Project No 213744

SECURE
Security of Energy Considering its Uncertainty, Risk and Economic Implications

SP1 – Cooperation
Collaborative project
Small or medium-scale focused research project

DELIVERABLE No 5.8.1
Energy efficiency and security of supply of primary energy in the industrial sector

Due date of deliverable: End September 2009
Actual submission date: 25th November 2009

Start date of project: 1/1/2008 Duration: 39 months

Organisation name of lead contractor for this deliverable: FEEM
Contributions by OME (Sections 1.1 and 3) and Ramboll (Annex II).

Revision: 1
(16th March 2010)

Project co-funded by the European Commission within the Seventh Framework Programme		
Dissemination level		
PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Energy efficiency and security of supply of primary energy in the industrial sector

Fondazione Eni Enrico Mattei (FEEM), with the contribution by Observatoire Mediterraneen de l'Energie (OME) (Sections 1.1 and 3) and Ramboll (Ramboll Oil & Gas) (Annex II)

1. Introduction ... 3
1.1 Key recent energy policies of the European Union ... 5
Box .1 Energy saving policies around the world ... 9
2. Main Energy Efficiency Indicators for the EU ... 11
2.1 The EU Energy Consumption ... 11
2.2 Energy Intensity in the EU ... 16
2.3. The EU Carbon Intensity ... 20
2.4 Energy efficiency within the European Union ... 24
3. Energy saving potentials in the industrial sector ... 26
3.1. Industrial energy consumption in the EU ... 26
3.2. Latest evolutions in the fuel switching options and energy savings potentials in the industrial sector per sub-sector ... 26
3.3 European policies for improving energy efficiency in the industrial sector ... 28
4. Panel Analysis: Methodology ... 30
5. Panel Analysis: Data ... 33
6. Panel Analysis: Results ... 35
6.1. Panel analyses of energy polices in the EU for the whole economy ... 35
6.2. Panel analyses of energy polices in the EU for the industrial sector ... 38
6.3. Discussion ... 39
7. Conclusions ... 40
References ... 43
Annex I – Data Dictionary ... 45
Annex II. Literature about security of supply in the industrial and residential sectors. ... 48
Search and Results ... 48
Conclusions ... 51

1. Introduction

Representing 27 countries and roughly 500 million consumers the European Union (EU) is the world's second largest energy market and thus the decisions taken by European policy makers could heavily influence the way to tackle hot topics such as global warming, energy security and competitiveness.
Indeed, as highlighted in the Green Paper Energy (European Commission, 2006), these three topics are high on the European Commission agenda, which has identified them as guiding principles of a prospective European Energy Policy. The achievement of such an ambitious goal requires however an immediate effort for finding the optimal balance between competitiveness and sustainability.

In recent decades, increasing demand for energy, fluctuating oil prices, uncertain energy supplies and global warming made the EU-citizens to realize that secure and safe supplies of energy can no longer be taken for granted. It becomes obvious that improved energy efficiency can play a critical role in addressing energy security, environmental and economic objectives.

The International Energy Agency (IEA, 2009) estimates that if the full set of appropriate measures it recommends would be implemented without delay, the proposed actions could save around 8.2 Gigatonne/CO_2/year by 2030 – equivalent to twice the European Union's yearly emissions, or to one fifth of global « business as usual » energy-related CO_2 emissions in 2030. Within the European countries, there is certainly room for further energy efficiency action. For example, no European G8 country has substantially implemented more than 55% of the IEA recommendations. In other words, around 40% of the energy efficiency potential from the IEA recommendations remains to be captured for those countries.

The current high energy prices and potential successful energy efficiency policies can strongly enhance the uptake of energy efficient technologies and procedures. In addition, they may also lead to important innovation effects that occur when energy efficiency technologies are used in a broad manner and that will drive down the cost differential of more efficient technologies compared to less efficient technologies.

Security of energy supply has been widely debated, mostly in relation to the upstream (security of supply for specific geographical region or single country). However, as the literature survey in Annex II highlights, there are not many studies about the implication of energy security for the residential and industrial sectors.

Yet it can be argued that one way to reduce the dependence from external energy sources, or the exposure to energy prices volatility and increase, is simply to reduce the demand for energy. Energy savings may thus be considered a policy priority when concerns for energy security are particularly strong. Thus, in order to fully understand how energy security affects the European society and how demand-side policies can be geared a detailed knowledge of energy intensities in the Europe member countries' sectors and of their potential for efficiency improvement is potentially very important.

WP 5.8, of which the present document is the first deliverable, analyzes energy efficiency issues within the European context, looking in detail into energy use by sector and by source in Europe.

To this purpose an innovative econometric approach is applied. We check whether policies and measures that affect indicators of energy efficiency performance have an analogous effect on security of supply indicators, and vice-versa, both at the whole economy level and within the main sectors of energy use, in the EU 15 countries[1].

The analyses have shown that the indicators studied are affected by a number of policies and measures (P&Ms); however very few P&Ms seem able to tackle effectively and simultaneously, energy efficiency, carbon efficiency and energy security.

The main lesson to be drawn from this analysis is that there is a number of energy efficiency policies in the EU that do work, but there is no silver bullet able to successfully address different policy objectives. Taking a more general perspective, what seem to work is the policy mix rather this or that policy in insulation.

Deliverables 5.8.1 - 5.8.3 follow the same approach and apply the same methodology. They have thus much in common, and, in particular, they share the same common background about energy consumption and carbon emissions in Europe. However, due to the peculiarities of the sectors considered, it is not possible to use the same indicators of energy efficiency for all the subsectors. In particular:

- Energy intensity, that is, the ratio between energy consumption and value added, makes sense only for sectors yielding output measurable in value terms. Thus it is used for the analyses of the industrial, service and agricultural sectors;
- For the residential sector, whose contribution to the welfare of the economy cannot be measured in terms of value added, an index of energy efficiency based on physical quantities is computed in Deliverable 5.8.2;
- For the transport sector, both energy intensity and energy efficiency indexes are used in Deliverable 5.8.3. This is because the "transport" sector encompasses both commercial transport services, whose value added data are available, and hence energy intensities can be computed, and private transportation, for which the same considerations made for the residential sector apply.

[1] The analysis also covers carbon intensities. Knowledge of CO_2 emission reduction potential of each sub-sector and category of end-use is very useful in order to understand the interactions of EU CO_2 emission targets with energy consumption patterns and therefore with security of supply issues related to energy demand.

- Similar considerations apply to the case of carbon efficiency: when value data for the output of the sector under scrutiny are available, one can compute the *carbon intensity* (that is, the ratio of CO_2 emissions and value added); otherwise, physical indicators such as emissions per capita must be used.

For economy of space and clarity's sake, this first deliverable of WP 5.8, beside analyzing in depth the situation of the industry sector, also provides a general overview of the macro aggregates and indicators (energy consumption, energy intensity, energy efficiency, carbon emissions and intensity)[2] in Section 2, of the methodology applied (in Section 4) and of the data used (in Section 5).

The remainder of this introductory chapter looks at the European policy framework for the promotion of energy efficiency. The rest of the report is organized as follows. Section 2 gives a general overview of energy consumption in Europe in the last 3 decades and describes in more detail the indicators studied. Section 3 (provided by OME) looks to the fuel switching and energy reduction potential in the industrial sector. Section 4 explains the methodology applied in our panel analyses, Section 5 describes the dataset and Section 6 discusses the results. Section 7 concludes. In the Annexes, Annex I lists and explains the variables used in the econometric analyses, and Annex II (provided by Ramboll) looks at the relevance given in the literature to the energy security for the industrial and residential sectors.

1.1 Key recent energy policies of the European Union

The current situation of the EU energy requires Member States to reach a consensus view about a common strategy in the energy field. In the attempt to kick-start this process, The Green Paper "Energy", adopted by the EC in March 2006, lays the basis for a European Energy Policy; this document highlights that the development of a common policy is a long-run project whose ultimate purpose is to balance three core objectives: sustainable development, competitiveness and security of supply.

As a foundation for this process the European Commission (EC) proposes establishing a Strategic EU Energy Review to be presented to the Council and Parliament on a regular basis, covering all the energy policy issues. This would help updating the European Council and Parliament monitoring progresses and identifying new challenges and responses concerning energy policy issues. Moreover, the Strategic EU Energy Review would also be a tool for achieving the first core objective, namely sustainability. Indeed, through the Strategic EU Energy Review, the EC aims at covering all aspects of energy policy, analysing all the advantages and drawbacks of different energy mixes. Although a country's energy mix is and will remain a question of subsidiarity, its decisions have consequences for other countries and the EU as a whole, both in terms of pollution and

[2] Deliverable 5.4. and 5.5 need a different approach and deal independently with their respective topics.

energy security. All in all this should eventually lead to the definition of a EU's overall energy mix to ensure security of supply and sustainability, whilst respecting the right of Member States to make their own energy choices.

A more sustainable, efficient and diverse energy mix is identified as the third priority area. The Strategic EU Energy Review is identified as the tool for defining common strategies for what concerns the choice of an environmental sustainable energy mix that could improve the security of supply, while allowing Member States to be independent on this issues.

The fourth action area is strictly related to the third one and addresses the challenges of global warming. An Action Plan on energy efficiency and a new Road Map for renewable energy sources should be adopted by the EC to select the measures necessary for the EU to save 20 percent of the energy that it would otherwise consume by 2020.

Environmental concerns are somehow addressed also in the fifth action area that aims at developing and deploying new energy technologies in order to secure energy supply and improving sustainability and competitiveness. The EC proposes to establish a strategic energy technology plan in order to develop promising energy technologies and to make them marketable. At the end of the day, what emerges from the Green Paper is that the three policy objectives, competitiveness, security of supply and sustainability, are closely interlinked and complementary.

