2. Energy efficiency trends in industry

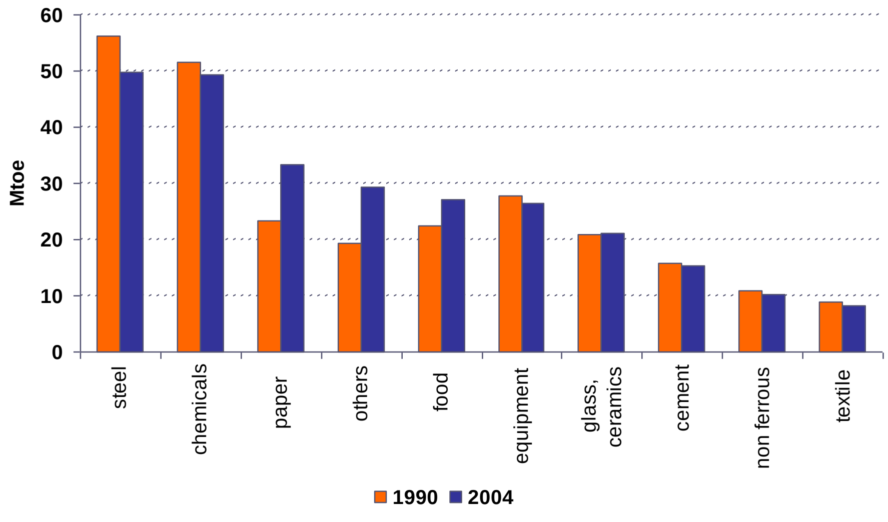
2.1. Energy use pattern

In 2004 the industrial sector consumed around 27 % of the energy used by final consumers in the EU-15 (279 Mtoe), of which 97 % was in manufacturing[21]. Industry is the sector with the slowest progression in energy consumption; as a result, its share in final energy consumption has been falling (minus 3 points between 1990 and 2004). In seven countries (Greece, the UK, Ireland, Germany, Luxembourg, Portugal, and Belgium), the drop in the importance of the sector has been quite significant (minus 5 points on average).

There has only been a slight reduction in the significance of energy-intensive branches for the energy consumption of industry due to strong growth in pulp and paper industry

Steel and chemicals are the largest energy consuming industrial branches: together they made up 36 % of total manufacturing industry energy consumption in 2004 in the EU-15 (42 % in 1990) **(Figure 2-1)**. With the other energy-intensive branches (cement, glass/ceramics and pulp and paper), their total share in energy consumption reached 62 % in 2004 (66 % in 1990). The decreasing role of steel and chemicals has been partly offset by the strong growth in the paper industry from 9 to 12 % of industrial consumption. The energy consumption of most industrial branches has decreased in absolute terms, except for two energy-intensive branches (paper and glass & ceramics), food and others.

Figure 2-1: Energy consumption trends by industrial branch in the EU-15



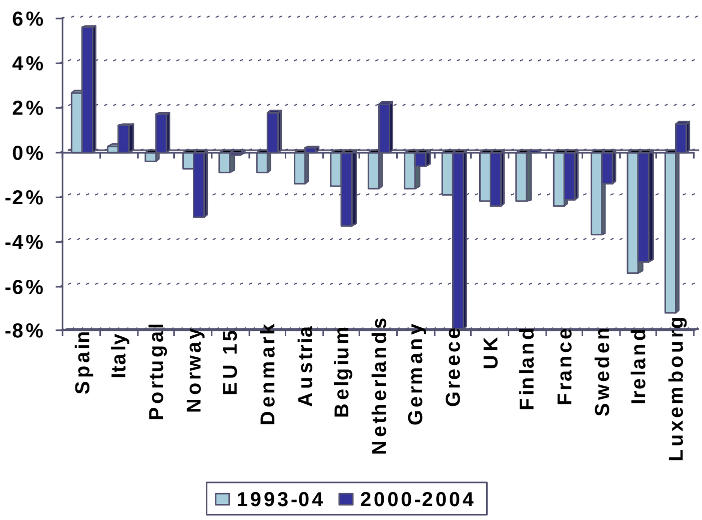
[21] Industrial energy consumption includes the manufacturing industry, construction and non-energy mining; it excludes the energy used for non-energy uses (e.g. gas or naphtha used as feedstock in the petrochemical industry). The share is calculated in relation to the final consumption for energy uses under normal climate conditions.

