 summarizes the annualised growth rates of RUEC and of their two drivers.

Graph I.1.5: **Average annual change 1995-2009 - Manufacturing**



Note: Energy Intensity includes feedstock
Due to data limitation the assessment of Energy intensity and Real energy prices stops at 2009. Therefore to allow comparability the growth rates of RUEC have also been computed only up to 2009.
Source: Commission Services based on WIOD, ESTAT, OECD and World Development Indicators databases.

Japan is the country that faced the fastest increase in RUEC during the 15 years considered. A result that was brought about by a large increase in real energy prices compensated only partially by very little improvements in the terms of energy intensity. This indicates that the country suffered from strong energy cost pressure that was not compensated via a reduction of energy intensity.

China on the other hand shows the slowest increase in RUEC despite the fastest increase in real energy prices; substantial energy intensity improvements have counterbalanced the upward pressure of the real energy prices. China started from very high levels of energy intensity and had therefore greater margins to improve.

The EU and US have evolved in a very similar fashion and the increase in RUEC has been almost the same in the two regions. On average the real energy price increase has been slightly faster in the US than in the EU and was compensated by an equally slightly faster improvement in energy intensity performances (bearing in mind that the absolute levels of the two indicators are very different). The EU and the US have followed therefore very similar patterns where the differentials in real energy price levels have been matched by equally distant levels of energy intensity which translated in almost equal levels of RUEC.

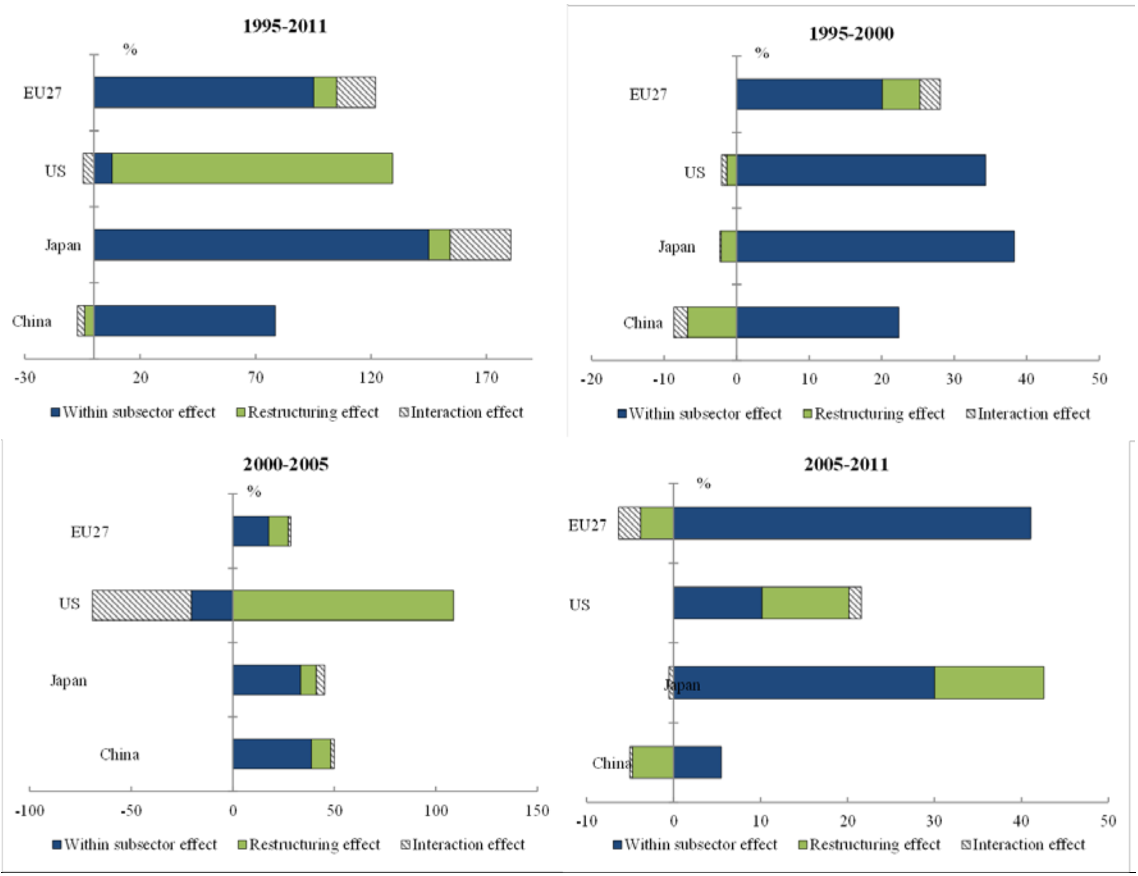
1.3.3. Disentangling the effect of industrial restructuring on the growth of RUEC

It is also interesting to analyse to what extent the developments in energy costs of the manufacturing sector were driven by (1) energy cost pressures apparent in all subsectors and/or (2) a restructuring taking place among subsectors. For instance when facing strong energy cost pressures, the industry may respond by reallocating resources from sectors with high energy costs to others with low energy costs. This would then result in a decline in the market share of high energy cost industries, while those with low energy costs would see a rise in their share.

In order to investigate the effects of these two factors, a shift share analysis is carried out. The RUEC in the total manufacturing industry can be interpreted as the weighted average of the RUECs of the subsectors making up the manufacturing sector with the weights being the shares of subsectors in total manufacturing value added. This way, changes in the RUEC of aggregate manufacturing can be broken down into two distinct effects: a change in the RUECs of subsectors (energy cost effect) and a change in the shares of subsectors in total manufacturing (restructuring effect) along with a dynamic

([8]) The high level of energy intensity in China can be partly explained by the PPP effect which however is not captured by the dataset used.

Graph I.1.6: **Shift share analysis of manufacturing sector RUEC growth**



Source: Commission Services based on WIOD.

interaction component of the two effects ([9]). In particular, the shift-share analysis decomposes the growth of RUEC into the following three components ([10]).

Within subsector effect: This shows what would be the growth of RUEC of the total manufacturing sector if the shares of the subsectors had stayed unchanged throughout the period of analysis. Therefore this effect shows the pure energy cost pressure filtering out the effect of restructuring.

Restructuring effect: This measures the contribution of changes in value added shares of the different subsectors to overall manufacturing RUEC growth keeping the RUECs of subsectors unchanged. This component therefore shows the static restructuring effect. For instance a negative restructuring effect could show that the share of industries with high energy costs has fallen, thereby reducing RUEC growth.

Interaction effect: This term captures the dynamic component of restructuring by measuring the co-movement between RUECs and value added shares. If it is positive, it signals that energy costs are rising in subsectors that are expanding, and/or they are falling in shrinking sectors, i.e. the two effects complement each other. If it is negative, then RUEC growth is positive in shrinking sectors, and/or negative in expanding sectors, i.e. the two effects are offsetting each other. A negative interaction effect could signal that businesses in a country are reallocating resources from high to low energy cost sectors in response to rising energy costs.

([9]) The decomposition of manufacturing is done with 14 subsectors on the basis of the NACE Rev.1 nomenclature. It is possible that there is some restructuring taking place at a lower aggregation level which may not be captured by this analysis.
([10]) See the technical details of the shift-share analysis in Appendix 1.

Table I.1.1: **Average % annual change 1995-2009 - Manufacturing**

	Real Energy Price	Energy Intensity	RUEC	Nominal effect	NUEC
EU27	6.12	-1.50	4.51	1.19	5.71
US	7.42	-2.51	4.72	0.01	4.73
JP	7.92	-1.07	6.76	-2.51	4.25
CN	8.24	-4.3	3.57	3.46	7.03

Note: Energy Intensity includes feedstock.
Due to data limitation the assessment of Energy intensity and Real energy prices stops at 2009. Therefore to allow comparability the growth rates of RUEC have also been computed only up to 2009.
Source: Commission Services based on WIOD, ESTAT, OECD and World Development Indicators databases.

Looking at the shift share analysis of manufacturing sector RUEC growth in the period 1995-2011, the main result is that the bulk of RUEC growth in EU27, Japan and China were driven by the within effect; i.e. energy cost increases within sectors (Graph I.1.6**).** There is no evidence of a significant restructuring effect in the EU during this long period. In contrast, RUEC growth in the US was dominated by the static restructuring effect, i.e. by an increase in the share of high energy cost industries, particularly of the coke and refined petrol industry. Overall these developments may signal an increased specialisation of US manufacturing in high energy cost production with respect to other countries ([11]).

The picture is changed if the shift share analysis is decomposed into three shorter periods. The period 1995-2000 was characterised by a marked increase in RUEC dominated by the within subsector effect in the EU, US and Japan. The period 2000-2005, however, brought significant differences with the US being the only country with a negative within subsector effect. At the same time the US showed a very large positive restructuring effect which was mitigated to some extent by a negative interaction term. Overall this indicates that the US started specialising in high energy cost production already in this period ([12]). Finally, the last period – 2005-2011 – includes the beginning of the development of shale gas in the US as well as the peak in oil prices of 2008 and the subsequent fall in 2009 and has brought a significant adjustment and restructuring on a global scale. While the RUEC of the EU rose only moderately, this was due to a limited restructuring – both static and dynamic – away from high energy cost sectors offsetting a pure energy cost effect which was substantially higher than in the other countries. In the US, RUEC increased visibly less than in the EU over this period. Once again a positive restructuring effect can be observed, and is brought about by the continuous growth of some energy intensive sectors, in particular coke and refined petrol. Japan saw a positive within subsector effect with a positive restructuring effect and its RUEC grew more than in the US and in the EU. Finally, China experienced positive but modest within subsector effect and a similarly modest negative restructuring effect.

The shift share analysis of the manufacturing sector excluding the coke, refined petrol and nuclear fuel sector helps to single out the relevance of this sector in the evolution of the RUEC and of the industrial composition of the countries (Appendix 3). The restructuring effect observed with the full data set essentially disappears once the refinery sector is excluded. This is most evident in the US where in the period 1995-2011 the shift share analysis reported above in Graph I.1.6 displays a very big positive restructuring effect while excluding the refinery sector this effect is no longer present. This points to the increased relevance of this sector in the US economy over the past years which is also confirmed when looking at the growing contribution of the sector to the total industrial

([11]) In order to check the sensitivity of these results to the start and end date of the analysis, we carried out the calculations for the period 1998-2006 as well, which gave similar conclusions.
([12]) This evolution could be explained by a domestic restructuring or investment of foreign companies in the US. The analysis here does not differentiate between these factors.

GVA of the US. Another important observation can be made looking at the period 2005-2011 which includes the shale gas production surge. By excluding the refinery sector highly dependent on oil products, the RUEC growth in the US is actually negative. This is probably due to the substantial reduction in electricity and gas prices which shale gas has made possible. In the EU the difference between the shift share analysis with or without the refinery sector is also significant. For a start the growth of RUEC is greatly diminished, over both the longer period 1995-2011 and the shorter period 2005-2011. This implies that oil price dynamics play a major role in determining the energy costs of the manufacturing sector. The less dependent a sector is from oil products the less it appears to be exposed to real unit energy costs increase. The second observation is that once the refinery sector is excluded from the analysis the small negative restructuring effect observed over the period 2005-2011 disappears, implying that it was mostly related to this sector ([13]).

1.3.4. Nominal Unit Energy Costs

Table I.1.1 presents the decomposition of the different elements of NUEC and can be read from left to right in an (approximately) additive manner. The nominal effect represents the difference between RUEC and NUEC and it measures the combination of sectoral inflation and exchange rate fluctuations.

The table shows that nominal developments have added some pressure to the energy costs of the EU over the period 1995-2009 as compared to the US and Japan as shown by the higher average growth rate of nominal effect for the EU than for the US and Japan. With US dollar being the common currency of comparison, the nominal effect of the US is close to 0 ([14]). On the other hand Japan has gone through a period of internal deflation which resulted in a negative nominal effect partially offsetting the evolution of the RUEC. China experienced the lowest annual change in RUEC complemented by a sizeable increase of the nominal effect and therefore has experienced the fastest increase in NUEC. This means that other sectoral price and exchange rate dynamics have added upward pressure to the pure energy-related effects captured by the RUEC in China.

1.4. UNIT ENERGY COSTS: A SECTORAL COMPARISON

A more disaggregated analysis involving 14 manufacturing subsectors shows that most of these subsectors in the EU have a generally low unit energy costs per value added in an international comparison ([15]).

Certain sectors in the EU show however a significant vulnerability because of their high RUEC levels and/or RUEC growth rates in a global comparison, indicating elevated sensitivity to energy-cost pressures (Table I.1.3 **and Table** I.1.2**)**. Overall the sectoral analysis confirms that the low unit energy costs level for the total manufacturing industry of the EU hides a substantial heterogeneity among subsectors. This highlights the need for more disaggregated sectoral analysis as it is possible that some subsectors of manufacturing show high vulnerability to energy inputs despite the fact that energy costs are very low for total manufacturing. A more detailed split could reveal even more vulnerabilities within sectors. In this sense the top-down approach applied here – from a high to a medium level aggregation – should be interpreted as complementary information to more disaggregated sector-specific analyses.

In the **food, beverages and tobacco** sector the RUEC of the EU were the second highest in 2009. They showed a similar pattern to that of the US, but both of them were performing significantly worse than China and Japan. Energy intensity improvements in the EU have been rather limited but Japan and the US deteriorated their performances. The real energy price increased

([13]) It is important to keep in mind that there may be restructuring taking place at a lower level of aggregation than the available data which cannot be captured by this analysis.

([14]) For the US the nominal effect measures only the sectoral value added inflation, since all figures are expressed in USD. Between 1995 and 2009 the US had a sectoral deflator evolution somewhat U-shaped which after a period of inflation came back down to its initial levels. This explains the annual growth figure being close to 0 in the table.

([15]) As for the total RUEC, data limitation does not enable a full decomposition after 2009. For this reason data for 2011 are presented separately.

faster in the EU than in either Japan or US although in absolute levels the EU is still below Japan. Compared to 2011 the RUEC of the EU have increased while in the US they have decreased, this was however matched in both countries by a small decline in the share of the sector in total manufacturing value added.

The **textile** industry of the EU has performed substantially worse than that of the US and Japan in terms of RUEC and their level is also higher than in China, both in 2009 and in 2011. The energy costs of the Chinese textile industry showed a marked upward trend and reached similar levels to that of the EU at the end of the sample. The increasing trend of China and the stable trend of the US could be a sign of outsourcing although data availability does not allow the assessment of the evolution of energy intensity and real energy prices in the two countries. The good performances in terms of energy intensity in both the EU and Japan have been met by opposite trends in terms of real energy prices which translated into similar annual increases of RUEC.