Several Directives to improve energy efficiency have been implemented during the last years:

1992	***2000***	***2002***	***2005***	***2006***	***2008***
European Directive on labeling of the energy consumption's household appliances	*Action Plan for Energy Efficiency 2000-2006*	*European Directive on building's efficiency*	*Eco-Design Directive concerning all new products outside of the transport sector*	*European Action Plan for Energy Efficiency (2007-2013)*	*Climate Action and Renewable Energy Package*

Table 1 Key energy savings policies in the EU. *Source: ADEME*

In 2005, the Green Paper of the European Commission assessed the potential savings pro sector if implemented its recommendations[3]:

- 16 Mtoe in the industrial sector;
- 56 Mtoe in buildings, including 41 Mtoe for heating and cooling and 15 Mtoe for electrical appliances;
- 40 Mtoe for cogeneration.

On January 2007 the European Commission presented an Energy and Climate Change Package including a Strategic Energy Review. This package was finally agreed on

[3] The recommendations are in the European Action Plan on Energy Efficiency proposed by the Commission. The Action Plan calls mainly on the Member States to mobilize all political forces in the fight against excessive energy consumption.

December 2008. On March 2007 the EU Summit of Head of States agreed on an action plan, including among others:

- A target to save 20% of the EU's total primary energy consumption by 2020;
- A binding target to raise the EU's share of renewable to 20% by 2020;
- An obligation of 10% biofuels in the transport fuel mix by 2020 for each EU member
- An European Strategic Energy Technology Plan for low carbon technologies

Most European countries are actively implementing energy efficiency measures. For example, Italy submitted the action plan to achieve an energy savings of 9% in 2016 (directive 2006/32/EC). The plan shows the current and future actions sectors with an expected energy savings of 35.7 Twh per year in 2010 and 126.3 Terawatt hour (Twh) per year in 2016. From 2008 a fund of 40 million euro per year is established to promote renewable sources and energy efficiency.

The Green Paper on Energy Efficiency points out that the EU could save at least 20 percent of its present energy consumption in a cost-effective manner, equivalent to 60 billion euro per year.

In order to support a better integration of energy efficiency measures into national legislation the European Commission has proposed several directives which have been adopted and are now in force. These concern broad areas where there is significant potential for energy savings, such as:

- End-use Efficiency & Energy Services;
- Energy Efficiency in Buildings;
- Eco-design of Energy-Using Products;
- Energy Labelling of Domestic Appliances;
- Combined Heat and Power (Cogeneration).

Directive 2006/32/EC sets an indicative energy saving target of 9 percent on total energy use, over a period of 9 years, to be reached by means of energy services and other energy efficiency improvement measures. According to the Article 14(2) of the Directive, Member States submitted their first National Energy Efficiency Action Plan (NEEAP) to the Commission in June 2007. In their NEEAPs, Member States show how they intend to reach the 9 percent indicative energy savings target by 2016.

Among the main Community legislation for the building sector are the Boiler Directive (92/42/EEC), the Construction Products Directive (89/106/EEC) and the buildings provisions in the SAVE Directive (93/76/EEC). The Directive on the energy performance of buildings (EBPD 2002/91/EC), enforced since January 2003 builds on those measures with the aim to carry out an ambitious step-ahead to increase the energy performance of public, commercial and private buildings in all Member States. In order to support the implementation of the Directive the European Commission established the EPBD Buildings Platform which provides information services for practitioners and

consultants, experts in energy agencies, interest groups and national policy makers in the European Member States[4].
As far CHP is concerned, the Communities strategy outlined in the Commission's cogeneration strategy of 1997 sets an overall indicative target of doubling the share of electricity production from cogeneration to 18 percent by 2010. The indicative target was taken up in the Communication on CHP (COM(97)514 final) providing for an analysis of the barriers and strategies for is realization. Afterwards, the Directive 2004/8/EC has been introduced. This Directive aims to reduce energy demand as a means to achieve security of energy supply, and to contribute towards the EU's carbon-saving targets. As the indicative target value from the 1997 strategy is out-dated, the Directive does not include targets but it urges Member States to carry out analyses of their potential for high efficiency cogeneration. Therefore the overall objective of the Directive is to create a framework to facilitate and support the installation and proper functioning of cogeneration where a useful heat demand exists or is foreseen.

The European Union has highlighted the existence of a potential energy saving of over 20 percent by 2020, which can be met removing wastes and inefficiencies. Realizing this potentials will bring to some 390 Mt of oil equivalent energy savings, along with large energy and environmental benefits. For example, it is estimated a CO_2 emissions reduction of 780 Mt CO_2 with respect to the baseline scenario, which is more than twice the EU reductions needed under the Kyoto Protocol by 2012. On basis of the policies and measures contained in the Green Paper on Energy Efficiency: "Doing More with Less", an Action Plan has been presented in October 2006, by the European Commission. The Plan is built on the existing EU energy efficiency legislation and its objective is to provide a framework, which helps achieving the 20 percent saving potentials. This framework is constituted by a list of cost-effective measures, by priority actions to be either immediately initiated or executed gradually along the Plan's six years period. The NEEAPs will integrate well with the objectives of the Action Plan, as far as the latter represent the instruments for monitoring, reviewing and updating the plan.
The Commission has published an impact assessment report for the Action Plan for Energy Efficiency, which allow to quantify the effects of the action proposed (Tipping et al., 2006). The estimates however contain a certain degree of uncertainty, as far as a

[4] The existing implemented Directives for ECO-design of energy-using products are related to ballasts for fluorescent lighting (2000/55/EC), household electric refrigerators and freezers (96/57/EC), hot-water boilers fired with liquid or gaseous fuels (92/42/EEC). These Directives have been amended in July 2005 by the article 21 of the Directive 2005/32/EC. The latter define conditions and criteria for setting requirements regarding environmentally relevant product characteristics (such as energy consumption). In principle, the Directive applies to all energy using products (except vehicles for transport) and covers all energy sources. For energy demand in households the most important Directives are the energy labelling for electric refrigerators (2003/66/EC), electric ovens (2002/40/EC), air-conditioners (2002/31/EC), dishwashers (1999/9/EC) and household lamps (98/11/EC). Others Directives are related to household dishwashers (97/17/EC) washing machines (96/89/EC), household combined washer-driers (96/60/EC) household electric tumble driers (95/13/EC), household washing machines (95/12/EC), household electric refrigerators, freezers and their combinations (94/2/EC), household appliances (92/75/EEC).

wide range of topics, at all levels of policy and decision makers, is involved. After evaluating a large set of possible instruments, some priority actions have been selected on the ground of their impact on energy savings. By far the most promising measure seem to be the extension of white certificate schemes, after evaluation of present national schemes, to all EU-countries coupled with energy efficiency obligations on energy suppliers (80Mtoe of potential savings), followed by maximum CO_2 emission standards for different type of cars coupled with more stringent agreements with car and truck producers after 2008-2009 (28Mtoe of potential savings) and end-user price increase to discourage fuel use (20Mtoe of potential savings). Taken altogether the eighteen policy options identify up to 353 Mtoe of potential primary energy savings over and above the 'business as usual' projection without taking into account antagonistic or synergetic interactions (overlap) between the different policy options. Taking into account the separate policy options overlap the gross estimated aggregate energy savings potential estimate reduces by 26% to 262 Mtoe in year 2020.

Box .1 Energy saving policies around the world

An interesting study has been published by the World Energy Council, to review and evaluate some energy efficiency measures around the world[5]. The study focuses in particular on five measures - Mandatory energy audits, Energy Service Companies (ESCO's), Energy incentives for cars, Energy efficiency obligation for energy utilities, and Package of measures for solar water heaters- and it covers instutional aspects, regulations and financial measures. The analysis has been conducted by means of case studies.
Clear conclusions are stated:

- It is recognised a crucial role of pricing for the promotion of energy efficiency. A correct price signal should be provided to consumers, to build the incentives to modify their behaviour or to acquire energy efficient equipment. Fiscal and pricing policies are a strong instrument to internalise long-term costs and benefits in energy markets.
- It is emphasized that the establishment of institutions, such as agencies, is necessary to design, coordinate and evaluate programmes and measures. Moreover, they prove to be important to contract various types of stakeholders, such as companies or banks.
- Mandatory efficiency standards are another important instrument for energy efficiency. Their effect is maximized if policy makers provide both consumers and manufacturers or constructors with signals of future regulations well in advance, so that they can adapt in advance of these. Moreover, it is stated that standards should be regularly updated to be effective.
- Innovative standards for buildings are more costly than current standards, but the extra cost drops rapidly due to the externalities generated by the learning effect. Therefore the application of the most efficient appliances and buildings should be boosted by complementary policies, aiming at an increase in their market share. These efficient appliances and buildings are highly effective to reduce the cost and to make the implementation of the new regulations easier.
- Regulations on buildings or equipment need to be enforced. In fact, enforcing the existing regulations may be as efficient as innovating the regulations.
- Energy efficiency norms for appliances and equipment contribute to differentiate between low and high efficiency equipment. Moreover they can be used for advertising incentive policies, such as tax credit or eligibility to funding schemes.
- The industry sector provides the best result in terms of energy efficiency progress, whereas

[5] World Energy Council (2008).

passenger transport and households are the worst performing areas. On the one hand, the increased income and lifestyle changes have partially offset the technical energy efficiency gains. In this regard, technologies such as speed limiters, thermal regulation of room temperature, automatic switch off of lights and light sensors should be promoted to reduce the effect of behaviour and limit the rebound effects[6]. On the other, the bad performance of the transport sector is due to a rapid energy demand growth and the existence of limited real measures that have been implemented so far.