2.2. Trends in manufacturing energy intensities

Since 2000, the reduction in the energy intensity of manufacturing industry has slowed down

Industrial energy consumption[22] increased less rapidly than the value added over the period 1993-2004 in the EU-15 as a whole (respectively by 1.2 %/year and 1.8 %/year, which corresponds to an elasticity around 0.7[23]), showing that energy consumption and growth are decoupled[24]. As a result, the energy intensity of manufacturing industry decreased by 0.9 %/year over the period 1993-2004 for the EU-15 (**Figure 2-2**). It only increased in two countries: Spain and Italy. After 2000, the reduction is much slower (0.1 %/year for the EU-15), and there was even a reversed trend (i.e. an increase of this intensity) observable in some countries (e.g. the Netherlands, Portugal, Denmark and Luxembourg) and a more rapid increase in Spain and Italy. To a large degree, this recent trend is due to the influence of the economic downturn (see **Box 2-1** on the impact of business cycles).

Figure 2-2: Trends in the energy intensities of manufacturing industry in the EU-15



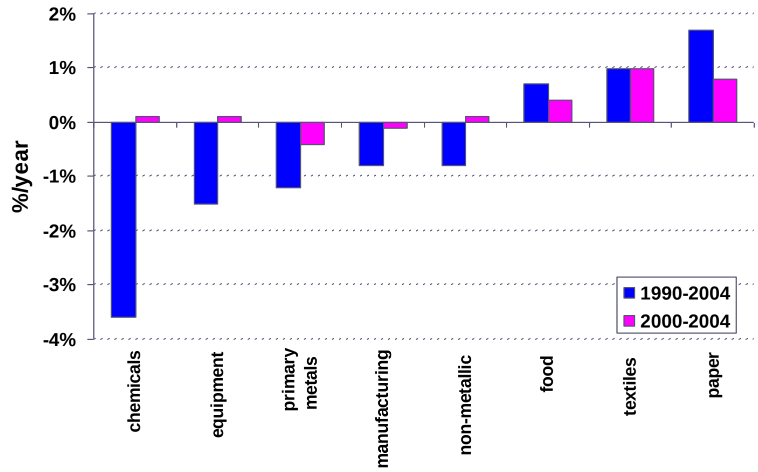
Box 2-1: Business cycles strongly influence short-term energy intensity variations

The energy intensity of industry tends to decrease more with high industrial growth, and to decrease less (or even increase) in the reverse situation. This observation, which has already been made for the overall energy intensity of the GDP, is even more significant in the case of industry. In industry, most of the energy used is not proportional to the production level. First of all, process energy does not decrease proportionally to the activity as the efficiency of equipment drops if it is not used at full capacity. Secondly, the energy that is not consumed by the process involved (e.g. for heating and lighting premises) is independent of the production level. If production declines, only the former part of consumption decreases, but not proportionally, whereas the first share remains constant: as a result, the energy consumed per unit of production tends to increase[25].

[22] Throughout this chapter, energy is given in final energy terms, which means that the fuels used for the self-generation of electricity are not accounted for in industrial energy consumption.
[23] The elasticity of the energy consumption to the value added measures the ratio of their annual growth rate.
[24] There was a recession in the period 1900-1993: the value added decreased by 1.5 %/ year and the energy consumption by 2.4 %/ year. As this period is exceptional, it will not be considered in the analysis.
[25] As a rule of thumb one could say that each percentage point of growth/decrease in industrial value added implies a similar short-term decrease/increase in industrial final energy intensity.

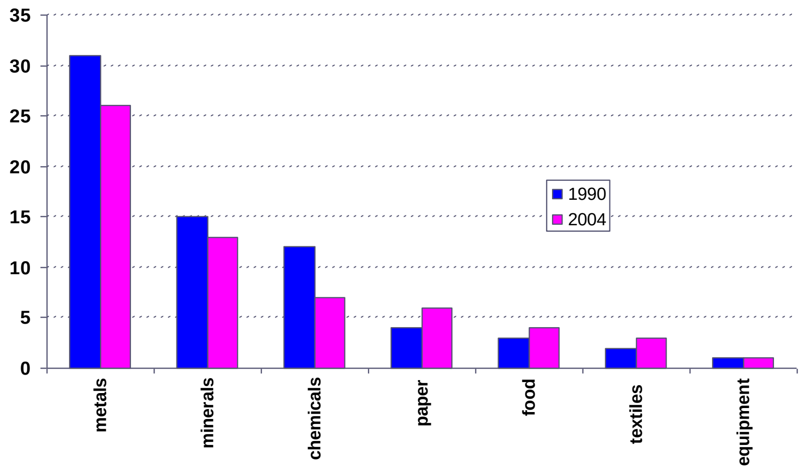
Most individual branches show a similar development to the overall energy intensity, i. e. a declining trend (**Figure 2-3**). However, three of them (textiles/leather, food and pulp/paper/printing) actually increased their energy intensity throughout the period 1990-2004. For the textile industry, this is linked to the dramatic decrease in value added over the decade while energy consumption was not reduced proportionally. In the pulp, paper and printing industry, the increase in the energy intensity may be linked to a strong rise in more energy-intensive pulp and paper production methods. For the branches with decreasing energy intensity throughout the 90s, the trend has reversed since 2000, with the exception of the metals. The strong decline in chemicals before 2000 may be due to structural changes within the branch, with a shift from heavy to light chemicals (e.g. cosmetics, pharmaceuticals)[26].