The developments in the **leather and footwear** sector are in many ways similar to those of the textile industry. The EU, Japan and China have reached similar levels in the second half of the sample period in terms of RUEC. The US reached a considerably lower level by 2009, and again the opposite trends between the US and China raises the possibility of potential outsourcing. As with most other sectors, Russia exhibited by far the highest levels of RUEC throughout the entire period. Both the textile and leather sectors have experienced a sharp decline in the share of manufacturing value added in Japan, Russia and US, while the decline in the EU and China was much less evident during this period. Data from 2011 confirms the trend of the previous period.

In the **wood and wood product** industry the EU has shown the second lowest RUEC following Japan. The pattern of marked improvement in 2009 for the US is not visible in this sector, in fact, RUEC was trending upwards in US over the entire period of analysis, much so than in any other of the five countries. China was slightly above the EU while Russia was fluctuating at a considerably higher level. Unlike for other sectors, the energy intensity performances of the EU and Japan have deteriorated but have been matched by a moderate decrease in real energy prices similarly to Japan. In the US the increase in real energy prices has been much faster than the decrease in energy intensity. In 2011 however the RUEC in the EU, Japan and China continues to increase while the opposite happens in the US.

Table I.1.2: **Sectoral breakdown: decomposition of RUEC and annual growth rates 1995-2009**

	Energy Intensity (10MJ/$)		Real Energy price ($/10MJ)		RUEC (%)		*Share of sector in Manufacturing VA*		RUEC level	Share of sector in manufacturing VA
	level 2009	annual growth rate	level 2009	annual growth rate	level 2009	annual growth rate	*level 1995*	*level 2009*	2011	
Other Non-Metallic Mineral										
EU27	2.04	-0.7%	0.13	3.1%	25.6	2.4%	*4.8%*	*4.4%*	27.2	*4.0%*
US	3.27	1.8%	0.05	1.3%	16.1	3.2%	*2.8%*	*2.3%*	15.2	*2.0%*
JP	2.20	2.0%	0.20	2.9%	43.1	4.9%	*3.7%*	*2.4%*	53.8	
RU					50.6	2.6%	*10.9%*	*5.3%*	49.8	*5.1%*
CN					53.6	3.7%	*10.8%*	*6.8%*	56.8	
Basic Metals and Fabricated Metal										
EU27	1.42	-2.8%	0.12	4.3%	17.3	1.3%	*13.4%*	*13.9%*	18.2	*15.2%*
US	1.55	-1.5%	0.07	3.5%	11.6	2.0%	*12.2%*	*10.0%*	12.9	*9.4%*
JP	2.02	2.5%	0.15	3.5%	30.1	6.1%	*15.7%*	*16.1%*	39.2	
RU					57.2	1.9%	*18.7%*	*15.5%*	55.3	*17.7%*
CN					49.6	3.0%	*14.2%*	*16.0%*	50.1	
Machinery										
EU27	0.17	-2.1%	0.28	2.9%	4.7	0.7%	*10.8%*	*11.9%*	4.7	*12.8%*
US	0.39	0.4%	0.07	-1.1%	2.8	-0.7%	*8.1%*	*7.3%*	2.2	*8.2%*
JP	0.14	-2.3%	0.30	4.6%	4.2	2.1%	*9.5%*	*8.6%*	4.4	
RU					37.4	2.1%	*7.6%*	*7.7%*	36.8	*7.3%*
CN					15.0	3.8%	*9.6%*	*9.6%*	15.4	
Electrical and Optical Equipment										
EU27	0.12	-5.2%	0.37	6.9%	4.6	1.3%	*11.3%*	*10.9%*	4.6	*10.8%*
US	0.08	-19.8%	0.19	16.5%	1.5	-6.6%	*13.7%*	*17.1%*	0.8	*19.2%*
JP	0.13	-9.5%	0.56	14.9%	7.0	4.0%	*15.9%*	*13.4%*	7.1	
RU					20.6	2.0%	*6.5%*	*5.3%*	21.1	*5.5%*
CN					8.1	3.2%	*9.3%*	*14.3%*	8.4	
Transport Equipment										
EU27	0.20	-1.5%	0.32	2.7%	6.4	1.2%	*9.6%*	*10.2%*	6.3	*11.0%*
US	0.33	-1.1%	0.11	3.6%	3.5	2.5%	*12.1%*	*10.1%*	3.9	*7.1%*
JP	0.09	-5.2%	0.69	8.3%	6.5	2.7%	*9.8%*	*11.9%*	6.9	
RU					18.1	1.9%	*9.2%*	*5.7%*	20.6	*5.9%*
CN					7.9	1.0%	*5.2%*	*6.7%*	8.2	
Manufacturing, Nec; Recycling										
EU27	0.32	1.6%	0.26	1.1%	8.0	2.7%	*3.9%*	*4.2%*	8.4	*3.8%*
US	0.13	-6.9%	0.21	6.7%	2.7	-0.7%	*3.8%*	*3.7%*	1.5	*4.0%*
JP	0.61	1.2%	0.21	4.7%	12.9	5.9%	*1.8%*	*0.9%*	14.3	
RU					26.8	3.6%	*2.2%*	*2.1%*	31.5	*1.8%*
CN					4.8	-1.8%	*1.6%*	*2.0%*	5.0	
Total Manufacturing										
EU27	2.45	-1.5%	0.12	6.1%	29.1	4.5%			34.8	
US	3.65	-2.5%	0.08	7.4%	28.3	4.7%			33.3	
JP	1.94	-1.1%	0.12	7.9%	23.9	6.8%			26.9	
RU					73.7	2.9%			79.9	
CN	5.11	-6.6%	0.07	8.2%	37.7	3.6%			39.6	

Note: Energy Intensity includes feedstock.
Due to data limitation the assessment of Energy intensity and Real energy prices stops at 2009. Therefore to allow comparability the growth rates of RUEC have also been computed only up to 2009.
Source: Commission Services based on WIOD, ESTAT, OECD and World Development Indicators databases.

In the **pulp, paper and printing** sector the EU has been performing in line with the US with Japan also reaching similar RUEC levels at the end of our sample. China and particularly Russia showed higher levels of RUEC. The almost stable performances in terms of energy intensity in the EU means that the increase in real energy prices has been therefore almost symmetrically translated into higher energy costs for EU industries although the trends in the US and Japan are broadly comparable. As for the other sectors, data for 2011 show an increase in RUEC for EU, Japan and China while the opposite is true in the US and to a lesser extent Russia.

The production of **coke, refined petrol and nuclear fuel** is the sector that shows the worst performance in the EU with RUEC several times above the levels of US, Japan, China and Russia. RUEC in this sector showed a steep upward trend

Table I.1.3: **Sectoral breakdown: decomposition of RUEC and annual growth rates 1995-2009**

	Energy Intensity (10MJ/$)		Real Energy price ($/10MJ)		RUEC (%)		*Share of sector in Manufacturing VA*		RUEC level	Share of sector in manufacturing VA
	level 2009	annual growth rate	level 2009	annual growth rate	level 2009	annual growth rate	*level 1995*	*level 2009*	2011	
Food, Beverages and Tobacco										
EU27	0.56	-0.8%	0.22	3.2%	12.1	2.3%	*12.1%*	*13.0%*	12.8	*12.0%*
US	0.77	1.2%	0.14	1.9%	10.5	3.1%	*10.9%*	*12.9%*	8.0	*12.0%*
JP	0.21	0.2%	0.28	2.8%	5.9	3.0%	*13.4%*	*16.6%*	6.4	
RU					16.2	0.4%	*17.9%*	*18.0%*	19.4	*13.6%*
CN					5.6	1.0%	*12.9%*	*11.6%*	6.3	
Textiles and Textile Products										
EU27	0.40	-2.5%	0.29	5.1%	11.5	2.5%	*5.1%*	*3.4%*	11.9	*3.0%*
US					6.0	0.9%	*4.1%*	*1.6%*	5.9	*1.4%*
JP	0.27	-1.5%	0.30	4.1%	8.3	2.5%	*3.7%*	*1.7%*	8.8	
RU					15.8	-2.8%	*3.2%*	*1.6%*	18.1	*1.5%*
CN					9.9	5.2%	*11.1%*	*8.2%*	10.8	
Leather and Footwear										
EU27					5.3	0.2%	*1.0%*	*0.8%*	5.6	*0.8%*
US					1.3	-8.2%	*0.2%*	*0.1%*	1.6	*0.1%*
JP	0.21	-1.2%	0.28	3.7%	5.9	2.4%	*0.3%*	*0.1%*	6.3	
RU					16.5	-1.1%	*0.4%*	*0.3%*	17.7	*0.3%*
CN					5.2	6.1%	*2.2%*	*1.7%*	5.9	
Wood and Products of Wood and Cork										
EU27	1.12	2.8%	0.10	0.0%	11.6	2.8%	*2.3%*	*2.1%*	12.4	*2.0%*
US	2.10	-2.1%	0.07	7.9%	14.8	5.6%	*2.1%*	*1.3%*	9.4	*1.3%*
JP	0.78	3.3%	0.10	-0.8%	7.7	2.4%	*2.6%*	*1.4%*	8.3	
RU					29.5	1.7%	*3.3%*	*2.0%*	27.0	*2.1%*
CN					13.1	1.4%	*2.3%*	*2.4%*	13.7	
Pulp, Paper , Printing and Publishing										
EU27	0.98	0.6%	0.11	1.6%	11.0	2.2%	*9.2%*	*8.2%*	11.4	*7.6%*
US	1.52	-0.7%	0.06	3.1%	9.0	2.3%	*11.6%*	*10.3%*	8.5	*9.5%*
JP	0.74	-0.1%	0.14	1.6%	10.1	1.6%	*6.3%*	*6.4%*	10.9	
RU					30.3	2.6%	*4.7%*	*4.1%*	29.8	*4.1%*
CN					14.0	0.6%	*4.2%*	*3.5%*	14.7	
Coke, Refined Petroleum and Nuclear Fuel										
EU27					1033.4	7.2%	*1.6%*	*1.6%*	1051.9	*2.0%*
US	31.01	-5.4%	0.09	5.9%	275.2	0.2%	*3.0%*	*7.3%*	264.1	*9.9%*
JP	18.29	1.3%	0.07	7.1%	129.4	8.6%	*4.5%*	*7.3%*	138.7	
RU					199.4	-4.7%	*5.1%*	*22.7%*	201.5	*24.8%*
CN					398.1	3.7%	*3.1%*	*2.8%*	412.5	
Chemicals and Chemical Products										
EU27	2.96	-3.0%	0.11	6.9%	33.2	3.7%	*10.3%*	*10.9%*	36.2	*10.7%*
US	4.38	-0.7%	0.05	2.6%	22.1	1.9%	*11.1%*	*12.6%*	23.1	*12.2%*
JP	3.53	-0.6%	0.13	6.8%	44.1	6.2%	*8.4%*	*9.2%*	47.3	
RU					74.0	-0.5%	*8.5%*	*7.3%*	77.9	*8.1%*
CN					84.9	6.5%	*9.5%*	*10.2%*	92.6	
Rubber and Plastics										
EU27	0.47	0.5%	0.29	3.0%	13.4	3.5%	*4.5%*	*4.5%*	14.1	*4.4%*
US	0.26	-5.7%	0.38	7.1%	10.0	1.0%	*4.2%*	*3.4%*	6.8	*3.7%*
JP	0.16	-5.5%	0.81	9.2%	13.3	3.2%	*4.3%*	*3.9%*	13.7	
RU					36.6	1.7%	*2.0%*	*2.2%*	42.1	*2.2%*
CN					17.0	3.0%	*4.2%*	*4.0%*	17.9	

Note: Energy Intensity includes feedstock.
Due to data limitation the assessment of Energy intensity and Real energy prices stops at 2009. Therefore to allow comparability the growth rates of RUEC have also been computed only up to 2009.
Source: Commission Services based on WIOD, ESTAT, OECD and World Development Indicators.

in the period 1995-2009 in the EU unlike in any other country analysed here which indicates an increasing vulnerability. Looking at energy costs as a share of output – not reported here – would show a somewhat better relative performance of the EU suggesting that this sector is suffering not only from high energy costs but also from low and drastically worsening value added in a global comparison. The oil-price shock of 2008 had a significant upward effect on the RUEC of all the five countries, the EU however further increased its RUEC in 2009 while in the other four countries a reduction took place, bringing the levels back to pre-2008. However, the share of the sector in manufacturing valued added for the EU was and remained very small. At the same time the sharp increase of the share in Russia and the US need to be recorded as it signals the growing importance of coke and refinery activities in these two countries. Data for 2011 show that while in the EU the RUEC have further increased, an inverse trend is observed in the US where the sector reached almost 10% of total manufacturing value added.

In the **chemicals and chemical products** sector the EU has shown the lowest RUEC together with the US in the period of analysis ([16]). The low levels of energy costs of the EU and US significantly outperformed the other countries and also present the lowest growth rates. In 2011 RUEC increased in both regions. Russia and China showed the highest levels of RUEC throughout most of the period of analysis. A marked improvement is visible in Russian RUEC in the years of the Russian financial crisis (1998-99). This pattern is visible for many other sectors as well, but the improvement was only temporary and RUEC returned to pre-crisis levels in the following years. For the EU the fast increase in real energy prices which outpaced that of the US and to a lesser extent that of Japan, was counterbalanced by significant improvements in energy intensity which both in levels and progress way outperform the two competitors.

In the **rubber and plastics sector**, during the period 1995-2009, the EU has performed relatively well together with the US and Japan, while China and especially Russia exhibited much higher levels of RUEC. However the EU registers in 2009 higher RUEC than Japan and US and has the highest growth rate since 1995 mostly driven by the deterioration of its energy intensity. Looking at the components of RUEC it is to note that the EU had in 2009 the highest levels of energy intensity (compared to Japan and US) and unlike the other two countries did not record any improvement. The EU compensated partially with a lower real energy price than both Japan and US and with lower growth rates. In 2011 the RUEC in the EU and Japan continued to increase while in the US they significantly reduced, at the same time the contribution of the sector to the manufacturing value added remained broadly unchanged.