Other studies evaluate the impact of past energy efficiency policies and instruments. Among these, Geller et al. (2006), list the result of the evaluation of the most effective programs:

- application of energy codes;
- industrial voluntary agreements;
- pricing initiatives;
- financial incentives at national level;
- EU- wide appliance labelling and standards;
- Agreement on CO_2 emission intensity.

It is somehow possible to report the effective amount of energy saved, even if it may be hard to disentangle the effect of a single policy from the combination of market forces and ongoing technological changes. Therefore, the following measures should be interpred with caution.

- Thermal insulation reduced heating energy consumption per unit of floor area by 30 percent between 1978 and 1993 (Germany);
- Voluntary agreements program with industries allowed an increase in energy efficiency of 20 percent for the covered industries between 1989 and 2000 (the Netherlands);
- Voluntary agreements signed by the EC and appliance manufacturers, contributed to 20 percent decrease in energy consumption of clothes and dish washers, as well as 25-35 percent reduction in standby power consumption of TVs and VCRs (various countries in Europe);
- Labelling and standards dropped the average electricity consumption of refrigerators and freezers by 27 percent between 1990 and 1999 (various countries in Europe).

[6] The rebound effect measures the tendency to “take back” potential energy savings from fuel economy improvements as increased use of energy consuming technologies (e.g. more travels on a more efficient car). See Greening and Green (1998).

2. Main Energy Efficiency Indicators for the EU

This Section aims to provide a preliminary international comparison of energy efficiency indicators. Energy efficiency is evaluated by macro and specific indicators defined at the level of the economy as a whole, of a sector, of an end-use. Three indicators are considered to compare energy efficiency performances and to monitor energy efficiency trends.

- Energy Intensities index (E.I.): it is the ratio between energy consumption and a macro-economic variable, measured in monetary units;
- Energy Efficiency index (E.E.): it accounts for a synthesis of energy efficiency trends, assessed using unit consumption measures, that relate energy consumption to a physical indicator of activity;
- Carbon Intensity (C.I.): it is the ratio between emissions, generally expressed in terms of CO_2, and a macro-economic variable measured in monetary units.

The indicators can also be used to help monitoring the success of key policies that attempt to influence energy consumption and energy efficiency.

It is important to notice that, although energy efficiency indices are always computable for the household sectors, energy and emission intensity indicators cannot be calculated, since there is no GVA related to this sector.

To frame our discussion in its appropriate context, let us look briefly to the general situation of energy consumption in Europe.

2.1 The EU Energy Consumption

Despite being the largest economy in terms of GDP, the growth in energy consumption of Europe is rather limited. Europe contributes to 16 percent of total world energy consumption, which is as much as China, and less than the amount consumed by USA (Figure 1).

The primary and final energy consumption increased at approximately the same rate between 1990 and 2004 (1% per year on average) in the EU-15 and amounted to around respectively 1000 million of ton oil equivalent (Mtoe) and 1500 Mtoe (source: ODYSSEE). However, the period 1993-2000 was characterized by faster growth in energy consumption (1.5% per year) driven by a steady and rapid expansion of the economy (2.7% per year for the GDP and 2.3% per year for industry). Since 2000, there has been a slowdown in economic activity, which has resulted in a lower progression of energy use. Electricity demand underwent a more rapid progression of around 2% per year on average. The ODYSSEE database shows that the final energy consumption per unit of Gross Domestic Product (GDP) has been decreasing within the European Union during the last years:

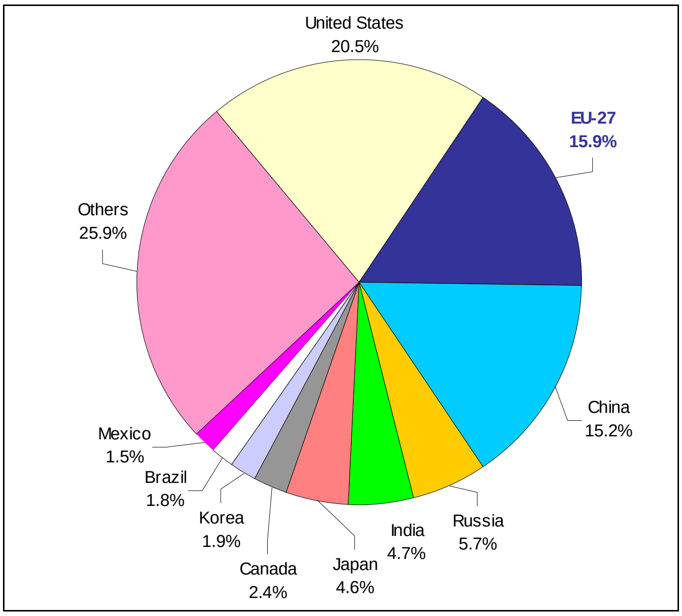
	1990	1995	2000	2005
EU-15	0.1220	0.1160	0.1090	0.1030
EU-27	-	0.1230	0.1120	0.1070

Table 2: Final energy consumption per unit of GDP in kilo oil equivalent per person in 2005, at ppp. ***Source :Enerdata, 2007***

In 2007, the final energy consumption of the European Union (EU-27) reached 1196 Mtoe. The industrial sector accounted for 25% of final energy consumption and the residential sector for 25%, the remainder was shared among services transport , and agriculture . The share of renewable energies in the total final energy consumption was 9% (source: Enerdata).

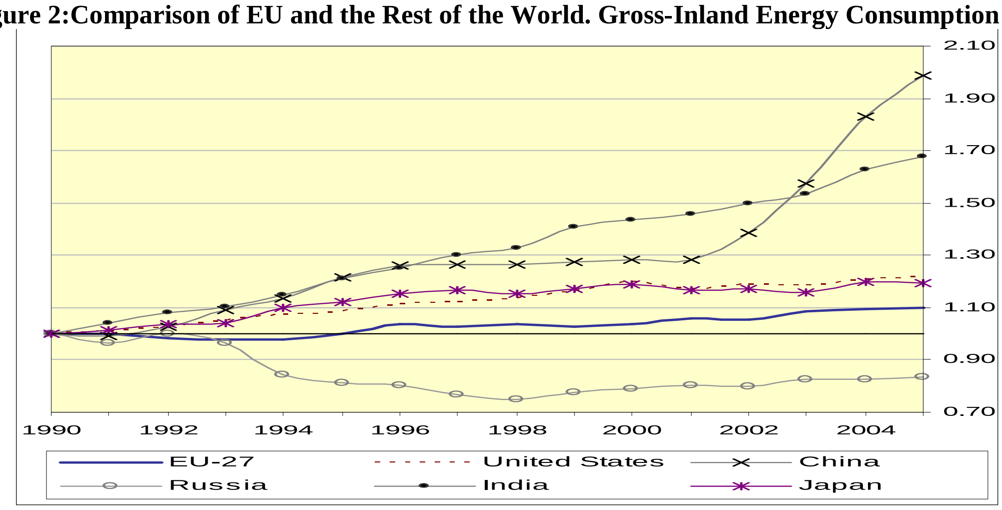
Indexing the level of energy consumption in 1990, the European consumption decreased right after, and from 1996 it smoothly increased at a rate of ten percent in 15 years, which is sensibly lower than the one shown by the other world economies (Figure 2).

Figure 1: Comparison of EU and the Rest of the World. Gross-Inland Energy Consumption. Year 200



Notes: 1990=1. China, including Hong Kong. Source: Eurostat.

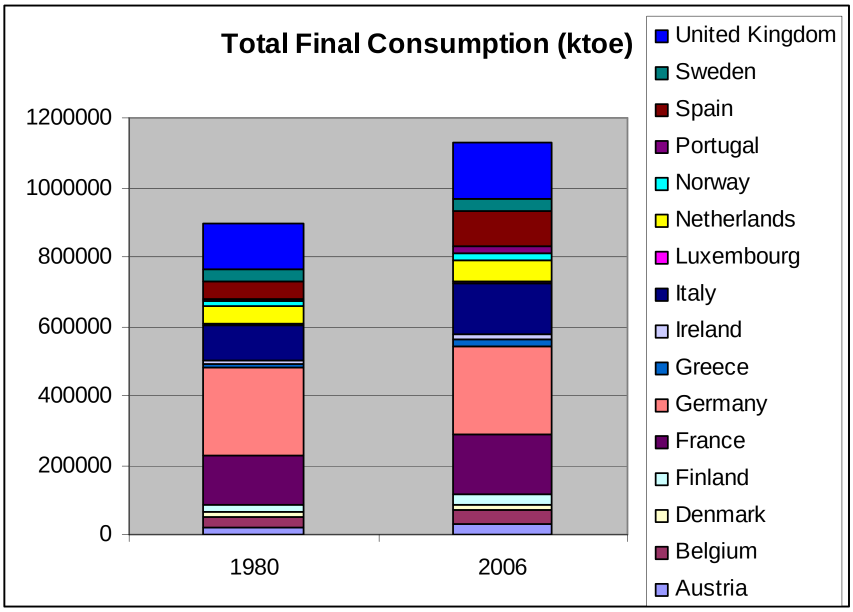
Figure 2:Comparison of EU and the Rest of the World. Gross-Inland Energy Consumption



Notes: 1990=1. Source: Eurostat data.