Figure 2-3: Trends in final energy intensities of manufacturing branches in the EU-15



Industrial branches do not have the same energy intensity. Primary metals and non metallic minerals required for instance 25 and 15 times more energy to produce one unit of value added than the equipment branch, which was the least energy-intensive branch in 2004; chemicals and paper are 6 and 5 times more intensive than equipment, respectively (**Figure 2-4**).

Figure 2-4: Relative values of energy intensities in manufacturing[27] (EU-15)



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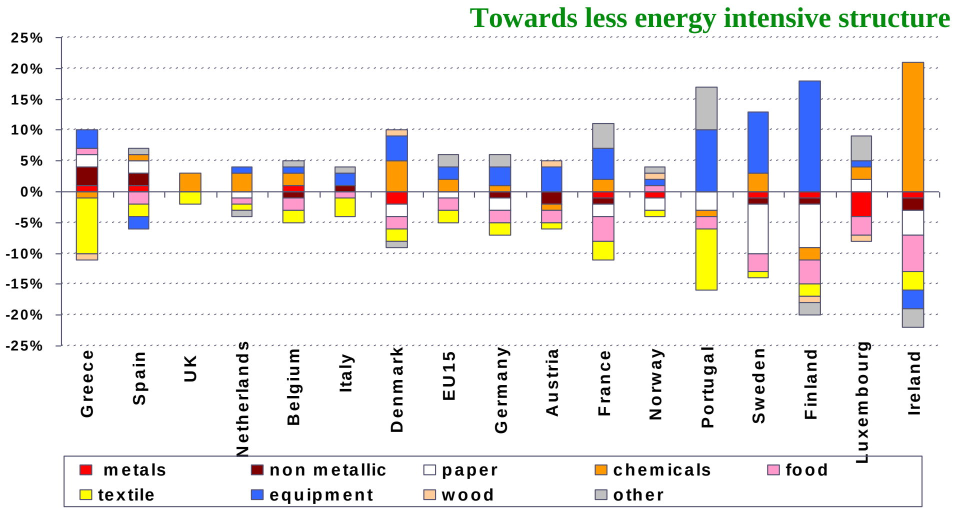
[26] However, due to a lack of differentiated data breaking down the consumption of chemicals by type of product, it is not possible to measure the impact of intra-branch structural changes.

[27] Relative values calculated taking 1 for equipment

Changes in the structure of manufacturing have been significant in some countries

In the EU-15, the structure of manufacturing value added only changed slightly since 1993, with a small progression in the equipment branch[28] (from 42 to 44 %) and chemicals (from 9 % to 11 %), compensated by a slight reduction in the role of food, paper, and non-metallic minerals (about -1 point each) and textiles (-3 points) (**Figure 2-5**). However, in some countries, these changes were significant, with a strong progression of equipment in Portugal, Finland and Sweden and a rapid progression of chemicals in Ireland. In some countries, there was an increase in the contribution of energy-intensive branches, such as in Greece and Spain (non metallic minerals and paper).

Figure 2-5: Changes in the value added structure in the manufacturing industry (1993-2004) (EU-15)[29]



[28] Equipment includes the production of fabricated metals, machinery and equipment.

[29] This graph shows the variation in the share of each branch in the total value added of manufacturing industry: a value of +5 % for instance for equipment indicates that the share of equipment increased by 5 points (e.g. from 42 to 47 % of the total). The sum of the variation is by definition equal to 0, as the total structure is equal to 100 %; therefore the bars are symmetrical along the horizontal axis. The larger the bars, the greater the structural changes.

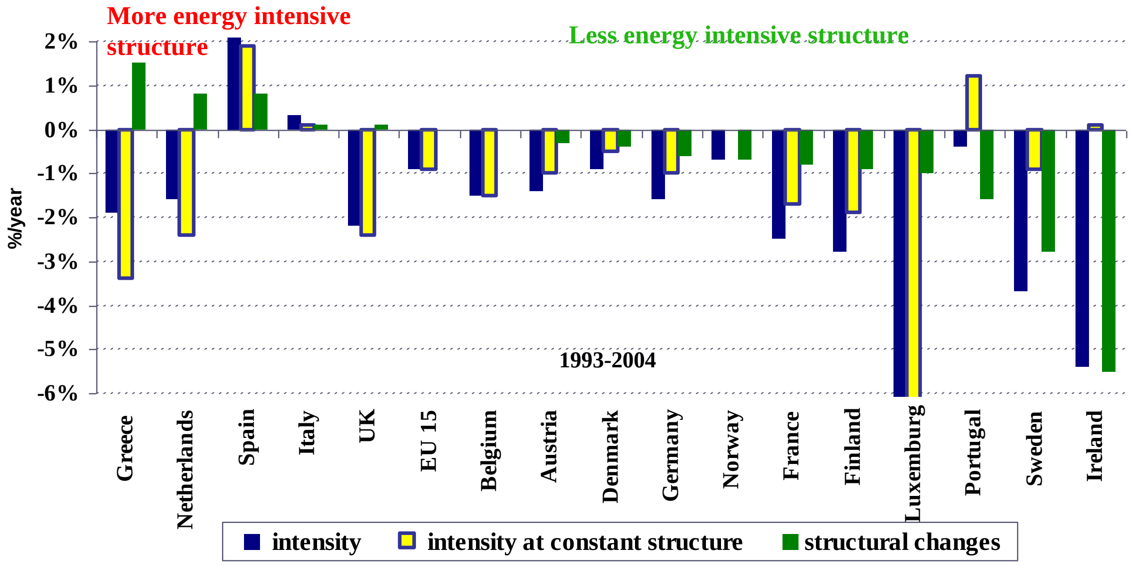
Changes in industry structure towards less energy-intensive branches contributed to reducing the industrial energy intensity in most countries; little effect at EU-15 level