In the **non-metallic mineral sector and the metals sector** the EU showed a much lower level of RUEC than Japan, China and Russia. The EU, however, was performing worse than the US and the gap in favour of the US has increased also in 2011. RUEC growth rates in the EU have been anyway the lowest among the five countries, mostly driven by energy intensity good performances. Energy intensity in the EU was in 2009 the lowest and it has experienced the most significant improvements while for Japan it actually deteriorated. At the same time, while the level of real energy prices is comparable in 2009 the EU experienced faster growth rates than both Japan and the US.

In the sector of **machinery** the RUEC of EU, Japan and US have had comparable very low levels in the entire period. The US is the country with the lowest level of RUEC and the only one for which the growth rate is negative. This positive evolution has been mostly driven by a decrease in real energy prices while energy intensity slightly deteriorated. US RUEC further decreased in 2011 while in the EU they remained stable. This happened in a context of increase in share of the sector in total manufacturing value added, in both regions. China has shown a moderately increasing trend and reached a level that is substantially higher than that of the other three economies. Russia in turn exhibited the highest RUEC in this sector but lower growth rates than China and also Japan. Energy intensity in the EU decreased rapidly but on the other side real energy prices increased at almost the same pace. In the US conversely energy intensity did not improve but real energy prices decreased by an average of only 1% per year.

In the **electrical and optical equipment** sector the EU, US, Japan and China started from similar levels of RUEC but have shown a remarkable divergence in the period of analysis. This concerns primarily the US and China, where the opposing trend again suggest the possibility of outsourcing of energy-intensive processes from the US to China. The EU exhibited a relatively constant RUEC which put it at the second lowest level after the US in 2009. Japan showed a mild increase over the period, while Russia fluctuated again at a substantially higher level. The dramatic collapse in energy intensity matched by an almost equally fast increase in real energy price in the US tends to confirm the assumption that the country may have experienced a substantial relocation of energy intensive activities. However the simultaneous increase in the share of the sector in the manufacturing value added signals that the US industry focused on innovation and higher valued added activities. Japan also presents similar features. This trend is confirmed also by looking at 2011, where the share of the sector in the

([16]) This sector includes basic chemicals as well as cosmetics and pharmaceuticals.

manufacturing value added further increased while RUEC decreased. The EU also recorded remarkable improvements in energy intensity although compensated by a significant increase in real energy prices.

In the sectors of **recycling and transport equipment** the EU has shown a significantly higher RUEC than the US and also of Japan, a gap that has further widened in 2011. In transport equipment the performance of the EU was more or less in line with that of Japan. China was fluctuating at a higher level and Russia at an even higher level in the transport equipment sector. However the collapse of energy intensity registered in Japan in the transport equipment sector could be the consequence of a drastic industrial restructuring and outsourcing of the most energy intensive activities in favour of lower energy intensive production with comparatively greater value added. EU RUEC in 2011 decreased slightly while an increase was registered in the other countries. On the other hand in recycling the EU has worsened its energy intensity performances while recording only a moderate increase in real energy price. The US shows the opposite picture, rapidly falling energy intensity matched by an increase in real energy prices which resulted in small decrease of RUEC over the 15 years considered.

In sum, the sectors that are most exposed to energy price shocks in terms of high RUEC levels in the EU are coke and refined petrol, chemicals, non-metallic mineral, metals, rubber and plastics. Coke and refined petrol stands out with much higher RUEC levels than in other countries and a growth rate that is also among the highest ones. This indicates significant vulnerability of this sector, though its share in total manufacturing value added of the EU has been low and stable. In contrast, US, Japan and Russia have seen a significant increase in this share. In the other four sectors with high energy cost vulnerability (chemicals, non-metallic mineral, metals, rubber and plastics) the EU shows RUEC levels that are generally comparable with those of Japan. The EU levels are, however, noticeably higher than the US in chemicals, non-metallic mineral, and metals. Nonetheless in all four sectors the figures of the EU remain substantially lower than those of China and Russia. In terms of the growth rates of RUECs, the four sectors in the EU perform generally in line with other countries with some variability observable.

Data for 2011 show that for all sectors the RUEC have generally increased in all countries, except in the US where the picture is more mixed and most sectors actually recorded a decrease. Although EU RUEC are above the US for all sectors in 2011, they are similar for total manufacturing due to the different composition of the manufacturing value added in the two regions. It is nonetheless interesting to note that two of the four sectors in the EU where the contribution to the manufacturing value added has increased are among the most energy intensive sectors such as: coke and refined petroleum products; basic metals and fabricated metals.

1.5. EU MEMBER STATES ASSESSMENT

The evolution of RUEC for EU Member States ([17]) between 2000 ([18]) and 2009 is in general characterised by an upward trend. With the exception of a handful of countries most Member States saw their RUEC increase on average by 47%. The biggest increases in percentage terms were recorded in Ireland (89%) followed by Malta (70%), Sweden, France and Belgium (around 60%). The upward trend is broadly confirmed with the data for 2011([19]) with the exception of Ireland and Germany where RUEC have been reduced. Looking at the evolution between 2000 and 2011 the Member States with the greatest percentage increase were France (144%) Belgium (124%) and Finland (111%). On the other hand Cyprus, Slovakia, Romania and the Czech Republic recorded a decrease in RUEC.

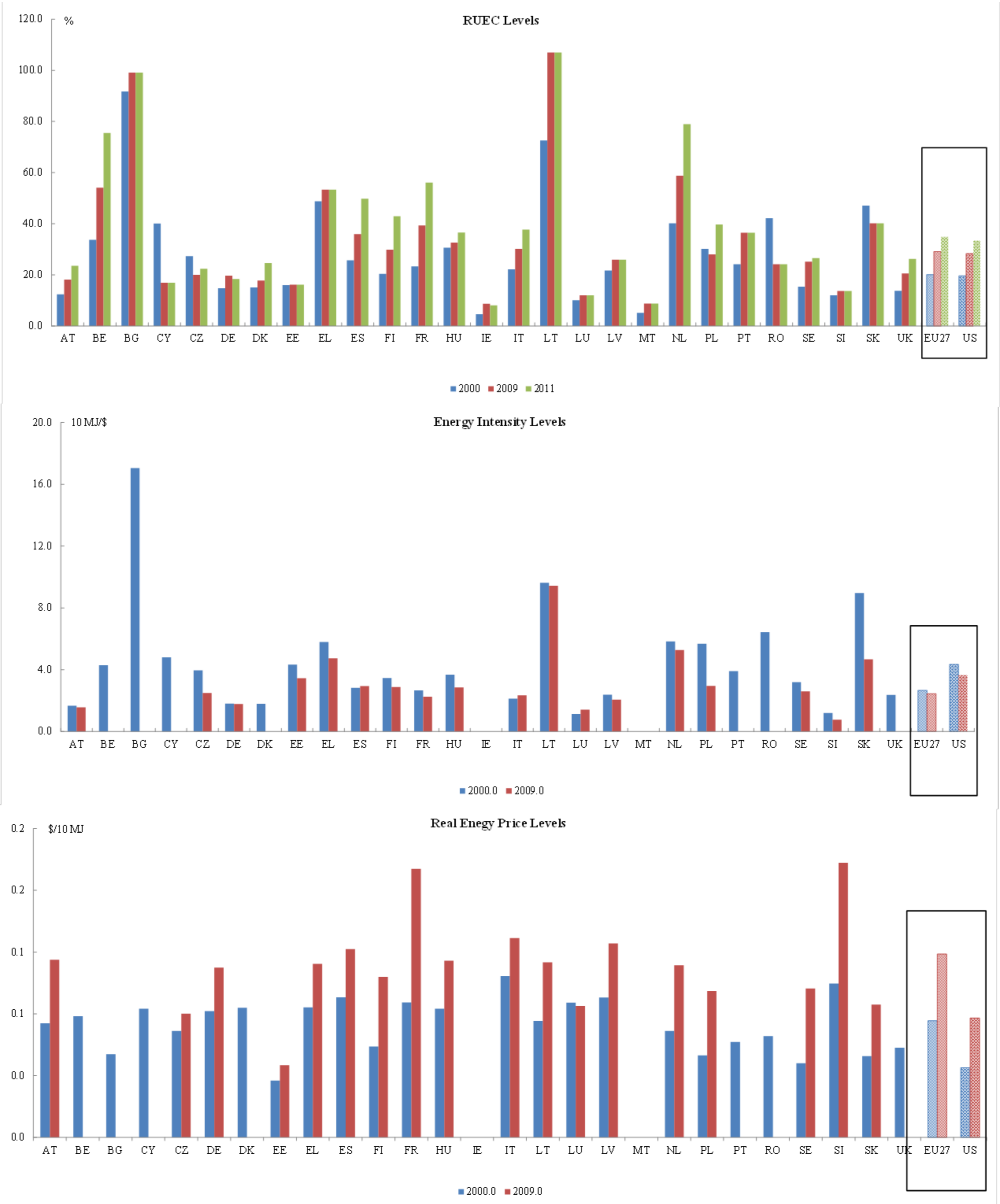
The heterogeneity in levels is rather wide. For some Member States the RUECs are sensibly lower than the EU average while others on the

([17]) There are two preliminary observations, first these data are aggregated to include all the manufacturing sectors hence the indicator can be affected by outliers; second, the occurrence in 2008 of a significant price increase for crude oil may have had more severe impacts on those countries with production activities more dependent on oil such as the refinery industry.
([18]) Due to data limitation, the analysis at Member States level starts with 2000 and not 1995.
([19]) As for the other sections, data limitations for real energy prices and energy intensity are not available after 2009.

contrary display levels that are significantly higher, not only than the average but also than the levels of their main international competitors (Graph I.1.7). In absolute terms Ireland and Malta, together with Luxembourg, Slovenia and Austria, display the lowest levels of RUEC in 2000, 2009 and 2011. The highest levels were reached by Bulgaria which however recorded a percentage increase well below the EU average (7.9%, between 2000 and 2011) and Lithuania, followed by the Netherland, Greece, Belgium and France.

The evolution of energy costs at Member States level is analysed in combination with the trends of energy intensity and real energy prices presented in Graph I.1.7.

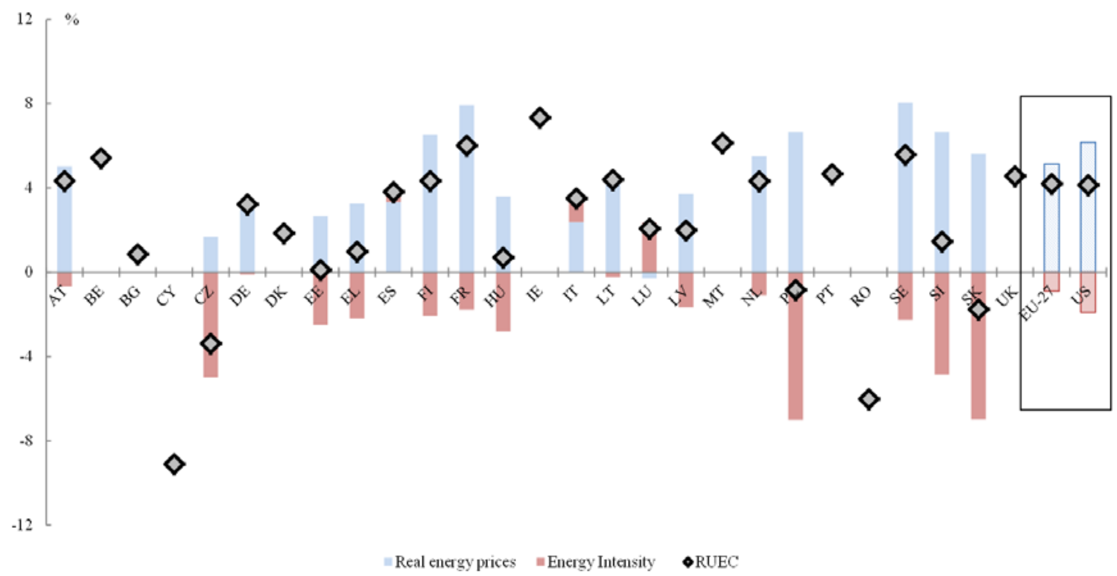
Graph I.1.7: **Decomposition of Real Unit Energy Costs - Manufacturing**



Note: Energy Intensity includes feedstock.
Due to data limitation the assessment of Energy intensity and Real energy prices stops at 2009. Therefore to allow comparability the growth rates of RUEC have also been computed only up to 2009.
Source: Commission Services based on WIOD, ESTAT and OECD.

The Member States with the highest levels of energy intensity in 2009 were Lithuania, the Netherlands and Slovakia. However, it is to note

Graph I.1.8: **Annual Growth Rates 2000-2009 - Manufacturing**



Note: Energy Intensity includes feedstock.
Due to data limitation the assessment of Energy intensity and Real energy prices stops at 2009. Therefore to allow comparability the growth rates of RUEC have also been computed only up to 2009.
Source: Commission Services based on WIOD, ESTAT and OECD.

that Bulgaria had until 2006 the highest level of energy intensity, but lack of data for 2009 does not enable a full comparison ([20]). The lowest levels of energy intensity are found in Slovenia, Luxembourg and to a lesser degree Latvia, Austria, Germany and Italy. At the same time real energy prices were the highest in France, Slovenia and Italy, while Estonia, the Czech Republic and Slovakia enjoy the lowest real energy prices, sometimes even below the US levels.

By looking at the growth rates, some new Member States (Czech Republic, Poland, Slovakia and Slovenia) stand out in terms of energy intensity improvements and, for the Czech Republic also for the low rates of real energy prices growth. These factors contributed to determine a negative growth of RUEC for these countries; except for Slovenia where the upward pressure of real energy prices determined a minor increase in RUEC. In some Member States (Italy, Spain and Luxembourg), despite worsening performances in terms of energy intensity, a moderate increase (a decrease in the case of Luxembourg) in real energy prices resulted in RUEC growth rates below the EU average and also the US. By contrast, some Member States such as France, Sweden and Finland report fast growing real energy prices, well above the EU average, which were not offset by sufficient improvements in energy intensity, hence a growth rate in RUEC well above the average of the EU and the US.

As said, an increase in Real Unit Energy Costs means that the amount of money spent on energy sources to obtain one unit of value added has increased and this negatively weights on the margins of the sector. The growth rates of NUEC presented in Table I.1.4 show to what extent other macroeconomic dynamics, such as sectoral price inflation and exchange rate fluctuations, have either exacerbated or alleviated the growth of RUEC.