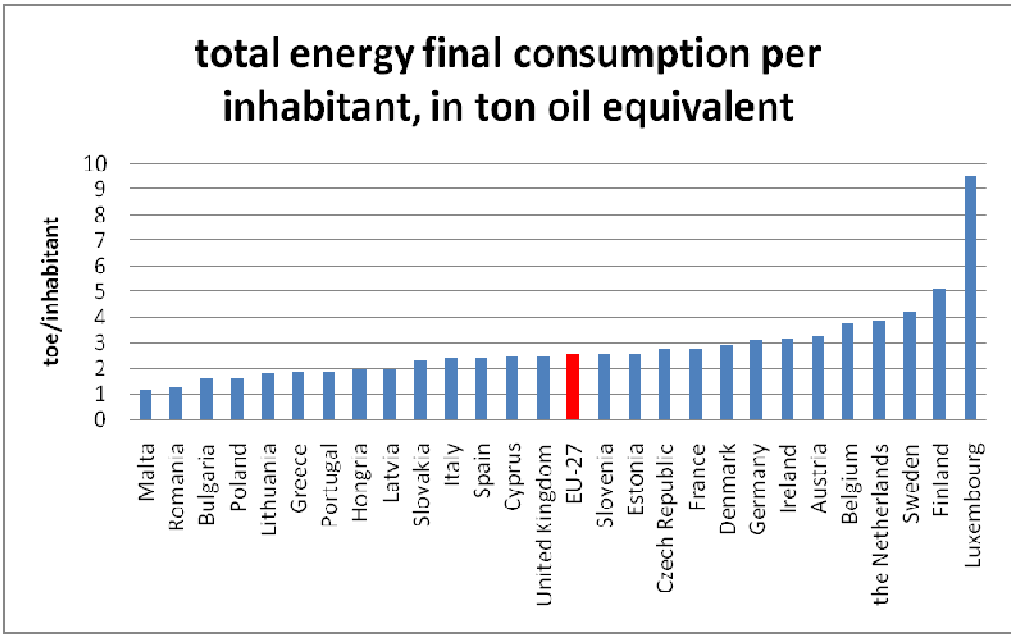
Regarding the relative contribution on European energy consumption from EU-15 Countries (Figure 3), it can be noticed that from 1980 the energy consumption has increased for the EU as a whole, while the consumption share of each country has remained rather stable. The highest portion of energy consumption is ascribable to Germany, followed by France, United Kingdom and Italy. While France, Italy and Spain registered the highest increase in energy consumption from 1980 to 2006.

Figure 3: Final Energy Consumption, by Country: EU-15 + Norway. Comparison between 1980 and 2006 levels, ktoe.



Source: Author s' computation on data from IEA.

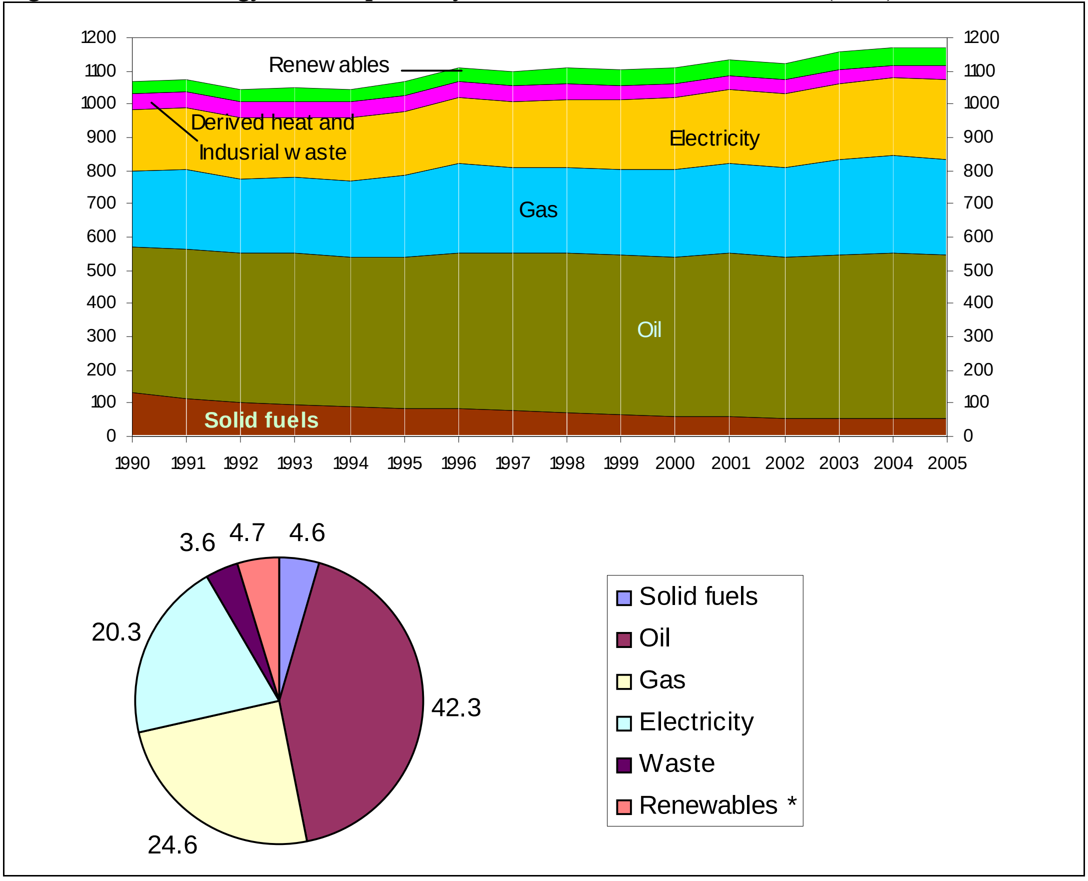
Figure 4. Per capita energy consumption in Europe ***Source: Enerdata, 2007***



The final energy consumption per inhabitant in 2007 (Figure 4) varies from a country to country within the EU. There is a large potential for the improvement of the energy efficiency among the new members in terms of final energy intensities of the member states in the EU (e.g. with the ODEX indicator), although their share in the European final energy consumption is only 12%.

Disaggregating demand by energy fuels, European consumption is mainly composed by oil, gas and electricity (Figure 5), and their shares are equal respectively to 42, 25 and 20 percent. Solid fuels, in spite of being historically an important source of energy, at the present it contributes only marginally to the total energy mix. Renewable energy sources and industrial waste own a limited share of total consumption and their contribution remained invariant during the last 15 years.

Figure 5: Final Energy Consumption, by Fuel: EU-27. Mtoe and Shares (2005)

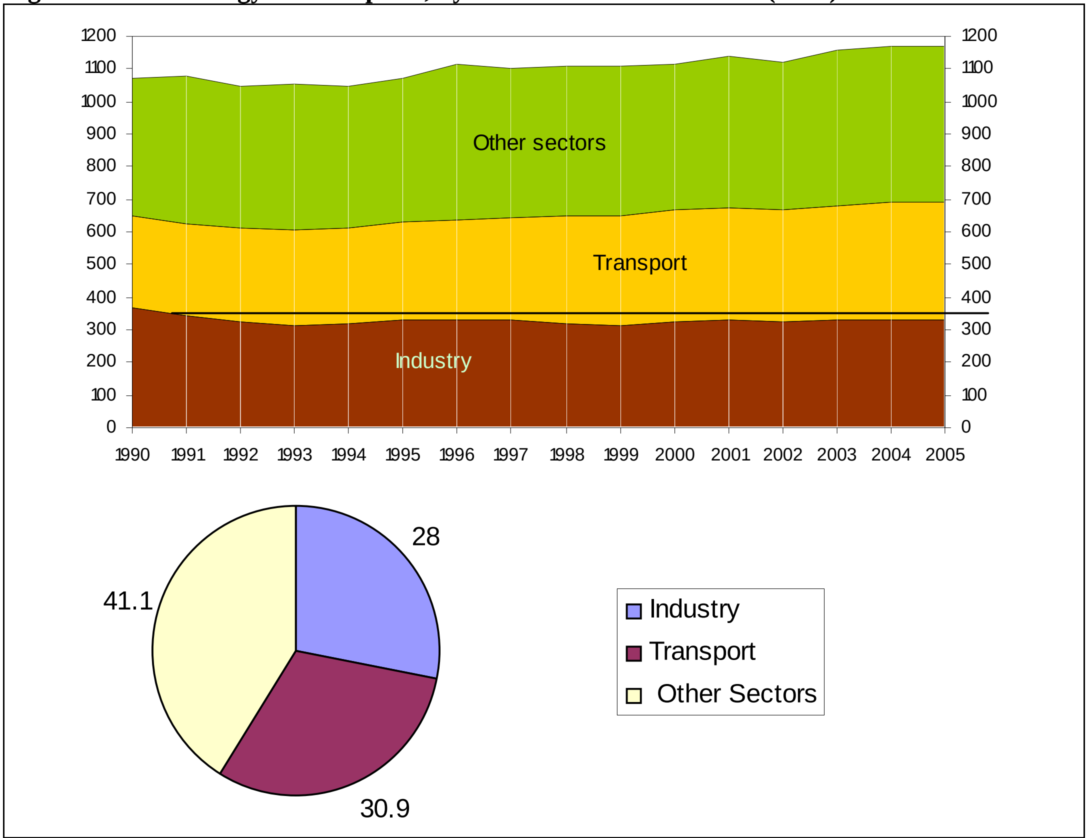


Note: * Renewables not including Electricity. Source: Eurostat.

Looking at energy demand from a different angle, it is worth noticing that the service and household sectors taken together (this aggregate is labelled "other sectors" in Figure 6) contribute to the largest share of total final energy consumption, then followed by industry and finally by transport. Over the 15 year period, the demand in the industry sector has slightly decreased, while an opposite trend characterizes the transport sector.