Because of the very different levels of energy intensity among the industrial branches, any structural changes reducing the share of energy-intensive branches (e.g. metal and non-metallic minerals) in the total value added will reduce the average energy intensity of manufacturing, all things being equal (and vice versa).

Comparing the variation in the observed energy intensity of the manufacturing industry with the final intensity at constant structure[30] of manufacturing shows the influence of the structural changes already described: the greater these structural changes, the wider the gap between these two intensities. In the EU-15 as a whole, there is no effect of structural changes on the manufacturing energy intensity (**Figure 2-6**).

In most countries, a shift towards less energy-intensive branches contributed to decreasing the energy intensity of manufacturing. The impact of these structural changes was particularly marked in Ireland, Sweden and Norway, where they were responsible for most of the reduction, as well as in France, Finland and Germany, where they account for about one third of this reduction. In Greece, the Netherlands and, to a lesser extent, Italy and the UK, a higher share of energy-intensive branches had the opposite effect and lessened the energy intensity reduction. There was also a shift towards energy-intensive industry in Spain, which explains part of the intensity increase here.

Figure 2-6: Impact of structural changes in industry on the energy intensity[31] (EU-15)



[30] The intensity at constant structure is "trimmed" of structural changes; it is calculated using the Divisia method at the level of 10 branches using a moving reference structure (that of the previous year).
[31] Manufacturing industry

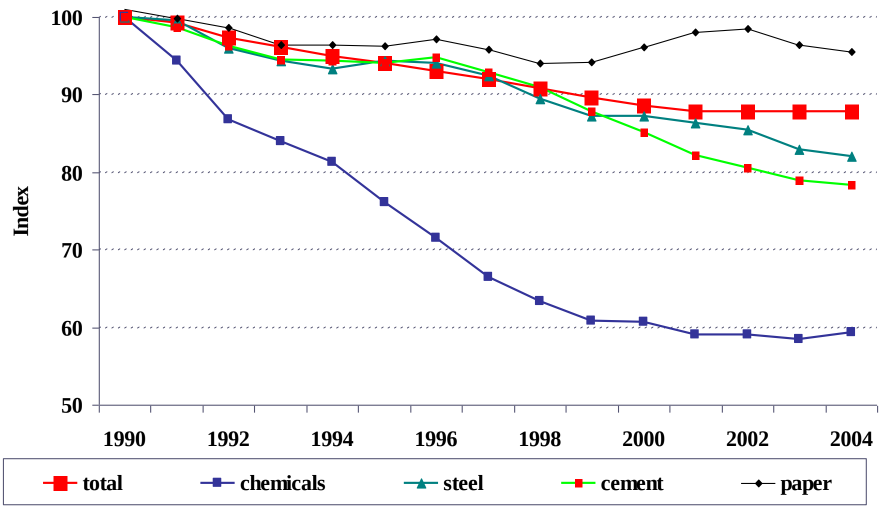
2.3. Overall energy efficiency trends

Energy efficiency has improved by 12 % in manufacturing industry. Chemicals, metals and cement contributed most strongly. Slowdown since 2001

Energy efficiency improved by 12 % in manufacturing industry in the EU-15 over the period 1990-2004[32] (**Figure 2-7**). The unit energy consumption of almost all branches decreased with quite diverse trends across the branches: chemicals (-40 %), steel (-20 %), cement (-13 %) and paper (-6 %).

Structural change has been eliminated to a large degree but some structural changes within branches are still present as they cannot be completely removed due to a lack of disaggregation[33].