Spain had the fastest growing NUEC in the EU followed closely by a group of other Member States which present all similar features, i.e. an high increase of the nominal effect well above the EU average (with the notable exception of France where the NUEC growth is more linked to

([20]) Note that energy intensity in this framework includes feedstock, which is a particularly important factor for the coke and refinery sector and to a lesser extent the chemicals sector. Moreover, energy intensity levels may be influenced by the PPP effect which is not captured by the present dataset.

the energy costs components). Conversely the lowest increases in NUEC have been in Poland, the Czech Republic and Slovakia. However only in the case of Poland this result can be ascribed mostly to the very low growth of the nominal effect. In Czech Republic and Slovakia the improvement in their performances must therefore be found in the energy components, notably in remarkable reductions of energy intensity.

Table I.1.4: **Average % annual change 2000-2009 - Manufacturing**

	Real Energy Price	Energy intensity	RUEC	Nominal Effect	NUEC
AT	5.0%	-0.7%	4.3%	4.9%	9.2%
BE			5.4%		
BG			0.9%		
CY			-9.1%		
CZ	1.7%	-5.0%	-3.4%	6.9%	3.5%
DE	3.3%	-0.1%	3.2%	5.2%	8.5%
DK			1.9%		
EE	2.7%	-2.5%	0.1%	7.5%	7.6%
EL	3.3%	-2.2%	1.0%	8.5%	9.5%
ES	3.3%	0.5%	3.8%	7.9%	11.7%
FI	6.5%	-2.1%	4.3%	1.2%	5.5%
FR	7.9%	-1.8%	6.0%	4.2%	10.2%
HU	3.6%	-2.8%	0.7%	7.8%	8.5%
IE			7.3%		
IT	2.4%	1.1%	3.5%	7.2%	10.7%
LT	4.6%	-0.2%	4.4%	6.4%	10.8%
LU	-0.3%	2.4%	2.1%	8.7%	10.8%
LV	3.7%	-1.7%	2.0%	8.7%	10.6%
MT			6.1%		
NL	5.5%	-1.1%	4.3%	5.9%	10.2%
PL	6.6%	-7.0%	-0.8%	3.3%	2.5%
PT			4.7%		
RO			-6.0%		
SE	8.0%	-2.3%	5.6%	0.6%	6.2%
SI	6.6%	-4.9%	1.5%	5.0%	6.5%
SK	5.6%	-7.0%	-1.8%	5.6%	3.9%
UK			4.6%		
EU27	5.1%	-0.9%	4.2%	4.9%	9.1%

Note: Energy Intensity includes feedstock.
Due to data limitation the assessment of Energy intensity and Real energy prices stops at 2009. Therefore to allow comparability the growth rates of RUEC have also been computed only up to 2009.
Source: Commission Services based on WIOD and ESTAT databases.

1.6. CONCLUSIONS

The results shown above indicate that the EU manufacturing sector has enjoyed some of the lowest Real Unit Energy Costs together with Japan and similarly to the US. This means that to obtain 1 USD of valued added they have spent a lower amount of money on energy sources than Russia or China. In addition, the evolution of RUEC plotted in Graph I.1.1 shows that the EU have suffered relatively less than other countries the oil price shock of 2008 which has on the other hand affected severely both Japan and the US. This impact is also clearly shown in Graph I.1.3 where real energy prices are presented. This may be the outcome of the energy mix composition of the US industry compared to that of the EU, since the US industry is more reliant on oil products than EU manufacturers ([21]).

The trend of the EU RUEC could also be determined by an industrial structure based on higher value added production. The relatively higher real energy prices may have induced EU manufacturers – together with Japan and US – to specialize in higher value added product categories with lower energy intensity while conversely the industry in countries such as China, Russia, India, Brazil lead by competitive energy prices may have opted for more energy intensive production activities with a comparatively lower value added.

The RUEC levels for the entire manufacturing sector in 2011 signal a continuation of the upward trend for all the countries. It is to note however that the EU overtakes the US, by a very thin margin, and China further converges towards the US, Japan and the EU.

The improvements of the EU industry in terms of energy intensity have helped to offset the increase in real energy prices. Despite the already low starting point the EU manufacturers have steadily improved their energy intensity

([21]) See in Appendix 3, Graph I.A3.7 and Graph I.A3.8.

performances converging towards the Japanese levels. The US and China have been catching up but the difference in absolute levels remain substantial.

The sectors that are most exposed to energy price shocks in terms of high RUEC levels in the EU are coke and refined petrol, chemicals, non-metallic mineral, metals, rubber and plastics. Coke and refined petrol stands out with much higher RUEC levels than in other countries and a growth rate that is also among the highest ones. This indicates significant vulnerability of this sector, though its share in total manufacturing value added of the EU has been low and stable. In contrast, US, Japan and Russia have seen a significant increase in this share. In the other four sectors with high energy cost vulnerability (chemicals, non-metallic mineral, metals, rubber and plastics) the EU shows RUEC levels that are generally comparable with those of Japan. The EU levels are, however, noticeably higher than the US in chemicals, non-metallic mineral, and metals. Nonetheless in all four sectors the figures of the EU remain substantially lower than those of China and Russia. The growth rates of RUECs of the EU in the four sectors are generally in line with other countries with some variability observable.

In 2011 data confirm that for all sectors, EU RUEC are higher than in the US. While this points to additional cost pressure on EU firms it is however to be noted that some typically energy-intensive sectors (coke and refined petroleum and basic metal products) have incremented their shares in the manufacturing value added of the EU.

The situation of Member States, is heterogeneous. On the one hand countries such as Bulgaria, Lithuania and the Netherlands have the highest levels of RUEC therefore their production structure is more sensitive to energy cost pressure and any increase in energy prices not matched by improvements of energy intensity may severely affect the margins of their manufacturing sectors. On the other hand countries like Italy and Luxembourg have experienced a worsening of their energy intensity performance which was however met by moderately increasing real energy prices. The growth of their RUEC has been therefore modest and their absolute levels remain low. More vulnerable in this sense appears France where the very fast growth in real energy prices was not sufficiently counterweighted by significant improvements in energy intensity. The growth rate of RUEC in France is well above the average although its level is still relatively low. Finally for some countries, especially Spain, the nominal effect led to a fast increase in NUEC. These dynamics are outside the scope of the present study but have nonetheless added cost-pressure on the Spanish manufacturing sector exacerbating the energy cost component.

2. THE RECENT DEVELOPMENT OF US SHALE GAS AND ITS IMPACT ON EU COMPETITIVENESS

2.1. INTRODUCTION

The previous chapter on Unit Energy Costs presented an empirical analysis based on the WIOD Database which provides data only until the year 2009 for some of the indicators (namely energy intensity and real energy prices) and for 2011 for the Real Unit Energy Costs.

The period after 2009 has however been marked by important events, some energy-related and some not. The development of US shale gas belongs to first category. It has changed substantially the energy system of the US and by consequence it has widely impacted on the global energy markets. The extent of these changes and their implication for the EU are the subject of this chapter. The economic and financial crisis that spread after 2008 is instead part of the second category of events, not energy-related. The economic recession that has affected the EU economic economy has however made more urgent the need to look at energy prices for consumers and industry, in a context of lacklustre domestic demand and loss of competitiveness.

The surge of the US shale gas ([22]) and the corresponding fall in energy prices for US manufacturers has reignited the debate on the EU's industrial competitiveness and has led to calls for policy changes aimed at reducing the energy costs for EU firms, either through reducing the stringency of energy and carbon policies or through stepping up EU gas production including shale gas ([23]).

This chapter will endeavour to assess impacts of the development of shale gas through a step-by-step comparison between the EU and US, using data from Eurostat, OECD and the US Energy Information Administration. Section 2.2 discusses how the introduction of shale gas has affected the US energy sector. The impacts are assessed through an EU-US comparison on the energy mix and on the energy import dependence. Section 2.3 addresses the development in the EU-US energy price-gap. The disparity in energy intensity and some reflections on the impacts on the production structure in the EU and US are presented in Section 2.4. Finally the developments in the trade balances for the EU and US will be discussed in section 2.5. The chapter is concluded by some preliminary remarks and open questions for future discussions.

2.2. THE IMPACTS OF THE SURGE IN US SHALE GAS ON THE US ENERGY SECTOR AND EU AND US ENERGY MIX

Many observers have noted the strong surge in US gas production and consumption because of what has been coined the "shale gas revolution." As depicted in Graph I.2.1, shale gas was already produced in the US in modest amounts at the turn of the century, but it became significant after the middle of the last decade.

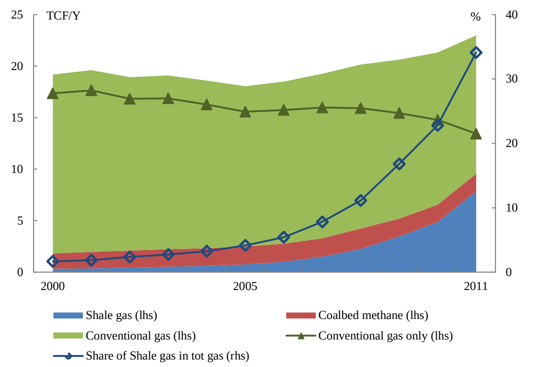
The exponential growth in production volume started to profoundly affect the make-up of the US natural gas supply from 2007/2008 onwards. By 2011, the US has become the biggest gas producer in the world, ahead of Russia, while shale gas constitutes now over one third of the natural production in the US (while only about 5% in 2005).

The current impact of shale gas on the overall make-up of the US energy sector has been significant but it should not be overstated, both as regards the net impact on the domestic gas sector and as regard the changes in the energy mix. Shale gas has revived the domestic natural gas sector whose production had stagnated earlier in the decade, and since a few years shale gas is also replacing domestic supply of conventional natural gas.

([22]) Shale gas refers to natural gas that is trapped within shale formations. Shales are fine-grained sedimentary rocks that can be rich sources of petroleum and natural gas. Over the past decade, the combination of horizontal drilling and hydraulic fracturing has allowed access to large volumes of shale gas that were previously uneconomical to produce.

([23]) PISM (2011) and Artus P (2013).

Graph I.2.1: **Natural gas production in the US and share of shale gas on total gas production**

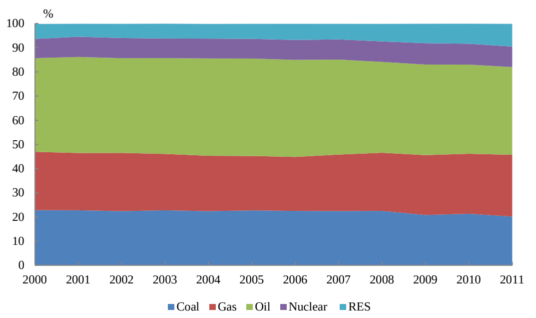


Source: Commission Services based on Energy Information Administration, US.

Over the period 2000 – 2011 natural gas production has increased by almost 20% and since the historic low in production in 2005 it has increased by almost 27%.

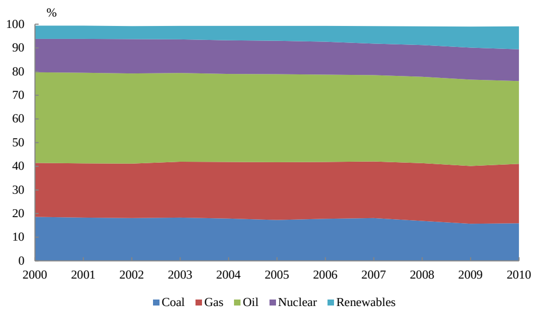
However, the share of natural gas in the US energy mix has only increased by 2 percentage points between 2000 and 2011, while it increased from 18% to 25% in the electricity mix (Appendix 4, Graph I.A4.3).

Graph I.2.2: **Energy mix US**



Note: Expressed as share per source in Primary Energy Consumption
Source: Energy Information Administration.

Graph I.2.3: **Energy mix, EU**



Note: Expressed as share of source in Gross Inland Consumption
Source: Eurostat.

The resurgence of gas as primary energy source in the US should be seen against the background of changes in the US consumption and production of the other primary energy sources. Graph I.2.2 on the US energy mix in the period 2000 – 2011 shows a similar increase in importance of renewable energy sources: its consumption share has risen from 6% in 2008 up to a share of 9% in 2011. On the other hand, a relative decline of oil and coal as primary energy sources is observed with their shares falling over the decade from 39% to 36% for oil and from 23% to 20% for coal.

These changes in shares reflect changes in domestic production levels: renewable energy generation has increased by 49% in the past ten years and natural gas, as already mentioned above, by 20%. Coal production has fluctuated but in 2011 it had decreased by 2% compared to 2000. In 2011 natural gas has for the first time overtaken coal as first source of energy produced in the US. Oil production after a period of slow and steady decline, culminated in 2008 has picked up again but in 2011 it was still 3% less than in 2000 (Appendix 4, Graph I.A4.1).

Together with renewables, US shale gas has undoubtedly contributed to significantly reducing the energy dependence of the United States and hence to decreasing their exposure to global commodity prices fluctuation and geopolitical risks.

As depicted in Graph I.2.4, the US energy import dependency has reached 18% in 2011, the lowest point since 2000.

Box I.2.1: **Potentials and Uncertainties for Shale Gas Exploration in the EU and in the US**

Various sources ([1]) ([2]) reported that the proved natural gas reserves of the world were in 2011around 190/200 trillion of cubic meters (tcm). However the estimation of potential natural gas reserves is an uncertain exercise.

The US had about 9 tcm of proved gas reserves in 2011 2.7 tcm of which concerns shale gas. According to the US-based, independent "Potential Gas Committee" (PGC) assessment in 2012, the total reservoir of potentially recoverable natural gas in the United States amounted to around 67 tcm, ([3]) 48% of which should be shale gas (30,5 tcm). One year earlier, the US Energy Information Administration (EIA) estimated total recoverable gas reserves in the US and the shale gas potential as about 72 tcm and 24.4 tcm respectively ([4]). A little less than half of this recoverable amount (11 tcm) should be found in what appears to be the largest US shale gas field, the Marcellus basin.

However, a recent study by the US Geological Survey has radically lowered these potential reservoir estimates: on the basis of more recent drilling and production data, they estimate the Marcellus basin potential to be only 2.3 tcm ([5]), which is about 80% less than previously reported by EIA. The EIA's Annual Energy Outlook 2012 reflects these newer insights as they have cut their reported estimate ([6]) of the "total unproved technically recoverable reserves" of US shale gas from 2011 to 2012 by almost half (around 13,6 tcm).