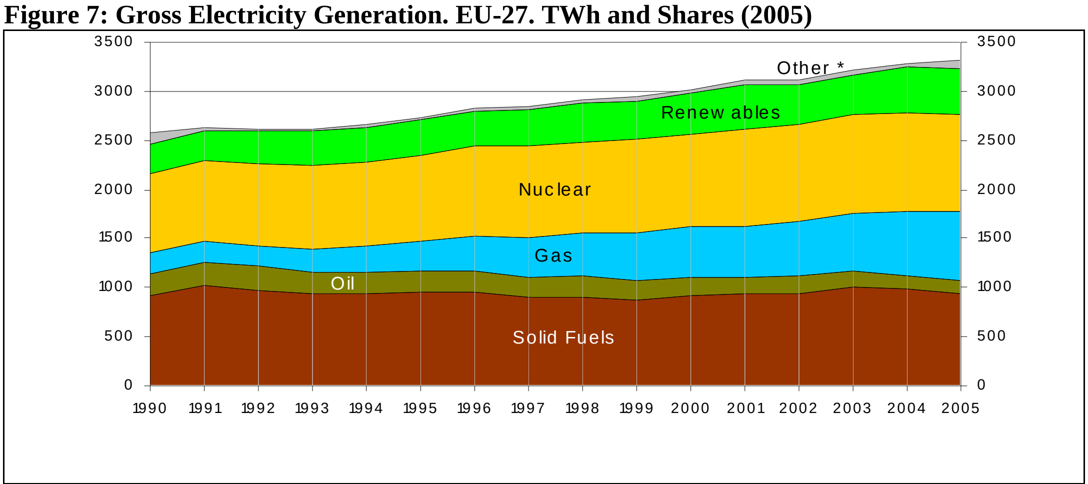
Moving to the production side, in particular electricity generation, solid fuels remain a significant energy source, contributing to 28 percent of total generation, although their use has diminished a little over time. The largest source is represented by nuclear, making more than 30 percent of total production. A sustained upward thrust is displayed by gas, which at present guarantees 21 percent of total production. Renewables own a relevant share, which amounts to 14 percent.

Figure 6: Final Energy Consumption, by Sector. EU-27 and shares (2005)



Source: Eurostat.

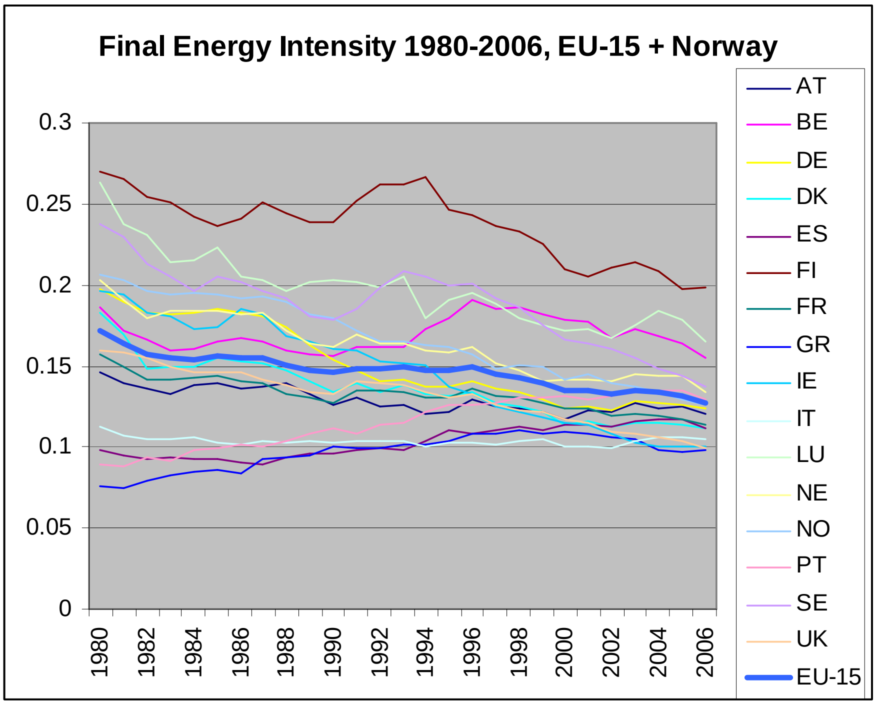
Figure 7: Gross Electricity Generation. EU-27. TWh and Shares (2005)



2.2 Energy Intensity in the EU

This Section provides a preliminary international comparison of energy intensity indicators. Figure 8 reports data on energy intensity[7] for 16 European countries. Because of data availability, we have decided to focus on the EU-15 countries and on Norway, i.e. the countries where those data are available since 1980. The countries that have recently joined the European Union have not been included in the analysis. In fact, for these countries time series are available only since 1990. In addition, because of their geographical and economic proximity, data for the EU-15 nations are more easily comparable.

Figure 8: Final Energy Intensity in European Countries + Norway, 1980-2006, ktoe/00$ppp.



Source: Author's computation on data from IEA, EUROSTAT, OECD.

Energy Intensity is an **economic** indicator of energy used in the production activity of a country. The index is defined as the ratio between energy consumption and an indicator of activity measured in monetary units (e.g. GVA). This indicator can be used whenever energy efficiency is assessed at a high level of aggregation (i.e. at the level of the whole economy or at a sector level), since in this case it is not possible to characterise economic activity with technical or physical indicators. High (low) E.I. indicates a high (low) price or cost of converting energy into GVA. The classical E.I. index is calculated by dividing energy consumption by GVA, on a sector basis.
In this study the final and sectoral energy consumption have been obtained from the IEA balance sheet (ktoe). The sectoral values added result from a combination of data from EUROSTAT national accounts and OECD database.
Figure 8 shows the patterns of final energy intensity of the overall economy in the EU-15 and Norway from 1980 to 2006. Looking at the European average, the index exhibits

[7] Estimated as energy use per unit of output.

a smoothly decrease over the entire period under scrutiny. The largest improvements are displayed by Luxembourg and Finland, the latter registering a sharp decrease in the E.I. index, which changes over from 0.27 ktoe/00$ppp in 1980 to 0.19 in 2006. By contrast, the Portuguese E.I. index shows a stable upward trend, interrupted by a drop starting from 2005. In Spain after a period of decrease, the index starts to grow from the '90s. On the other hand, Italy exhibits a pattern divisible in four phases. In the first one it displays a stable decrease in the E.I. index until the mid-'80s. From this period the index remains nearly constant up to 2002, when it starts to rise. In the latest phase, starting in 2005, the index drops again.

Table 3 reports data on energy intensity of the industry sector for the sixteen countries under scrutiny.

3-year Average Centered on 1985			**3-year Average Centered on 1995**			**3-year Average Centered on 2005**	
IT	0.113		IE	0.110		IE	0.063
ES	0.120		DK	0.113		DK	0.088
UK	0.121		IT	0.120		GR	0.108
DK	0.122		UK	0.123		UK	0.117
GR	0.125		GR	0.125		IT	0.126
AT	0.136		AT	0.130		NO	0.131
PT	0.150		ES	0.137		AT	0.139
FR	0.163		DE	0.137		DE	0.139
DE	0.165		FR	0.167		ES	0.142
IE	0.173		PT	0.184		FR	0.154
BE	0.209		NO	0.195		PT	0.201
NE	0.227		NE	0.215		SE	0.210
NO	0.240		BE	0.278		NE	0.234
SE	0.252		SE	0.285		LU	0.240
FI	0.330		LU	0.315		BE	0.297
LU	0.391		FI	0.370		FI	0.318
Average	0.190			0.188			0.169
Median	0.164			0.152			0.140
Minimum	0.113			0.110			0.063
Maximum	0.391			0.370			0.318

Source: Authors' computation on data from IEA, EUROSTAT, OECD.
Note: arrows shows movements between quartiles over time.

Table 3: Energy Intensity in Industry Sector: EU-15+ Norway, 1980-2006, ktoe/00$ppp.

As Table 3 shows, in 2005 the countries with the highest energy intensity were Ireland, Denmark and Greece. Energy policy decisions taken by the respective authorities (as well as their structure for the productive sector) have allowed these countries to reach good results in terms of energy intensity achievements.
Table 3 highlights that, between 1995 and 2005, apart from Portugal and Spain, energy intensity has improved significantly in countries like Norway, Luxembourg, Ireland, Denmark and Greece. The best performance is achieved by Ireland, climbing from the

tenth position in 1985 to the top of the ranking in 1995 and 2005. Some countries, such as Ireland, Denmark and Norway, have improved their position both in absolute and in relative terms during the period considered. Others, like France, in spite of the improvement of the E.I. index, have lost their position with respect to countries that have performed better.

In addition, Table 3 illustrates also a general trend regarding the energy intensity of European countries. The average value steady decreases, losing almost the 12 percent of the 1985 value. Even the median value displays a significant downward trend, switching most of countries closer to the minimum value.

Finally, the difference between the minimum value and the maximum value decreases as well (0.255 in 2005 with respect to 0.278 at the begin of the period). This information provides additional evidence on how energy intensity has improved (and converged) among the considered countries.The trend of energy intensity index for the other sectors is shown in Table 4.