Figure 2-7: Energy efficiency index in manufacturing industry (EU-15)



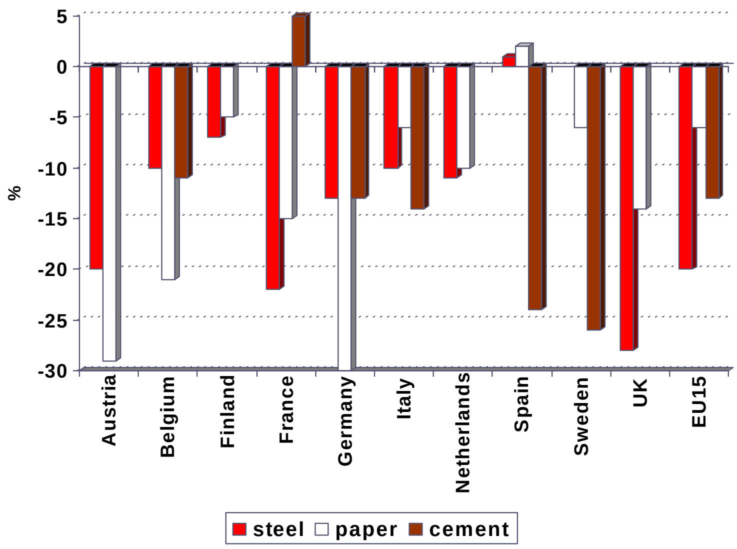
[32] Energy efficiency progress is measured with ODEX that is calculated from the unit energy consumption indices of individual branches (11 branches). Unit consumptions are expressed in toe per ton produced for steel, cement, and paper and in toe per unit of production index for other branches. ODEX better reflects the energy efficiency development than the energy intensity, even cleaned for structural changes, as it relies on physical indicators.

[33] In chemicals, the strong decrease in the index may also reflect internal structural change towards less energy-intensive products, as it is unlikely that the efficiency of the energy-intensive processes would rise by nearly 40 % within one decade. For steel, the variation of the index includes structural change within the sector from oxygen steel to the electric arc process, which may be considered an energy efficiency improvement. For cement, as discussed later, variation in the energy consumption per ton of cement includes changes in the process mix, from the wet to the dry cement process (however, this shift is now completed to a large extent), as well as the increasing use of clinker additives.

Energy efficiency improved unevenly across the countries, typically by 1-1.5 % per year.

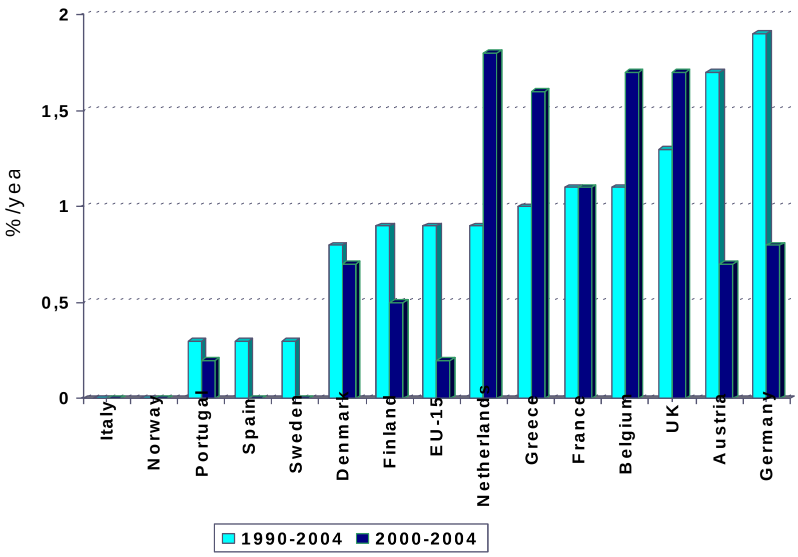
Among EU-15 countries, energy efficiency improvements are quite disparate for energy-intensive branches: steel reduced its unit consumption by 20 % on average for the period 1990-2004, with a range of 10-20 % for most countries; paper by 6 % (range of 5-30 %) and cement by 13 % (range of 10-25 %) (**Figure 2-8**). These trends may partially reflect the impacts of voluntary agreements signed with industrial trade associations in several countries (e.g. Germany, France, the Netherlands, and Finland).

Figure 2-8: Trends in unit energy consumption for steel, cement and paper (EU-15)[34]



Energy efficiency improved unevenly across the countries, typically by 1-1.5 % per year (**Figure 2-9**). Five countries showed no reduction at all or very limited energy efficiency gains. There has been a slowdown since 2000 in most countries and at the EU-15 level, partly due to the economic downturn (see **Box 2-1**). However, there has also been an acceleration in 4 countries (the Netherlands, Greece, Belgium and the UK).