Finally, in the most recent update of its assessment in June 2013, the EIA has further revised the potential unproved shale gas reserves in the world: in the US, slightly upward to 16.1 tcm; in the EU slightly downward to 13.3 tcm from 15.8 in 2011 ([7]) (Graph 1).

Some noted energy experts have expressed more pessimistic views as they not only expect recoverable reserves to be significantly smaller than predicted but also shale gas wells to be depleted at a much faster rate (33% a year) than conventional gas wells (20% a year), ([8]) indicating yet another source of uncertainty underlying the reservoir estimates ([9]).

In this context of uncertainty, the estimates for shale gas potentials in the EU appear equally diverging although also fewer in number. According to some sources, recoverable shale gas in the EU could range between 2.3 tcm and 17 tcm ([10]) against the background of which the EIA estimates for the EU, presented in Graph 1, appear rather optimistic. The EIA estimate for shale gas of 13.3 tcm for the whole EU should be seen against the background of total proved natural gas reserves in 2011 of about 4 tcm in the EU.

Graph 1's confrontation of the EU and US shale gas reservoir estimates leads to the following general observations. First, despite the wide range of estimates, Europe's shale gas reserves appear to be significantly smaller than the US ones. In addition, they are also more dispersed: while between one third and half of the potential US reserves are located in one huge basin (namely Marcellus) and some other US basin appear quite large as well (Haynesville, 10% of total, around 2 tcm), the EU estimated reserves are scattered across several countries, with France and Poland having the largest reserves. The dispersion over many smaller fields suggests lower economies of scale in their exploitation, compared to the US.

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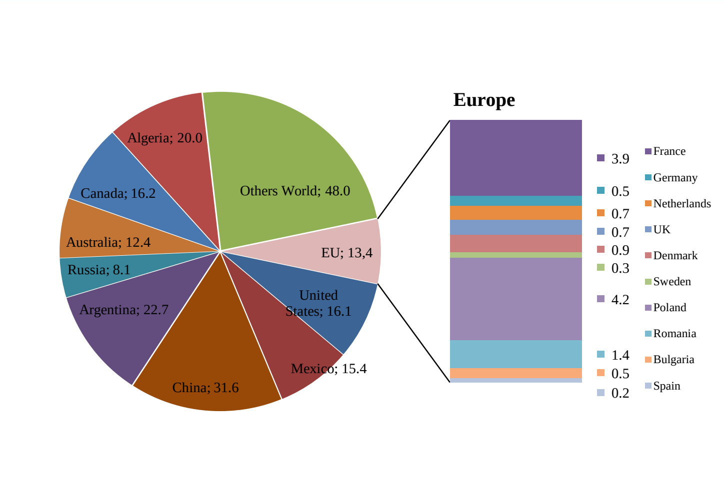
(1) Energy Information Administration, Proved Reserves of Natural Gas, http://www.eia.gov/dnav/ng/ng_enr_sum_a_EPG0_R11_BCF_a.htm
(2) BP Statistical Review of World Energy June 2012
(3) http://potentialgas.org/press-release (MAGNITUDE OF U.S. NATURAL GAS RESOURCE BASE, Press Release, 2012)
(4) EIA (2011).
(5) http://www.usgs.gov/newsroom/article.asp?ID=3419
(6) EIA (2012), Table 14 on p57.
(7) EIA (2013)
(8) A prominent example is Arthur Bernam, http://petroleumtruthreport.blogspot.be/, blog entry of the 16th February 2013.
(9) European Commission (2012c), p 24.
(10) European Commission (2012c), p 29.

(Continued on the next page)

Box (continued)

Graph 1: **Unproved technically recoverable shale gas resource**



Unproved shale gas Technically Recoverable Reserves		
Tcm	2011	2013
Total EU	18.1	13.3
Of which		
France	5.1	3.9
Germany	0.2	0.5
Netherlands	0.5	0.7
Norway	2.4	0
UK	0.6	0.7
Denmark	0.7	0.9
Sweden	1.2	0.3
Poland	5.3	4.2
Bulgaria	/	0.5
Spain	/	0.2
Romania	/	1.4
Total US	24.4	16.1
Of which		
Marcellus	11.0	/
Total World	187.5	203.9

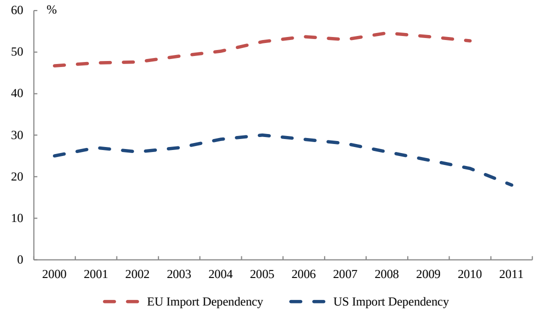
Source: Energy Information Administration

The second and more controversial observation relates to the actual extraction costs of shale gas. As mentioned in section 2.3, the prices for gas in the US have substantially fallen since the onset of the surge. Some expert assessments consider the current gas price level and production levels as incompatible, expecting prices to rise and production to fall in the medium term. This is because the current wholesale price appears too low for many shale gas fields (on-going and envisaged) to be profitably extracted (11) (12). However, these predictions have so far not materialised: shale gas supply and gas consumption have soared while prices have remained at low levels, notwithstanding a mild upward correction since early 2012 (13).

The learning curve of shale gas extraction may be one major cause of the sustained low prices: technological progress may help to keep on enlarging the part of the reserves that can be commercially exploited and reducing the production costs (14). The US EIA also provides another explanation: currently US shale gas is often jointly recovered with oil and liquid gas (NGL) reserves, the prices of which are closely related to the crude oil price (15). Since the oil price per MBtu is markedly higher than the various gas prices (Graph I.2.5), producers have been able to compensate for the lower margins made on shale gas sales. It is questionable whether the EU shale gas producers would be able to enjoy such a joint-production bonus, because oil drilling is rather marginal in Europe and therefore shale gas extraction is not likely to be associated with it.

Whether the low price levels will persist or not is subject of debate in the US and it is the reason of the request from some industrial sectors not to allow the export of shale gas in order to prevent domestic gas price increases. Due to the recent start-up of shale gas exploration, the information on EU shale gas reservoirs is rather scant and quite uncertain but seems to suggest that prospective shale gas producers in the EU cannot attain similar production volumes and production costs as their US counterparts. In addition, potentially significant imports of US shale gas into Europe at relatively low prices may discourage commercial exploitation of the more marginal EU shale gas fields.

Graph I.2.4: **Energy Import Dependency**



Source: Commission Services based on Energy Information Administration and Eurostat.

However, the fall in energy import dependency started around 2005 and hence somewhat *before* shale gas production levels became significant. This can be explained by the expansion of renewables and by the start of the increase in overall gas production.

In sharp contrast to the US, the EU's import dependency has increased from 46% to 52% between 2000 and 2010 ([24]). This reflects the combination of a decline in domestic energy production and an increase in energy consumption, even when taking account for the abrupt contraction of economic activities in 2008.

The production decline over the decade concerns all primary energy sources except renewables. EU gas and oil production have fallen by a quarter and 40% respectively. However coal, because of its sheer volume (still larger than for all other energy sources combined), has been the major driver of the overall decline with a production fall over 10%. In contrast, renewables increased their output in caloric terms by 72%.

Since the EU energy mix has similar make-up and trends as the one of the US (with a higher share of nuclear power as the major difference), the rise in consumption has been met by increasing imports. Natural gas provides an apt illustration: the increase of consumption share by 2 percentage points over the decade has prompted an import increase of more than 45%, whereas the US has satisfied the increased demand mainly from domestic sources (gas imports in monetary terms decreased by 56%, compared to their peak in 2005).

([24]) European Commission (2013b)

There is another recent phenomenon triggered by the development of shale gas and observed mainly between 2011 and 2012: the US have decreased their consumption of coal, exporting their excessive production and reducing their imports. This has driven coal prices down. As gas has became relatively more expensive and coal relatively cheaper in Europe a substitution is taking place: gas consumption declined by 7% while coal consumption increased by about 20% between the first half of 2011 and the first half of 2012. Notably imports of coal from the US increased substantially especially in some Member States: looking at the first half of 2012, Germany, Italy and the Netherlands respectively imported 37%, 83% and 86% more hard coal from the US than in the first half of 2011 ([25]). This shift raises evident climate change concerns as currently carbon prices are too low to offset the comparative advantage of coal over natural gas.

2.3. ELECTRICITY AND GAS PRICES: A US-EU COMPARISON

In the developed world, gas is increasingly seen as an attractive substitute for oil as it is a relatively clean source of energy and also because it has become relatively cheap (Graph I.2.5). For the purposes of this analysis, however, it is not enough to look at the gas spot market price, for a number of reasons.

First, unlike oil, there exists no global wholesale market and no global reference price for natural gas. In the European Union the majority of natural gas is supplied through bilateral long-term contracts which are negotiated between two parties, importer and exporter, and traditionally indexed to the price of oil. Currently, half of natural gas supply in the EU is still indexed to oil while across the EU a wide variation in import prices of piped gas and LNG has been observed ([26]). This is remarkable as at the same time a growing share of gas is traded on spot-markets ([27]) where short-term contracts are concluded on the basis of the market price determined by actual demand and supply. Spot

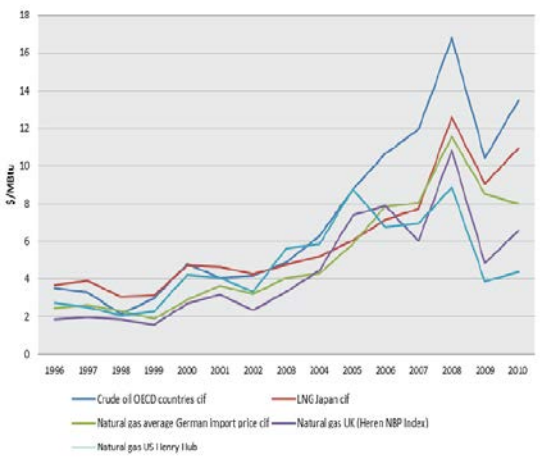
([25]) European Commission (2012b) (ii).
([26]) European Commission (2012b) (iii).
([27]) European Commission (2012c) and (2012d which reports on p182 that one quarter of continental European gas is spot traded).

market prices in the EU have been constantly lower than long-term contracts' prices, at least since 2005 ([28]).

In addition, gas can be used directly for heating or other purposes but can also be used as a primary energy source for electricity generation: in both regions, the share of gas in the electricity mix is currently around 25% and it has increased with a similar pace over the past ten years. Consequently, the wider impact of shale gas on energy prices can be illustrated by looking at the electricity prices.

In both the US and in the EU, spot-market gas prices have progressed in a similar fashion over the past decade and have followed the movements in the oil price, as depicted in Graph I.2.5. In 2005, however, these gas prices have started to clearly fall below the level of the oil price. Between 2008 and 2009 they fell significantly in both regions, likely as a consequence of declining demand due to the economic downturn.

Graph I.2.5: **Wholesale natural gas prices in Germany, Japan, UK and US compared with crude oil price**



Source: European Commission (2012).

The fall in energy consumption has led to an excess supply of gas on the gas markets around the world and both US and the UK spot markets temporarily converged, trading at around 4/5 USD/MBtu in mid-2009, while the German hub prices fell less evidently, trading still above 8 USD/MBtu in 2009. From 2007 onwards, the US gas spot price has fallen under the price level of the other gas spot markets, which most likely reflects the effect of the surge in domestic shale gas supply. This becomes quite clear after 2009, when energy consumption picked up again following the recovery of the economy.

Statistics from more recent years show that while the US spot prices remained low (around 4 USD/Btu in 2011), the EU spot prices (both in the UK and German hub) kept increasing([29]). Wholesale gas prices have continued to rise in the EU while economic activity contracted and consequently natural gas consumption in the EU has been declining: the first half of 2012 represented the EU's lowest first half year consumption of the last ten years. It was 7% and 14% less than the first half of 2011 and 2010 respectively ([30]).

The continued rise in EU wholesale gas prices despite the slump in gas demand and the lower gas spot prices vividly depicts the kind of vulnerability the EU is exposed to due to its high import dependency: as the Asian markets offer higher returns ([31]) and more robust demand, gas producing countries have increased their trade with Asia lowering supply to Europe. As a consequence wholesale gas prices in Europe have increased while in the US, which now can rely more heavily on domestic production, prices have remained low. US prices were shielded from potential upwards pressure from export demand because of export restrictions (generally expected to be gradually lifted). Furthermore, the impacts on

([28]) European Commission (2012b) (i).

([29]) On average in Q2 2013 wholesale consumers on the UK's NBP – traditionally the lowest priced hub in the EU, which however in March 2013 experienced a price spike - paid more than double the price paid by consumers on Henry Hub in the US. The gap between Henry Hub in the US and German border prices was even larger, with German border prices almost three times higher than Henry Hub prices over the first four months of 2013. European Commission (2013a).

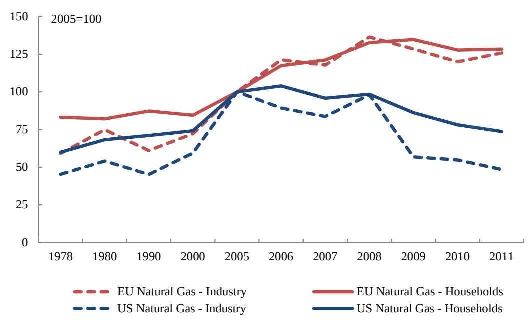
([30]) European Commission (2012) (ii).

([31]) European Commission (2012b) (ii). Average LNG price in Europe in 2012 was between $9 or $10/MMBtu, in Japan it was $17/MMBtun, in Korea $16.6/MMBtu. The price differences suggest that, in vivid contrast to oil, the world is divided in various regional gas markets. Some commentators have hinted at the possibility that the price differences may be reduced in the next decade due to an increase in gas consumption; the abandonment of the practice to base long-term gas contracts on the international oil price; and the world-wide surge in gas exploration and exploitation, including but not exclusively shale gas.

the EU have been further aggravated in this context due to the oil-price indexation of many long-term gas import contracts.

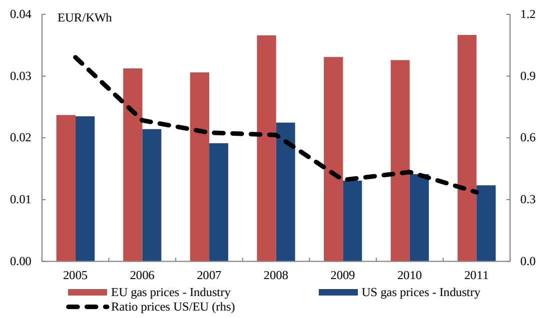
The evolution of end-user's prices ([32]) for gas (Graph I.2.6 and I.2.7) follows a pattern similar to that of the wholesale market.