3-year Average Centered on 1985			**3-year Average Centered on 1995**			**3-year Average Centered on 2005**	
GR	0.033		ES	0.042		LU	0.041
ES	0.035		GR	0.049		ES	0.046
PT	0.036		PT	0.05		PT	0.054
IT	0.060		IT	0.053		GR	0.055
LU	0.078		LU	0.058		UK	0.058
FR	0.093		FR	0.077		IT	0.060
AT	0.103		AT	0.084		IE	0.065
BE	0.104		UK	0.086		FR	0.070
UK	0.111		DE	0.093		AT	0.072
DK	0.116		DK	0.095		NE	0.072
NO	0.118		BE	0.100		SE	0.077
IE	0.120		NE	0.100		DK	0.080
NE	0.125		NO	0.102		BE	0.080
SE	0.132		IE	0.104		DE	0.082
FI	0.146		SE	0.120		NO	0.087
DE	0.149		FI	0.152		FI	0.109
Average	0.097			0.085			0.069
Median	0.107			0.090			0.071
Minimum	0.033			0.042			0.041
Maximum	0.149			0.152			0.109

Source: Authors' computation on data from IEA, EUROSTAT, OECD.
Note: arrows shows movements between quartiles over time.

Table 4: Energy Intensity in Other Sectors: EU-15+ Norway, 1980-2006, ktoe/00$ppp.

Similarly to the industrial sector case, the energy intensity declined significantly on average over the period considered.

Between 1995 and 2005, important improvements were achieved by Ireland and Luxembourg, in both cases the index decreased significantly (by 37 and 29 percent

respectively). In Germany, the E.I. index shows an U-shape trend, with a noticeable decline between 1985 and 1995 and a rapid growth in the following period.
Over the entire period considered, energy intensity remains particularly low in the Southern countries (Portugal, Spain, Greece and Italy), reflecting particularly favorable climate conditions that allows these countries to reduce the need of energy for heating. On the contrary, Scandinavian countries (Finland, Sweden and Norway) reported high values for the index.
Finally, Table 4 also shows a partial process of convergence of energy intensities across the European countries considered in the present study. In fact, since 1985, the dispersion of values for the energy intensity indicators as well the difference between the minimum and the maximum values of the energy intensity index significantly decreased.
Looking at the transport sector, Table 5 shows as the best performing countries in terms of energy intensity are Finland, Greece, Norway and Italy.

3-year Average Centered on 1985			3-year Average Centered on 1995			3-year Average Centered on 2005	
IT	0.42		NO	0.371		FI	0.356
AT	0.421		AT	0.414		GR	0.391
ES	0.423		FI	0.457		NO	0.399
NO	0.429		IT	0.463		IT	0.424
PT	0.432		BE	0.510		BE	0.441
FI	0.471		NE	0.515		DK	0.458
BE	0.490		DK	0.520		NE	0.474
SE	0.508		ES	0.522		SE	0.478
NE	0.510		UK	0.522		UK	0.481
FR	0.523		SE	0.553		FR	0.529
UK	0.539		FR	0.602		AT	0.545
DK	0.628		PT	0.604		DE	0.550
DE	0.633		DE	0.650		ES	0.631
IE	0.778		GR	0.662		PT	0.663
LU	0.862		IE	0.706		IE	0.744
GR	0.976		LU	0.955		LU	1.125
Average	0.565			0.564			0.543
Median	0.509			0.522			0.479
Minimum	0.420			0.371			0.356
Maximum	0.976			0.955			1.125

Source: Authors' computation on data from IEA, EUROSTAT, OECD.
Note: arrows shows movements between quartiles over time

Table 5: Energy Intensity in Transport Sector: EU-15+ Norway, 1980-2006, ktoe/00$ppp.

Between 1985 and 2005, despite of the decrease in average energy intensity, the dispersion among Countries (*proxied* by the standard deviation of the different values and the range between the minimum and the maximum values) increased from 0.169 to 0.187 for the former proxy and from 0.556 to 0.769 for the latter.
At the country level, while there were important achievements in term of energy intensity in the Denmark and Greece, (Greece climbed from the bottom in 1985 to the

second best in 2005), energy intensity increased significantly in Austria, Portugal and Spain, where it worsened severely, falling from the third position to the 13th in 2005.

2.3. The EU Carbon Intensity

CO_2 emission equivalents are computed on the basis of the global warming potential of each greenhouse gas[8], i.e. the contribution to global warming of each gas relative to CO_2. The recommended methodology considers the whole life cycle of each energy vector, thus including both direct emissions, related to the final uses of energy sources (that is, energy consumption) and indirect emissions, related to the production, transport and distribution stages of the energy vectors' value chains. Generally speaking, direct emissions are generated locally, while indirect emissions can take place both within and outside the region under scrutiny. Focusing on direct emissions may be more practical in absence of reliable Life Cycle Inventory data.

Carbon Intensity is an indicator akin to energy intensity, and measures the degree of carbonisation of an economy or of a given productive sector. At the aggregated level, Carbon Intensity is computed as the ratio of CO_2 emission equivalents generated (in terms of Mton of CO_2) to the indicator of economic activity, Gross Value Added (GVA). The same sectoral disaggregation as in the case of energy intensity can be performed. Moreover, note that Carbon Intensity can be interpreted as the product of energy intensity and the carbon content of the energy consumed, or

$$\mathrm{I.CO_2} = \frac{CO_2}{GVA} * \frac{E}{\mathrm{E}} = \frac{E}{GVA} * \frac{CO_2}{E} = E.I * \frac{CO_2}{E}. \qquad (1)$$

The *Carbon Content* of consumed energy measures the quantity of CO_2 (or, in its more general format, CO_2 equivalents), per unit of energy consumed. It can happen that energy intensity increases while carbon intensity decreases, for instance in presence of a massive switch from oil to natural gas; the latter being "cleaner" and allowing a decrease in CO_2 equivalents emitted while leaving unchanged the quantity energy consumed. The Carbon Content can thus be regarded as a technological parameter which takes into account changes in the fuel mix of country or of a sector.

Available information on CO_2 emissions starts from 1990 for the countries under scrutiny , therefore carbon intensity indexes cover a shorter period than energy intensity and energy security indexes.

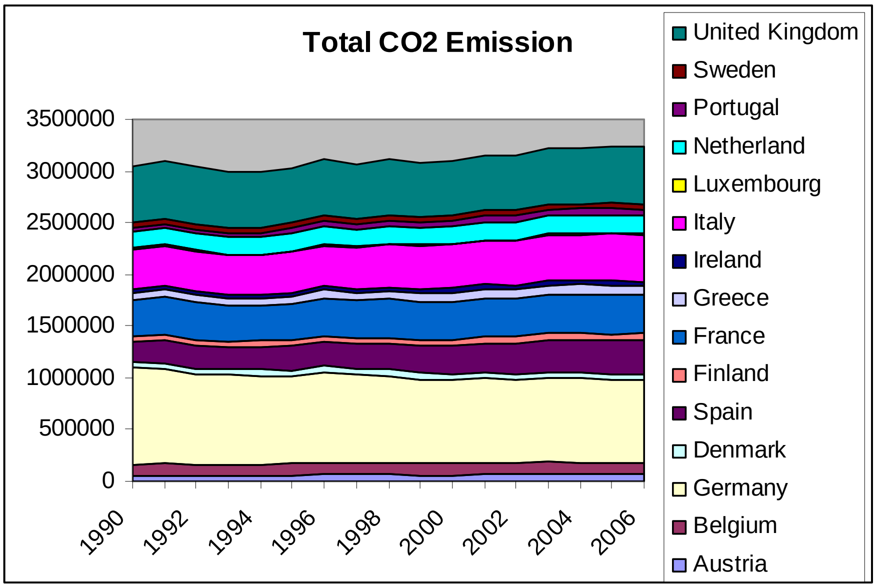
Figure 9 displays the trend of carbon intensity index in European countries over the period 1990-2006. The index refers to CO_2 emissions from all sectors, including emissions from energy sector.

In Europe, total CO_2 emissions marked a slightly increase from 1990, with a growth rate of 5.8 percent between 1990 and 2006. In 2006 the highest contribution to total CO_2 emissions in Europe is ascribable to Germany, followed by United Kingdom, Italy and France. As for the energy consumption, the shares of CO_2 emissions by country remain rather stable during the period considered. While being the main emitters, in relative terms, of CO_2 in Europe, Germany and United Kingdom are the only EU countries

[8] CO_2= 1, CH_4=21, N_2O=310.

which show a decrease of emissions during the period under scrutiny, by 14 percent and 1 percent respectively, while the largest increase takes place in Spain.

Figure 9: Total CO_2 Emission in European Countries , 1990-2006.

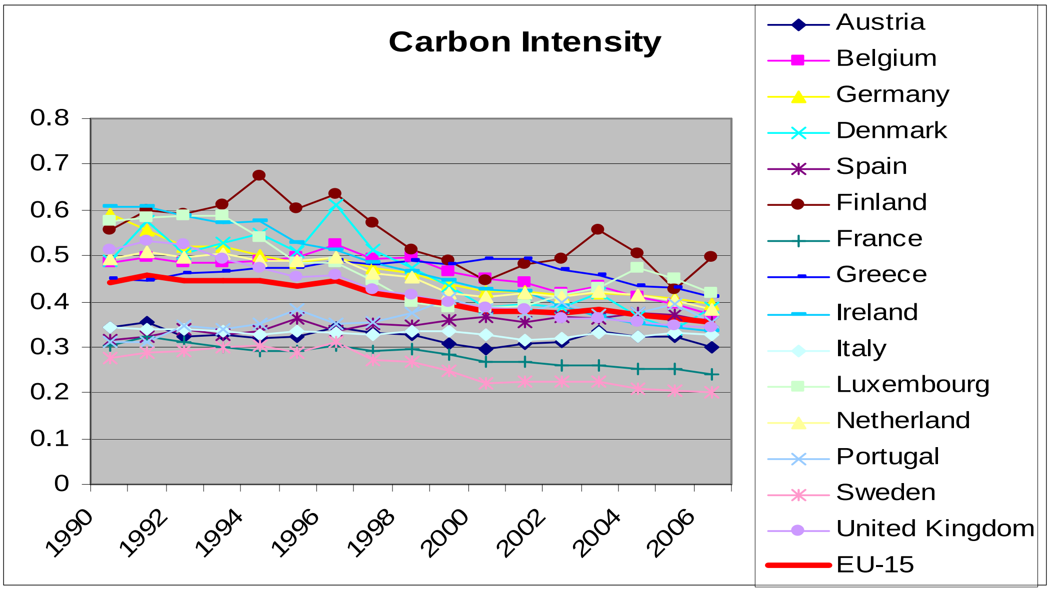


Source: Authors' computation on data from ENERDATA.