Figure 2-9: Energy efficiency trends in manufacturing industry in EU-15 countries



[34] Variation over the period 1990-2004

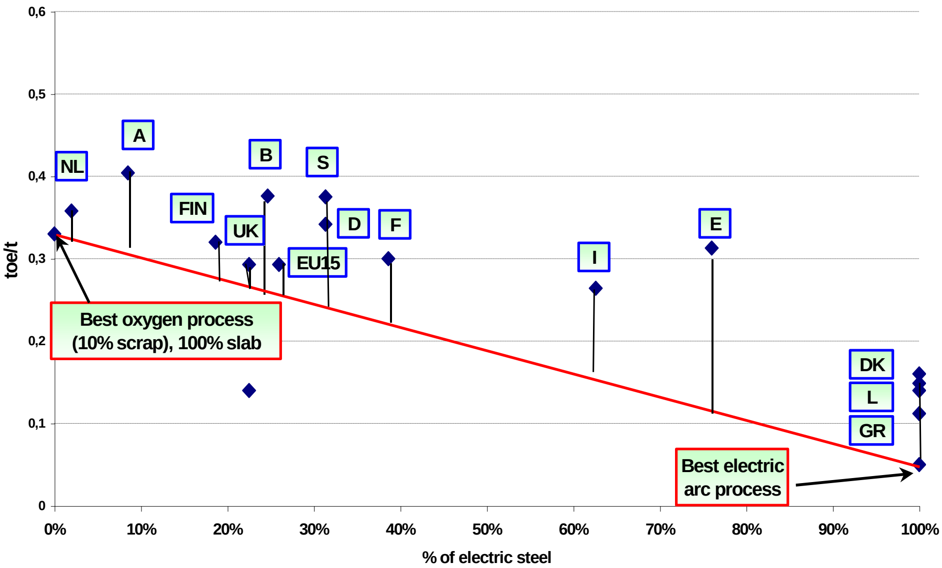
2.4. Comparison of energy efficiency performance in some energy-intensive industries

Comparisons of the unit energy consumption of industrial branches have to take into account the specificities of production process before any conclusion can be drawn as to the relative energy efficiency performance of countries, as will be shown below for steel, cement and paper.

The unit energy consumption per tonne of steel depends on the process mix

There are two main processes to produce steel with very different energy requirements: the oxygen process which uses pig iron produced in a blast furnace as input and electric steel making in which iron scraps are melted in an electric furnace. The oxygen process requires 2 to 3 times more energy than the electric process[35]. Therefore, when comparing the average energy consumption per ton of crude steel among countries, it is important to take into account how the steel is produced, in other words the relative share of the two processes, i.e. the "process mix". **Figure 2-10** compares the unit consumption of steel in the EU-15 countries, showing the share of electric steel in total crude steel production. The vertical distance from the benchmark (shown by a red line), which is based on the best available performance, shows the technological improvement possible at the given process mix of the country. The arrow to the x-axis which represents 100 % electric arc shows the potential theoretically open to process substitution. In reality, this might be more restricted due to the limited substitution possible between oxygen steel and electric steel.

Figure 2-10: Unit consumption of steel: targets of energy efficiency improvements (2004)

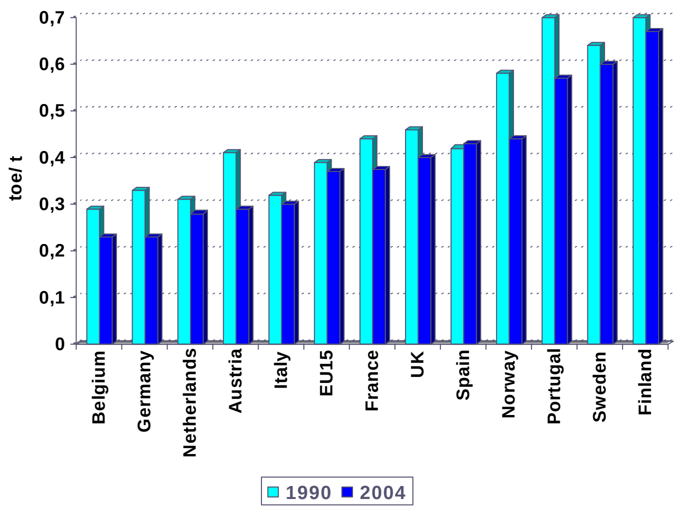


[35] The difference in energy inputs depends on whether we consider final energy or primary energy requirements. The electric process uses mainly electricity; the oxygen process relies mainly on coke. Therefore the results of the comparison will depend on the way electricity is converted in toe. In the Figure, the conversion is made in final energy terms on the basis of the calorific value of electricity.