Graph I.2.6: **Indices of real gas prices for end-users**



Note: "Real" price indices are the current price indices divided by the country specific producer price index for industrial prices, and by the consumer price index for the household sector.
Source: OECD - Electricity Information (2012).

Graph I.2.7: **End-user gas prices for industry**



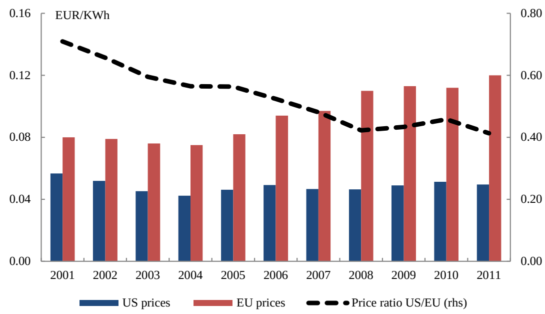
Note: For the US prices it was not possible to identify a specific consumption band. The EU prices are for the consumption band I3 (I3.1 and I3.2 until 2006) that is between 10,000 and 100,000 GJ.
Prices are nominal and the exchange rate used is from OECD. Taxes are included.
Source: Energy Information administration and Eurostat data.

A significant gap between the EU and the US starts appearing in 2006, prior to the development of shale gas but coinciding with the divergence observed between the oil price and the natural gas prices on the wholesale markets in the various regions in the world.

While the EU gas end user prices seem to stick closer to the oil prices and increased from 0.022 EUR/KWh in 2005 to 0.035 EUR/KWh, the US gas prices declined from about the same starting point of the EU in 2005 to 0.010 EUR/KWh in 2011.

On the other hand, the impacts of the fall in the gas price on electricity end user prices is much less evident yet it can still be observed. As shown in Graph I.2.8, electricity prices in the US have historically been much lower than in the EU.

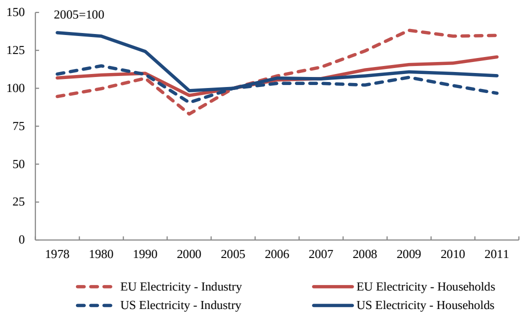
Graph I.2.8: **End-user electricity prices for industry**



Note: For the EU prices refer to average of consumption bands Ie If Ig until 2007, after 2007 consumption band ID. Prices are nominal and the exchange rate used is from the OECD. For the US no consumption band was available. 2011 provisional data. Taxes are included.
Source: Eurostat and Energy Information Administration.

([32]) Comparing end-user prices is complicated as there are differences in statistical conventions between the two regions as well as different taxation regimes. Nonetheless both the OECD data and the Eurostat data provide a similar picture (Appendix 4, Graph I.A4.6).

Graph I.2.9: **Indices of real electricity prices for end-users (2005=100)**



Note: "Real" price indices are the current price indices divide by the country specific producer price index for industrial prices, and by the consumer price index for the household sector.
Source: OECD - Electricity Information (2012).

The gap has been persistent at least since 2001 (Graph I.2.8). Also in this case, the price difference predates the development of shale gas.

The price differential has however been widening in the past few years as the European prices increased over the period (although not in a linear manner) while the US prices remained more or less constant.

The development of US shale gas is likely to be at the root of this widening gap mainly because its increased energy independence and export restrictions in the US has to some extent sheltered them from fluctuations on the global energy markets; in addition it has reduced the supply costs of gas for electricity generation. At the same time the EU energy dependence has increased and this has led to a higher exposure of the EU to energy prices volatility.

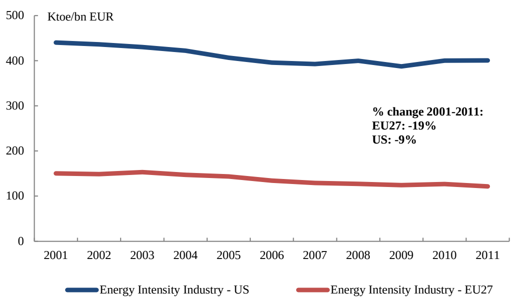
Finally it is to note that shale gas prices in the US do not fully reflect external costs as the current regulatory regime exempts shale gas projects from a number of pieces of federal environmental legislation, including the provisions of the US Safe Drinking Water Act.

2.4. ENERGY INTENSITY (33): A US-EU COMPARISON

Over the past years, the European industrial sector has been able to successfully decouple its performance in terms of value added from its energy consumption. The remarkable wide energy price gap between EU and US should be considered next to the equally remarkable energy intensity gap between the two regions.

The EU industry's energy intensity has been substantially lower than its US counterpart. In addition it has improved by almost 19% between 2001 and 2011 while in the US the improvement over the same period was only 9%.

Graph I.2.10: **Energy intensity of industry**



Note: Final energy consumption industry divided by gross value added in 2005 reference year, ktoe in billion of euros.
Source: Eurostat, Energy Information Administration, Bureau of Economic Analysis USA.

It appears that the increase in the European energy prices is likely to have provided manufacturing industry with the incentive to improve their energy intensity in order to limit the cost of their production inputs. Conversely, the relatively cheaper energy supply in the US did not provide similar incentives.

The development of shale gas has exacerbated this difference as it has further lowered electricity and

(33) It is to note that for the calculation of energy intensity in this section data taken from Eurostat and Energy information administration of the US have been used. Unlike in section 1, energy consumption does not take into consideration feedstock (ie. energy sources used as raw material). In addition the definition of Industry is broader than the 14 Manufacturing sectors included in the analysis of section 1 and it includes also agriculture, construction and electricity and gas supply. Differences in levels and evolution with respect to what observed in section 1 can therefore be explained by these statistical differences.

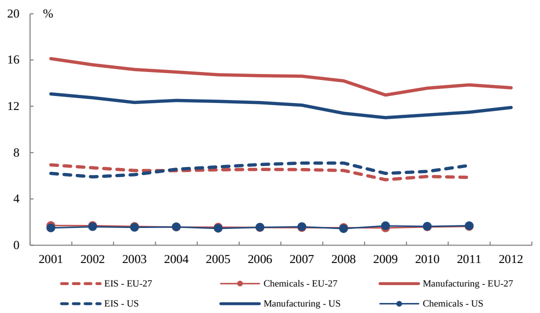
gas prices. This seems to have halted the gradual improvement in the energy intensity of the US industry: after 2006 energy intensity performances remained constant and actually started to slowly deteriorate in the last two years considered.

There appear no significant divergences in the production structure between the two regions which can explain the marked difference in energy intensity performance between EU and US industry. First, the general picture of the EU-US energy intensity divergence also emerges when looking at various branches within manufacturing industry (Graph I.2.12).

Second, in terms of contribution to GDP, the European manufacturing sector is still larger than its US counterpart, although the difference seems to have become smaller during the decade.

A similar convergence can be observed in the energy intensive industry sector, whose GDP share has become smaller in the EU than in the US but the difference in size seems to slightly widen only in 2011.

Graph I.2.11: **Share of some Energy Intensive Sectors (EIS) and share of Manufacturing in GDP - 2001-2012**



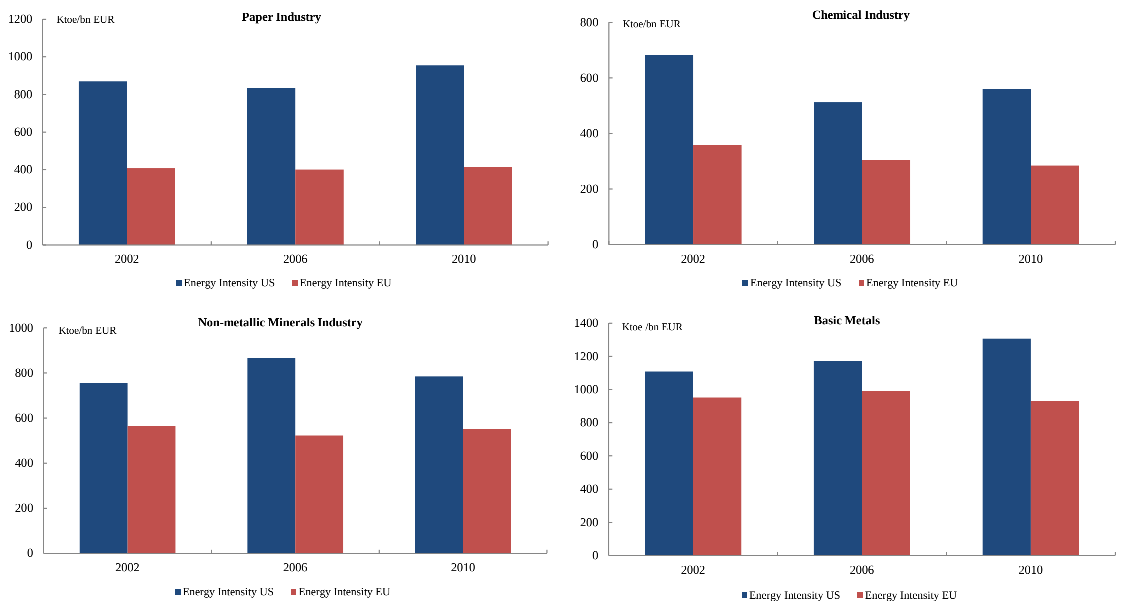
Note: For the EU-27 energy intensive sectors include Fabricated metal products, Basic metal, Other non-metallic mineral products, Chemicals and chemical products, Coke and refined petroleum products, Paper and paper products, Mining and quarrying.
For the USA, energy intensive sectors include Mining, Non-metallic mineral products, Paper products, Petroleum and coal products, Chemical products, Primary metals, Fabricated metal products.
Source: Own calculations on Eurostat and US Bureau of Economic Analysis.

The better performance of the EU's manufacturing industry in terms of energy intensity has therefore happened in the context of comparable overall production structures. Nonetheless, a certain process of restructuring away from energy intensive sectors is observed in the EU from 2005 (see the shift-shares analysis carried out in chapter 1). Graph I.2.11 corroborates this insight as it shows that it is around 2005 that the share of energy intensive sectors in the US exceeds that of the EU. However as shown in chapter 1 and Appendix 3 this is largely driven by the increased importance of the refinery sector in the US economy.

This suggests that while European business as a whole has been able to compensate for the higher energy prices through improvements in energy intensity and possibly also through other non-energy-related efficiency gains - facilitating the substitution of energy with other production factors ([34]) - the energy intensive sectors have been relatively more strongly affected. Yet the restructuring started already before the development of shale gas and might therefore accelerate as the energy price gap widens. .

([34]) The extent and nature of this adaptation would require more in-depth empirical research.

Graph I.2.12: **Energy intensity of industry, selected sectors**



Note: Final energy consumption in Ktoe per billion EUR, reference year 2005.
Paper Industry for the EU includes Paper and paper products and Printing and reproduction of recorded media. For the US: Paper; Printing and Related support
Chemical Industry for the EU includes Chemicals and chemical products and Basic pharmaceutical products and pharmaceutical preparations. For the US: Chemicals, Pharmaceuticals and Medicines.
Non-metallic minerals for the EU includes Other non-metallic mineral products. For the US: Non-metallic Mineral Products.
Basic Metals for the EU includes Basic metals. For the US: Primary Metals.
Source: Eurostat, Energy Information Administration and US Bureau of Economic Analysis.

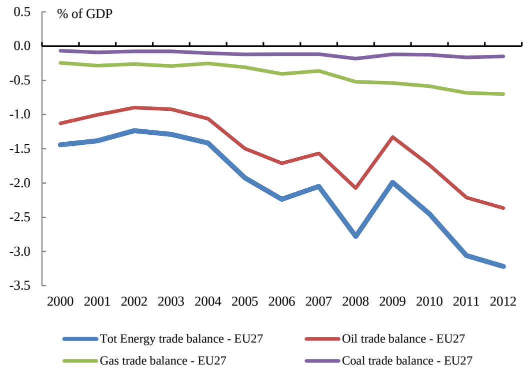
2.5. TRADE

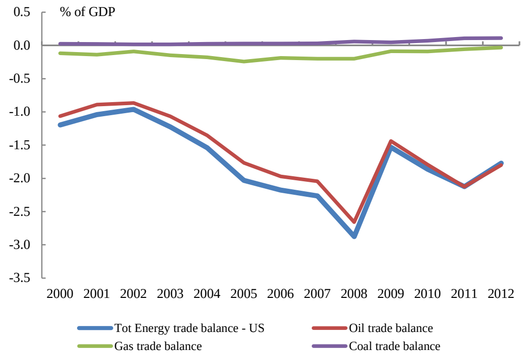
2.5.1. Energy trade

The most evident effect on trade of the US shale gas development has been the sizeable reduction of the US energy trade deficit over the past few years. While for the first eight years of the decade the energy trade deficits of EU and US deteriorated in very similar fashion, after 2008 they developed quite differently.

The US energy trade deficit improved much more in 2009 than the EU counterpart, while in later years it has deteriorated much less pronouncedly, also in part because of its higher share of oil in its energy imports that experienced larger volatility than the other energy carriers. This has resulted in a wider gap in GDP terms between the US and EU energy trade deficit.

Graph I.2.13: **Energy trade balances as % of GDP, total and per energy source - 2001-2011, EU-27 and US**





Source: Commission Services on Eurostat and US Bureau of Economic Analysis.

The drive to self-sufficiency in domestic gas consumption and the related increase in coal exports which took place after 2008 help to explain this trend. In contrast, the EU became more dependent on gas and coal. Graph I.2.13 illustrates these divergent developments.

While the US gas trade has tended to move closer to balance, the EU's gas trade deficit has actually increased. This trend has its origins well before 2008 but the gap in GDP terms has widened considerably after 2008. The difference is likely to become bigger when the US starts to export shale gas; this tendency could be countered if the EU could rely more on domestically produced gas ([35]).