Figure 10 shows the trend of carbon intensity in European countries between 1990 and 2006. Looking at the average of EU-15 countries, the carbon intensity falls from 1990 to 2006 by about 20 percentage points, although in two countries, namely Spain and Portugal, the index increased. The best performances are attained by Ireland and Germany, which show a variation of about -45 and -33 percent respectively between 1990 and 2006.
Disaggregating the carbon intensity by sectors, the analysis focus on the direct emissions, excluding emissions from the energy sector. Figure 11 shows the trend of carbon intensity index for five European countries during the period 1990-2006.

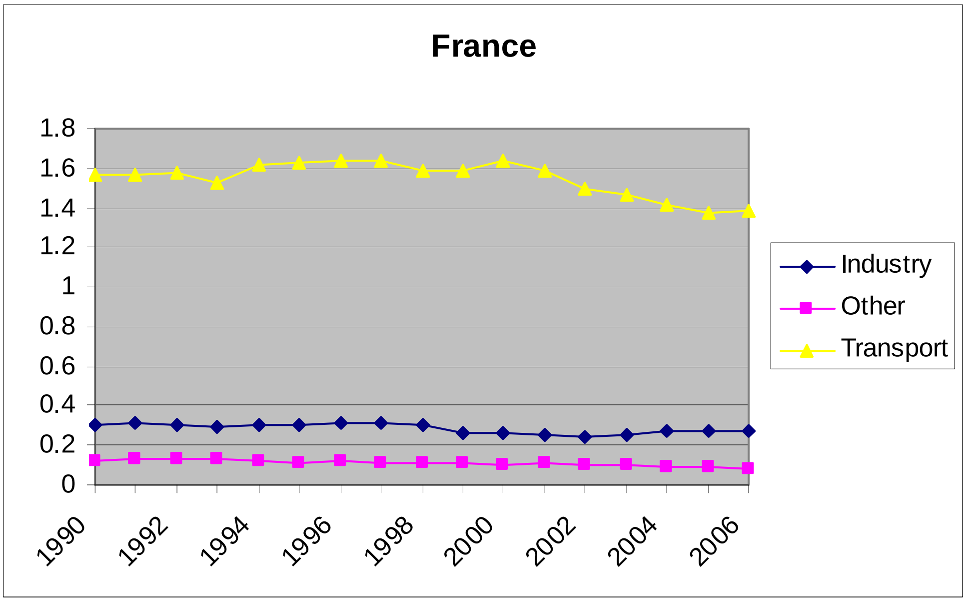
For all countries considered, the highest levels of carbon intensity take place in the transport sector, followed by the industry and the other sectors. Except Germany, where the C.I. index for industry and other sectors slightly declines, in the other four countries the index remains rather stable during the entire period considered. On the contrary, in the transport sector the trend of the C.I. index differs among countries. In France the index shows an upward trend, followed by a significant drop from 2001. An opposite trend is registered in United Kingdom, where the index shows a decrease until 2001 followed by a slight growth. In Germany a trend characterized by fluctuations of the C.I. index is followed by a significant decrease from 2000. The Italian index for transport falls from 2000 to 2003, while it remains practically constant in the rest of the period considered. Finally, the Spain is the only country analyzed which displays a continuous increase in the C.I. index for the transport sector.

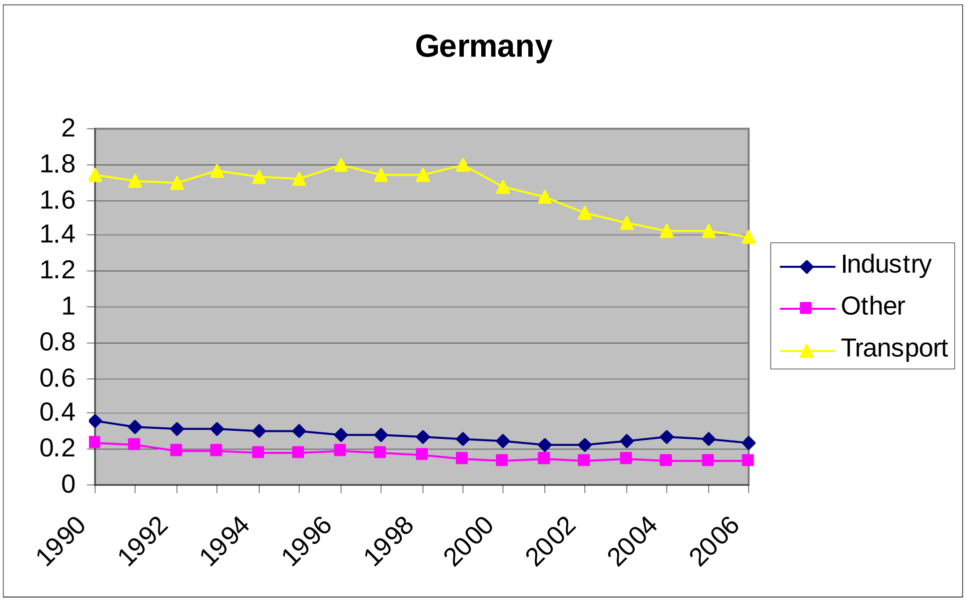
Figure 10: Total Carbon Intensity in European Countries, 1990-2006, kt CO_2/00$ppp.

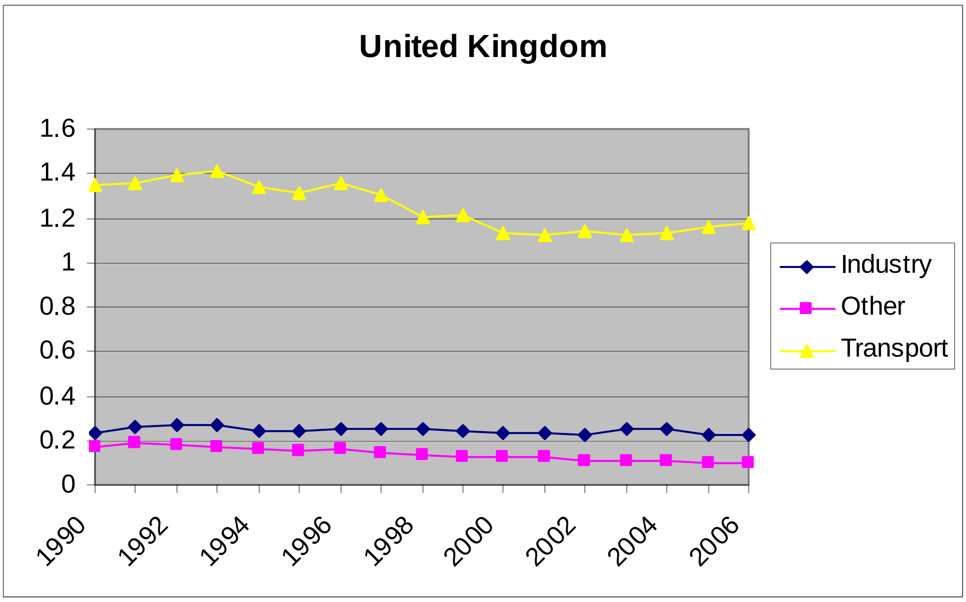


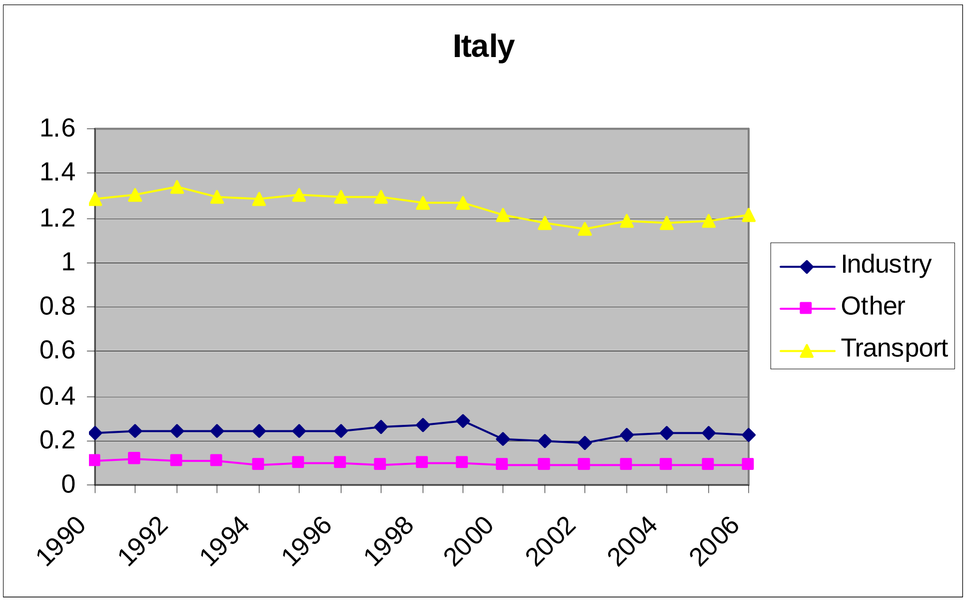
Source: Authors' computation on data from ENERDATA, EUROSTAT, OECD.