The energy performance of pulp and paper depends on the production of pulp

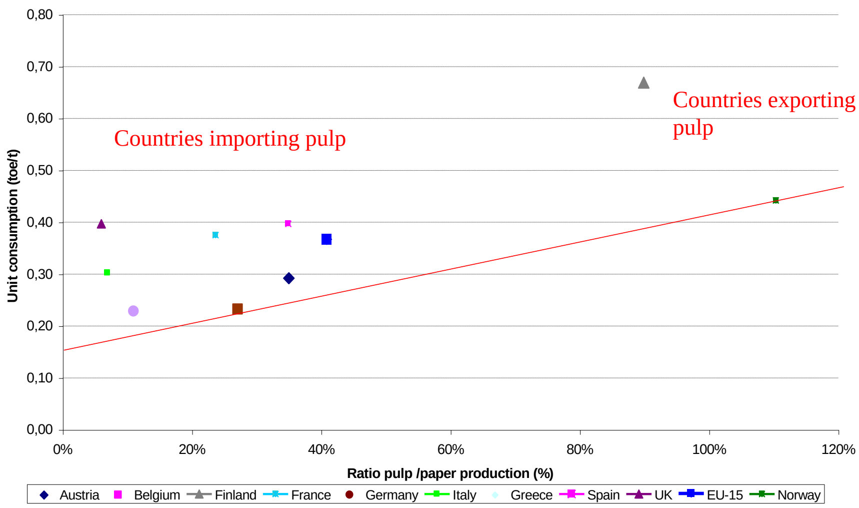
Unit energy consumption in the pulp and paper industry is very different among EU-15 countries: it varies by a factor of 2 to 3 from a minimum between 0.2 and 0.3 toe per ton of paper to a maximum between 0.6 and 0.7 toe/ton (**Figure 2-11**).

Figure 2-11: Unit energy consumption in the pulp and paper industry (EU-15)



To explain such differences, it is necessary to take into account how the paper is produced. Paper is produced from raw pulp or from recycled paper. Pulp production is energy-intensive. The pulp used in a given country may be produced in the country or imported from other countries. If it is imported, this means that the energy consumption for the pulp production has taken place in the exporting countries (in particular Sweden, Finland, or Norway). Therefore, the energy performance of the paper industry of a given country is linked to the share of pulp produced in the country in relation to the paper production: the higher this ratio, the higher the unit consumption as shown in **Figure 2-12**. Energy efficiency performance can only be benchmarked among countries with a similar ratio of pulp/paper production.

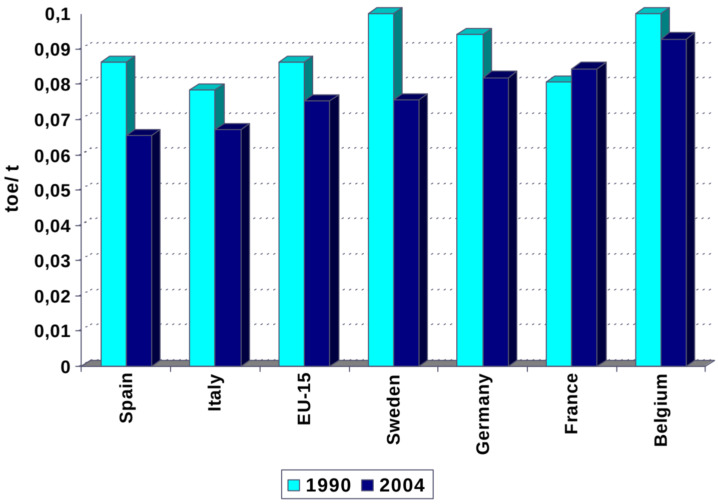
Figure 2-12: Pulp and paper industry: targets of energy efficiency improvements (2004)



For cement, comparisons of energy efficiency are more relevant if made for clinker

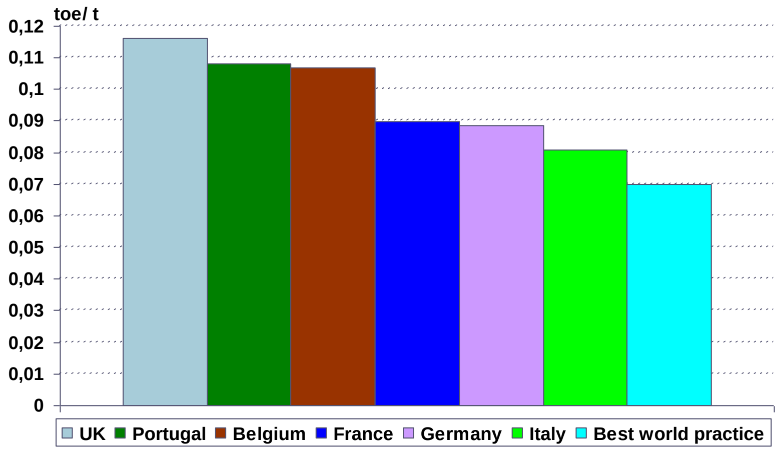
Cement production is very energy-intensive. However, most of the energy consumption occurs during the fabrication of clinker in high temperature kilns, and not for producing cement itself which consists of grinding clinker with additives (e.g. ashes). Therefore, differences between countries in the average energy consumption per ton of cement, as shown in **Figure 2-13**, not only reflect different levels of energy efficiency, but also differences in the composition of cement (% of additives) and the share of clinker produced in the country. In the same way, the fall in this unit consumption observed between 1990 and 2004 may well reflect increased imports of clinker and more additives in cement[36].