The significantly larger trade surplus for coal in GDP terms from 2008 onwards reflects the US excess coal supply. As a consequence, the relative price of coal vis-à-vis that of other primary energy sources has fallen, triggering a process of partial substitution in the European energy mix.

Finally, with the current near balance in both coal and gas trade, the US energy trade balance appears now basically driven by the developments in the oil trade balance. The US oil trade deficit has also been significantly reduced compared to its 2008 levels, indicating, next to a fall in oil prices from a peak level, a shift in US energy use away from oil towards gas (and renewables). In contrast, the EU energy trade balance is driven by the trends in all three main tradable primary energy sources (oil, gas and coal) and for each of them the deficit has worsened over the past ten years considered, although more for oil and gas than for coal. The increase in import dependency may expose the EU as a whole more to supply disruptions and geopolitical risks, and to the related danger of increased price volatility.

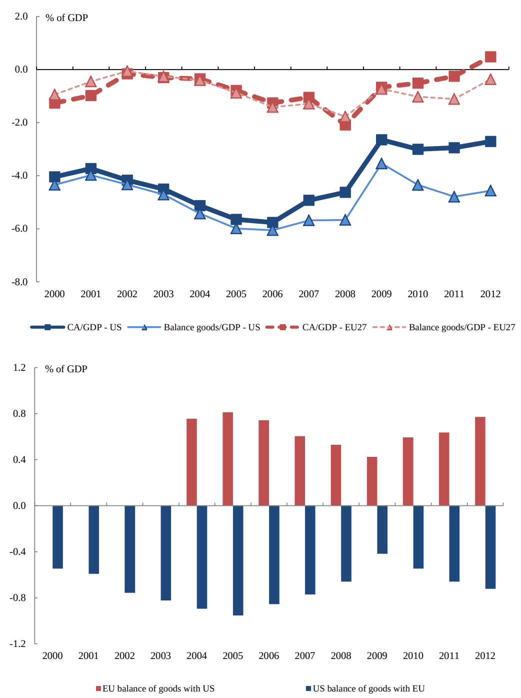
2.5.2. Trade of goods

The developments in the energy trade deficit should be seen in the context of the trends in the overall current account balance.

As it is well-known, the US has had a persistent large current account deficit, for a part fuelled by the global finance trends before the onset of the current financial and economic recession. However, it is of note that already in the years just before the outbreak of the financial crisis, the current account deficit had already started to fall.

([35]) This is possible when, for instance, Cyprus’ large offshore gas reservoirs turn out to be commercially viable for exploitation. Moreover, a number of EU countries report large potential reservoirs of shale gas.

Graph I.2.14: **Current account balance, external balance for goods and bilateral balance for goods, 2001-201 - US and EU-27**



Source: Commission Services based on Eurostat and US Bureau of Economic Analysis.

The sharp reduction in this deficit between 2008 and 2009 appears to have a close connection with a sharp reduction in domestic demand due to the onset of the economic crisis, as the goods trade balance moves in tandem ([36]). However after 2008, the goods trade deficit widens again, while the current account deficit more or less stabilises on a level close to 3%.

At the same time the US energy trade deficit has been reduced by about 1%-point of GDP, this suggests that the increasing self-reliance in energy has helped the US to get the current account more in balance. From this perspective, the US energy sector has helped to address one of the more prominent global imbalances.

Interestingly, the EU-US goods balance has shown a persistent surplus for the EU without any clear sign of deterioration. Since the direct trade in goods constitutes one of the key indicators for assessing (changes in) competitiveness, one can tentatively conclude that the widening EU-US energy price gap has so far not visibly affected the EU industry's market performance vis-a-vis their US counterpart, at least on the EU and US markets. This can for some part be explained by a better overall energy intensity performance in the EU; the relatively large share of services in US exports which are less energy-intensive than goods; the success of EU industry to realise cost improvements through a heavier reliance on global supply chains ([37]); the "income effect" of cheaper energy on US consumers' demand and for parts of the EU industry the cost benefit of cheaper US intermediary goods.

2.6. CONCLUSIONS

The findings of this chapter point to the importance to carefully check the on-going trends and to put them into perspective. The surge in US shale gas since 2007/2008 has led to marked changes in US energy sector and energy trade balance, as gas has replaced coal as dominant energy source in domestic production and the US energy trade deficit in GDP terms has been reduced since the dip of 2008. This improved performance of domestic US energy production and subsequent price differential has occurred in absence of any opening up of export of US shale gas to the rest of the world. Any such opening might limit future price differentials with the EU.

However, the investigated energy and trade data do not reveal any major shift in the EU-US goods

([36]) The analysis focuses on overall trade balance changes and it does not explicitly adress the impacts which run through changes in the exchange rate. It is of note however that over the period of study the Euro has almost steadily appreciated vis-à-vis the US dollar.

([37]) These first three points are corroborated by the elaborate empirical analysis of WIOD data 1995-2009 in section 3.2 of the Commission's 2012 European Competitiveness Report which shows that, next to improving its energy efficiency, the EU export sector has maintained its competitiveness by exploiting the opportunities from globalisation to source their intermediate inputs more cheaply. Table 3.2 of that publication shows that the total energy inputs embodied in one unit of goods exports has more or less stayed constant for the EU15 (and has fallen dramatically for the EU 12) where it has on balance increased for the US. Moreover, the share of embodied foreign energy inputs per unit of goods export has increased much more significantly in the EU than in the US. For services exports, a similar picture emerges, but with a smaller share of energy embodied per unit services exports than is the case for goods exports and with a level for the US exceeding that for the EU15.

trade balance nor significant divergent trends in the overall production structure of manufacturing industry which can be directly ascribed to the shale gas revolution.

In contrast to the US, the EU economy and industry have ever more heavily relied on energy imports, including gas imports, but the data strongly suggest that the EU industry has so far also responded to the persistently higher energy prices through the realisation of significant improvements in the use of energy as reflected in a secular decline in its energy intensity. By contrast, the US industry's energy intensity seems to have risen with the surge in consumption of the cheap shale gas. This divergence in EU-US energy intensity trends has partially helped EU industry to offset the energy price differential with the US and hence might have acted as a buffer to the US shale gas surge. The EU has been somewhat restructuring away from energy intensive sectors while maintaining an overall share of manufacturing in value added above that of the US. Moreover, although not demonstrated by the data presented in this chapter, one may surmise that cheaper US intermediate goods and the (future) availability of cheap (US) shale gas on the EU gas markets ([38]) can act as further buffers to the shale gas shock ([39]). The price gap with the EU may also be reduced should the shale gas producers be mandated to fully internalize external costs, on the environment and human health, as it is not currently the case.

However, this should not imply complacency on the widening EU-US energy price gap. Firstly because the impacts may become visible only after some delay and they may have in fact been obscured by the divergence in timing of the economic crisis between EU and US. Finally and importantly, energy efficiency improvements may slow down in the EU and speed up in US due to diminishing low cost options; but that would seem to require increased policy effort. Similarly the magnitude of opportunities to increase the foreign part of the EU industry’s supply chain remains unclear.

Consequently, high energy prices for EU industries should remain a policy concern, even more so in case the EU-US energy price gap will continue to increase. For this reason, EU energy and carbon policies have to be cost efficient while maintaining their ambition. Hence, on-going efforts to improve the efficiency of energy markets in the EU should be vigorously pursued, namely to diversify the energy mix, including a shift to multiple gas suppliers, increase the effective competition on the global and EU energy markets, and by integrating the various national energy markets in the EU into regional or EU energy markets.

Finally, since steady energy intensity improvements have proven to be one of the best asset of the EU industry to maintain their competitiveness, the EU should maintain and perhaps intensify its policy to bolster the EU industry's energy efficiency efforts.

([38]) This implies as well that so far the effects of the US shale gas on the EU have run through US goods production and the export of other energy sources such as coal, since US shale gas has not (yet) been exported to other parts of the world in signficant amounts.

([39]) Another counter-argument further explored in box 1.2.1 is that US gas prices may be unsustainably low and will inevitably increase to match production costs or decline in supply.

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APPENDIX 1

Data and Methodology

Unit Energy Costs: description of the data

The sectoral data on quantities of energy used, energy costs and value added in constant prices are collected from the World Input Output Database (WIOD) ([40]). The advantage of using this source is that it provides a large, consistent dataset of globally comparable sector-level data for a relatively long period of time 1995-2011, while its drawbacks are that it does not include the developments of the most recent years and data for some countries and sectors for 2009-2011 are estimated. In addition data limitations do not enable to compute energy intensity and real energy prices for the years 2010 and 2011. Data from WIOD allows the calculation of Real Unit Energy Costs for 27 EU Member States plus 13 other countries. These indicators are computed for the manufacturing sector and its 14 subsectors on the basis of the Nace Rev.1. nomenclature. The 14 subsectors of manufacturing are the following: food, beverages and tobacco; textile and textile products; leather and footwear; wood and products of wood and cork; pulp, paper, printing and publishing; coke, refined petroleum and nuclear fuel; chemicals and chemical products; rubber and plastics; other non-metallic mineral; basic metals and fabricated metal; machinery; electrical and optical equipment; transport equipment; manufacturing NEC, recycling. This is the most detailed sectoral breakdown available in the database. It is worth noting that in certain cases these sectoral aggregates could hide substantial variability in terms of lower subsectors.

Data is taken from national Use Tables of WIOD in purchasers' prices, because these prices reflect the total cost of inputs payable by the sector, as opposed to basic prices, which exclude taxes and margins (both of which can be substantial for energy products). Data from WIOD was complemented with constant price value added are taken from Eurostat for EU countries, from the OECD for the US and Japan and from the World Development Indicators for China. This enables the calculation of Nominal Unit Energy Costs, energy intensities and real (deflated) energy prices for these countries and sectors.

The analysis focuses only on direct energy costs. These are defined as the costs incurred by companies to directly purchase energy inputs including feedstock. The energy inputs considered here are the sum of 4 products categories: i) coal and lignite; ii) peat crude petroleum and natural gas, services incidental to oil and gas extraction excluding surveying; iii) coke, refined petroleum products and nuclear fuels; iv) electrical energy, gas, steam and hot water. The indirect energy costs are not analysed in the present note. These are defined as the share of energy embedded into the other production inputs used by the various sectors (for instance the energy inputs contained in the chemicals used by textile industry). Although admittedly the indirect energy costs could be significant for certain sectors, data availability and methodological issues represent important trade-offs that limit the usefulness of incorporating indirect costs into the analysis.

The methodology of shift share analysis

The shift share analysis presented in the paper is based on the following decomposition of the growth of RUEC between period *0* and period *T*:

$$\frac{\Delta RUEC_T}{RUEC_0} = \underbrace{\frac{\sum_i \Delta RUEC_{i,T} * m_{i,0}}{RUEC_0}}_{\text{within subsector effect}} + \underbrace{\frac{\sum_i \Delta m_{i,T} * RUEC_{i,0}}{RUEC_0}}_{\text{restructuring effect}} + \underbrace{\frac{\sum_i \Delta m_{i,T} * \Delta RUEC_{i,T}}{RUEC_0}}_{\text{interaction effect}}$$

([40]) The WIOD project was funded by the European Commission as part of the 7th Framework Programme for Research.

Where $\Delta RUEC_T = RUEC_T - RUEC_0$, *i* denotes a given subsector of total manufacturing, *mi,T* denotes the share of sector *i* in the value added of total manufacturing in period *T*, and $\Delta m_{i,T} = m_{i,T} - m_{i,0}$.

APPENDIX 2

Real unit energy cost in the world

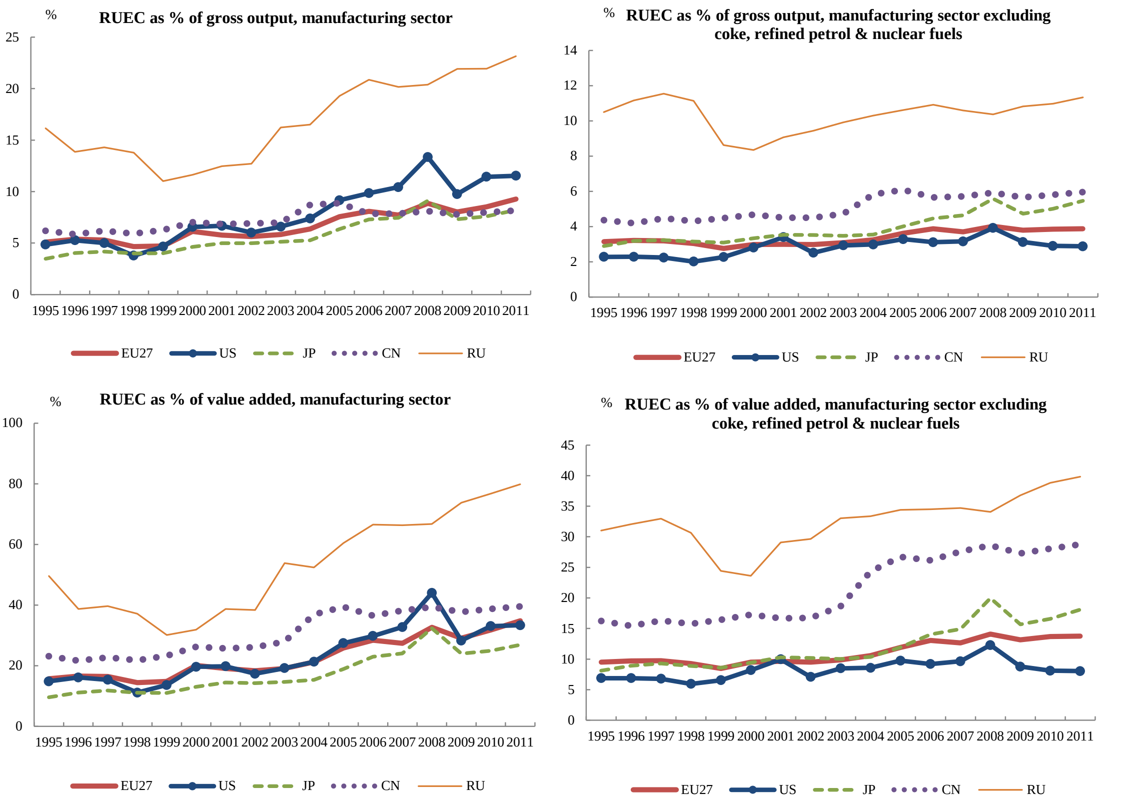
	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
EU27																	
RUEC as % of Value Added	15.7	16.6	16.4	14.4	14.8	20.1	19.1	18.3	19.1	21.2	25.8	28.4	27.4	32.6	29.1	31.8	34.8
RUEC as % of Gross Output	5.1	5.4	5.3	4.7	4.7	6.1	5.8	5.6	5.8	6.4	7.6	8.1	7.7	8.9	8.0	8.5	9.3
Australia																	
RUEC as % of Value Added	18.6	19.2	17.4	16.5	20.7	23.9	22.2	21.2	19.1	24.2	25.1	25.3	26.1	24.9	27.2	27.7	27.9
RUEC as % of Gross Output	6.0	6.2	5.9	5.4	6.6	7.3	6.6	6.5	6.1	7.2	7.4	7.4	7.7	7.3	8.0	8.1	8.2
Brazil																	
RUEC as % of Value Added	30.7	33.7	34.2	35.7	39.9	44.2	46.5	48.0	49.2	49.4	54.4	57.5	53.7	56.9	42.7	43.3	44.7
RUEC as % of Gross Output	9.4	9.8	10.1	10.4	11.4	12.1	12.6	12.9	12.8	13.0	13.8	14.6	13.5	13.6	11.7	11.9	12.3
Canada																	
RUEC as % of Value Added	10.4	10.9	10.4	9.4	8.7	10.9	11.8	11.2	13.0	12.6	15.3	15.4	15.1	15.0	14.7	13.2	13.1
RUEC as % of Gross Output	3.4	3.5	3.3	3.1	2.9	3.4	3.7	3.5	4.0	3.9	4.6	4.5	4.4	4.4	4.3	3.9	3.8
India																	
RUEC as % of Value Added	55.0	52.1	56.3	54.6	60.8	72.6	75.6	80.3	79.8	77.4	75.3	76.4	76.4	76.6	75.0	75.5	76.1
RUEC as % of Gross Output	12.2	11.9	12.2	11.9	13.5	15.9	16.3	17.0	16.7	16.2	16.1	16.1	16.1	16.0	15.5	15.6	15.7
Indonesia																	
RUEC as % of Value Added	7.6	10.1	8.3	18.8	20.2	25.7	23.1	22.5	22.8	23.4	26.6	27.0	27.1	25.0	23.4	22.6	22.3
RUEC as % of Gross Output	2.7	3.6	3.0	6.7	7.2	9.2	8.3	8.2	8.4	8.7	10.1	10.2	10.2	9.4	8.7	8.4	8.2
Korea (South)																	
RUEC as % of Value Added	23.7	27.9	34.0	38.5	35.7	40.1	40.6	34.6	35.7	38.3	43.9	49.3	49.5	69.5	58.3	60.6	63.4
RUEC as % of Gross Output	6.1	7.0	8.5	9.4	8.7	9.8	9.8	8.5	8.6	9.1	10.0	10.9	10.8	13.6	11.6	12.2	12.8
Mexico																	
RUEC as % of Value Added	30.1	24.5	25.1	24.3	23.7	23.6	25.1	25.1	24.6	27.2	29.3	31.2	31.5	38.5	33.1	31.3	32.9
RUEC as % of Gross Output	9.1	7.7	8.1	7.9	7.8	7.6	8.3	8.3	8.0	8.8	9.1	9.8	9.9	11.8	10.2	9.7	10.3
Turkey																	
RUEC as % of Value Added	20.7	19.3	18.4	17.1	28.6	36.3	36.4	26.5	26.2	26.1	26.9	28.4	28.0	23.5	24.2	23.8	23.6
RUEC as % of Gross Output	8.2	8.0	7.2	6.5	9.3	10.6	9.9	6.9	6.8	6.8	7.0	7.4	7.3	6.1	6.3	6.2	6.1
Taiwan																	
RUEC as % of Value Added	22.5	21.4	21.6	20.6	21.5	26.2	28.3	29.4	34.6	42.2	50.9	59.7	61.3	85.0	61.8	62.0	65.0
RUEC as % of Gross Output	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9

Source: Commission Services based on WIOD database

APPENDIX 3

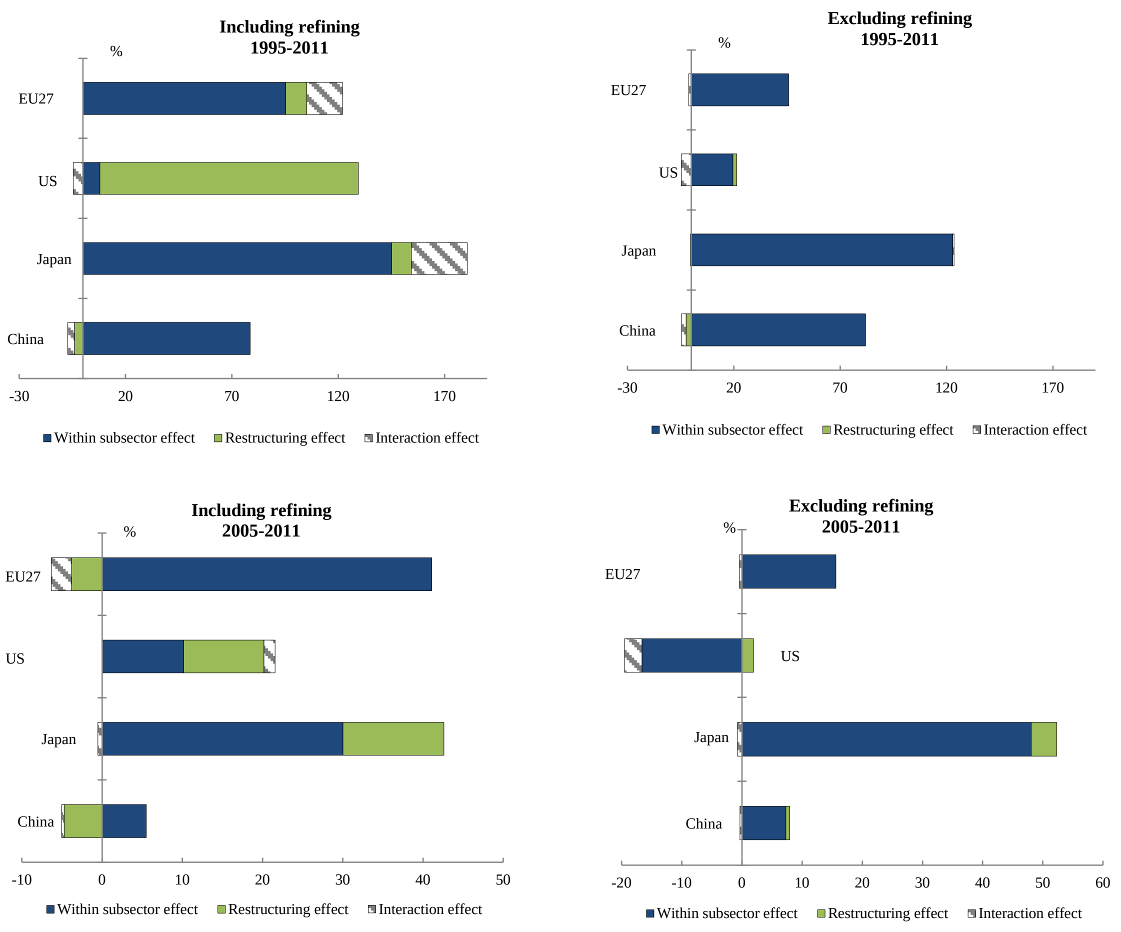
Real Unit Energy Costs & Shift-share excluding refining sector

Graph I.A3.1: **Real Unit Costs manufacturing sector including vs. excluding coke, refined petrol & nuclear fuels**



Source: Commission Services based on WIOD, ESTAT, OECD & World Development Indicators.

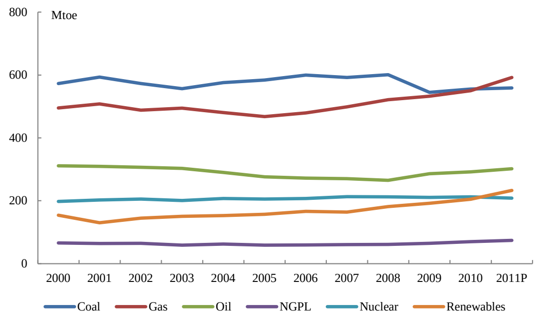
Graph I.A3.2: **Shift-share analysis for the manufacturing sector including vs. excluding coke, refined petrol & nuclear fuels**



Source: Commission Services based on WIOD, ESTAT, OECD & World Development Indicators.

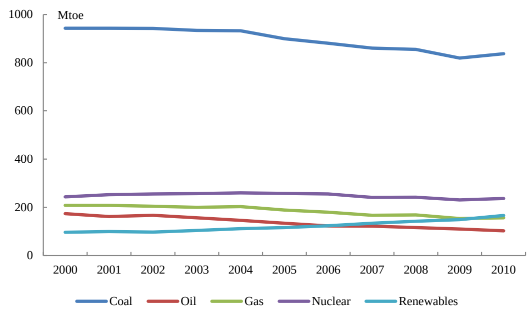
APPENDIX 4
Additional energy data on EU and US

Graph I.A4.1: **US Energy domestic production by source, 2000-2011**



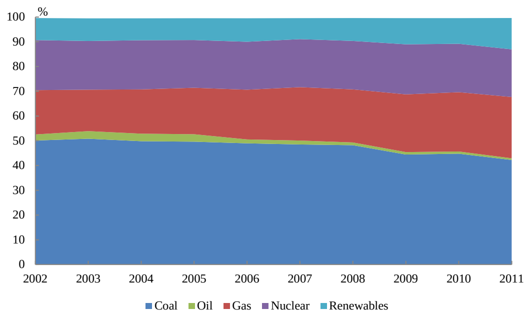
Source: US Energy Information Administration, conversion from BnBtu to Mtoe (1 BnBtu= 2,51996E-05 Mtoe)

Graph I.A4.2: **EU-27 Energy domestic production by source, 2000-2011**



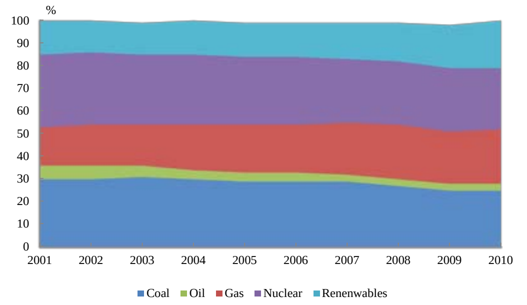
Source: DG ENERGY factsheet

Graph I.A4.3: **Electricity mix US, 2002-2011**



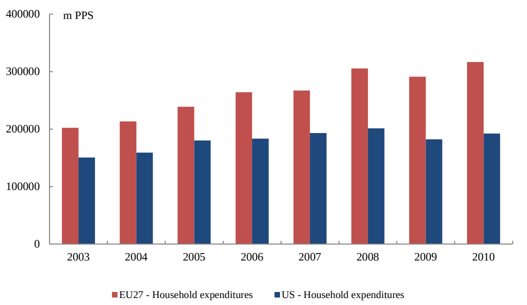
Note: Due to statistics collection differences, the US measures its electricity mix in terms of net electricity generation while the EU uses the gross electricity generation.
2011 provisional data
Source: Commission Services based on Eurostat data and Energy Information Administration of the US.

Graph I.A4.4: **Electricity mix EU-27, 2001-2010**



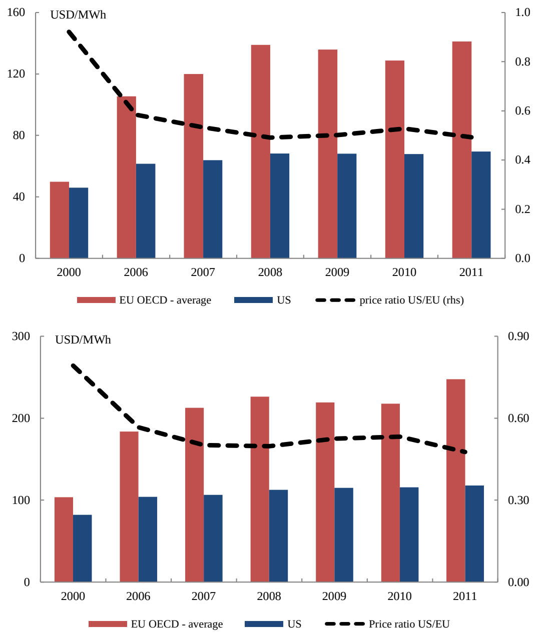
Due to statistics collection differences, the US measures its electricity mix in terms of net electricity generation while the EU uses the gross electricity generation.
Source: Commission Services based on Eurostat data and Energy Information Administration of the US.

Graph I.A4.5: **Household expenditures for energy products, 2003-2010 - EU-27 and US**



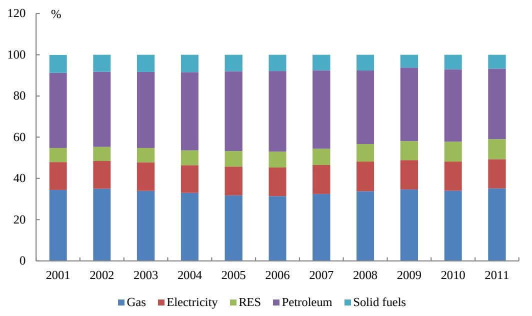
Note: Convention factor - OECD Dataset: 4. PPPs and exchange rates.
Source: Commission Services based on Eurostat and US Energy Information Administration.

Graph I.A4.6: Electricity prices for industrial consumers and households for the European countries in the OECD and for the US



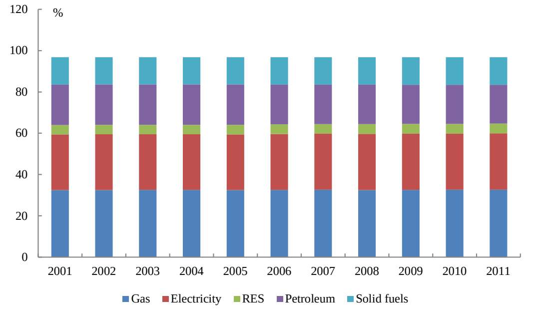
Source: Commission Services based on OECD Electricity Information (2012).

Graph I.A4.7: Energy consumption of industry breakdown by sources - US



Source: Commission Services based on US Energy Information Administration

Graph I.A4.8: Energy consumption of industry breakdown by sources, EU



Note: In order for the data to be comparable with the US, Industry includes also agriculture and fishing.
Source: Commission Services based on Eurostat database.