Figure 2-13: Unit energy consumption in the cement industry (EU-15)



In other words, benchmarking energy performance in the cement industry should be made based on clinker production as shown in **Figure 2-14**. For clinker, there may still be differences due to the process mix (wet versus dry process), although the wet process has been almost completely phased out[37].

Figure 2-14: Benchmarking of unit energy consumption for clinker (2004) (EU-15)



[36] Because of differences in energy prices, there is a trend to increase imports of clinker.

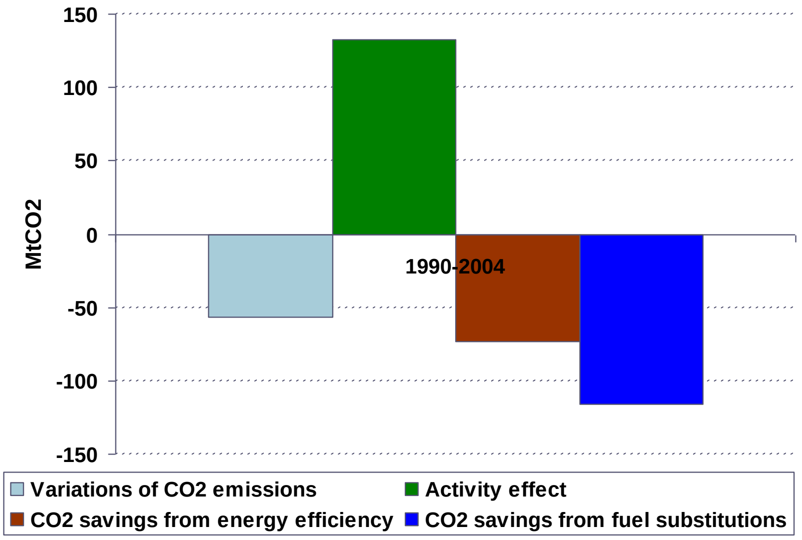
[37] The data for Spain and Sweden are not shown as non-conventional fuels are not accounted for; as a result, their average unit energy consumption is below the world's best practice. Non-conventional fuels make up 1/3 of the total consumption in France and 40 % in Germany.

2.5. CO_2 emissions

Large CO_2 savings in industry; 60 % from fuel substitutions

Direct emissions from the industrial combustion of fossil fuels (oil, natural gas and coal) made up 17 % of total CO_2 emissions from energy use in the EU-15 in 2004[38], down from 20 % in 1990. This is much smaller than the share of this sector in the final energy consumption (27 %), even more so since emissions from the combustion of fuels used for self-generation of electricity are included in this figure, whereas the consumption of these fuels is excluded from the final energy consumption of industry. This remarkable position of industry in total CO_2 emissions is due to the fact that CO_2 emissions of industry were 9 % below their 1990 level in 2004: this corresponds to a reduction of 57 Mt CO_2[39]. This was achieved despite a 16 % increase in the value added of industry. This reduction in the level of emissions was made possible by significant CO_2 savings from fuel switching, accounting for 60 % of total savings (116 Mt CO_2) and from energy efficiency improvements accounting for 40 % (73 Mt CO_2) (**Figure 2-15**). It is too early to see the impact of the Emission Trading Directive that came into effect in 2005.

Figure 2-15: Variations in CO_2 emissions from industry in the EU-15



[38] If indirect emissions are also included (i.e. emissions from the production of the electricity and heat used by industry), the contribution of industry almost doubles (30 %).
[39] Source EEA, 2006

2.6. Conclusions

- Energy efficiency in the manufacturing industry improved by 12 % in the EU-15 as a whole between 1990 and 2004.

- Energy efficiency improved unevenly across the countries, typically by 1-1.5 % per year.

- In general, the energy efficiency progress slowed down after 2000, in part due to the economic downturn. In four countries, there was the opposite effect, i. e. an acceleration in energy efficiency progress (the Netherlands, Greece, Belgium and the UK).

- Structural changes in industry only made a minor contribution towards the reduction in the energy intensity of industry in the EU-15 as whole, but had a significant impact in individual countries, such as Ireland, Sweden and Norway, where they were responsible for most of the reduction, and to a lesser extent in France, Finland and Germany.

- CO_2 emissions were 17 % below their 1990 level in 2004 despite a 16 % growth in the value added of the industrial sector over the period because of large CO_2 savings. Fuel substitution accounted for 60 % of the total savings.

- Comparing the energy intensity of manufacturing industry is more relevant if intensities are adjusted to the EU-15 average value added structure; the range between the 2 extremes is reduced from a factor of 8 to a factor of 3.