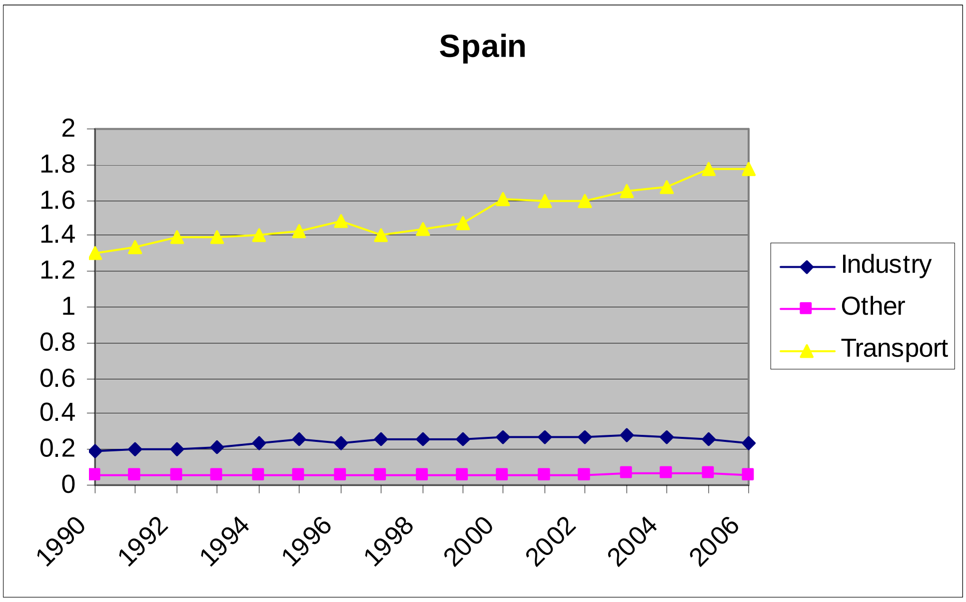
Figure 11: Final Carbon Intensity by Sector, for Selected European Countries, kt CO_2/00$ppp, 1990-2006.




Germany
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1990
1992
1994
1996
1998
2000
2002
2004
2006
Industry
Other
Transport


United Kingdom
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1990
1992
1994
1996
1998
2000
2002
2004
2006
Industry
Other
Transport





Source: Authors' computation on data from ENERDATA, EUROSTAT, OECD.

2.4 Energy efficiency within the European Union[9]

Energy efficiency can be also assessed in physical terms. One indicator allowing that, is the ODEX indicator, thus representing an alternative proxy for assessing energy efficiency trends at an aggregate level (e.g. overall economy, industry) than the traditional energy intensities. It has the advantage of not being affected by structural changes and by other factors not related to energy efficiency (more appliances, more

[9] This sub-section has been prepared by OME.

cars…). Since the energy efficiency index is crucial for the analysis of the residential sector, the construction of such indexes is discussed in detail in Deliverable 5.8.2. Here we limit ourselves to a brief summary of the overall energy efficiency in terms of the ODEX index.

Energy Efficiency has improved by about 22% or 1.3% per year between 1990 and 2006 in the EU-27. All sectors participate to those improvements.

In the industrial sector, energy efficiency improved by about 2.1% per year since 1990. Each branches, except textile, contributed to decrease the overall industrial efficiency index. Since 1998, structural changes toward less energy-intensive branches now strengthen the influence of efficiency improvements on actual energy intensity in industry. However the impact of these structural changes is limited: they explain about 13% of the reduction in the industrial intensity since 1998. The situation varies across countries.

	1990	1999	2000	2005	2006
Austria	118.2	109.1	100	94.2	94.1
Belgium	108.7	102.5	100	94.9	94.5
Denmark	110.5	106	100	96.9	95.6
Finland		105	100		
France	109.8	106.3	100	93.3	92.6
Germany		108.2	100	94.8	92.4
Greece	116.6	108.5	100	94.8	94.2
Irland		109.1	100	97	96.3
Italy	100.9	99.5	100	97.8	96
Luxembourg	166.9	125.6	100	120.5	
Netherlands	112.5	108.5	100	93.6	92.9
Portugal	102.6	98	100	98.2	97.9
Spain	105.4	103.1	100	102.9	
Sweden	105.8	102.6	100	93.9	
United Kingdom	112.4	101	100	94	93.1
EU-15	**112.4**	**104.9**	**100**	**94.9**	**94**
Bulgaria			100	93.5	93?8
Cyprus			100	89.9	87.5
Czech Republic			100	101.6	101.8
Estonia			100	91.9	95.3
Hungary			100	91.3	90.1
Latvia			100	93.3	92
Lituania			100	89.2	
Malta			100	99.8	101.1
Poland		82.2	100	85.3	86
Roumania			100	94.8	
Slovaquia			100	92.1	90.2
Slovenia			100	92.8	91.7
EU-27			**100**	**95.1**	**94.5**

Source: Enerdata

Table 6 Evolution of "ODEX" indicator in the EU.

Energy efficiency in households has improved by 1.1% per year since 1990. Space heating and large appliances experienced the greatest energy efficiency improvement: since 1990, close to 1.5% each year.

3. Energy saving potentials in the industrial sector[10]

3.1. Industrial energy consumption in the EU

The International Energy Agency (IEA, 2007) reports that industry accounts worldwide for nearly one third of total global primary energy supply[11] and 36% of CO_2 emissions. Total final energy use by industry was 113 EJ in 2004[12]. Rough estimates suggest that 15% of total energy demand in industry is for feedstock, 20% for process energy at temperatures above 400°C, 15% for motor drive systems, 15% for steam at 100-400°C, 15% for low-temperature heat and 20% for other uses, such as lighting and transport.

In Europe (EU-15, in 2004), the industrial sector consumed around 27% of the energy used by final consumers (279 Mtoe)[13], of which 97% was consumed by the manufacturing industry. Industry is the sector with the slowest progression in energy consumption (comparing to residential and transport sectors); as a result, its share in final energy consumption has been falling between 1990 and 2004 (by 3 points). In some countries (Greece, the United Kingdom, Ireland, Germany, Luxembourg, Portugal, Belgium), the drop in the importance of the sector has been quite significant (minus 5 points on average). Over the same period, energy efficiency improved by 12% in manufacturing industry.
IEA's analysis shows that substantial opportunities to improve industrial energy efficiency remain within the European countries. For example, it recommends to establish standards for industrial electric motors, or to examine the barriers to the optimization of energy efficiency in motor-driven systems. Its analysis shows that there is a significant potential for energy savings through enhanced energy efficiency policies for motors.
The IEA estimates that if all countries adopt best-practice, minimum-energy-performance standards for industrial electric motors, between 240 and 475 TWh of electricity demand could be saved by 2030.

3.2. Latest evolutions in the fuel switching options and energy savings potentials in the industrial sector per sub-sector

Industrial energy intensity (energy use per unit of industrial output) has declined substantially over the last three decades across all manufacturing sub-sectors and all regions of the world. In absolute terms, however, energy use and CO_2 emissions have increased worldwide. Industrial final energy use increased 61% between 1971 and 2004, with an average annual growth of 2%.

---

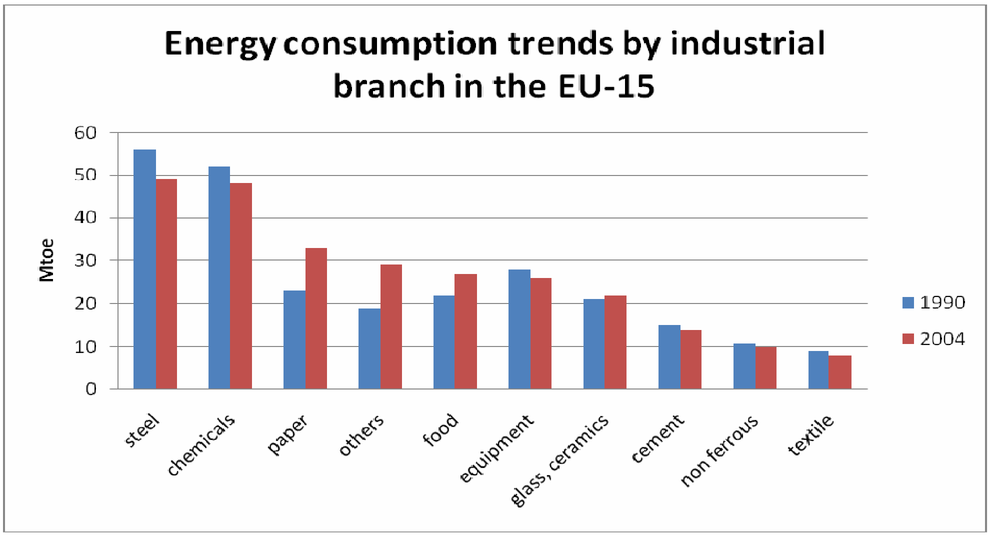
[10] This Section has been prepared by OME.
[11] 11,213 Gtoe in 2004
[12] 1 Mtoe = 41 868 EJ
[13] In the EU-25, the industrial energy use was 319 Mtoe or about 28% of the annual EU final energy use, and 30% of primary energy demand.

In Europe, industrial energy consumption increased less rapidly than the value added over the period 1993-2004 in the EU-15 as a whole (respectively by 1.2% per year and 1.8% per year), showing that energy consumption and growth are decoupled. As a result, the energy intensity of the manufacturing industry decreased by 0.9% per year over the period 1993-2004 for the EU-15. It only increased in two countries: Spain and Italy. After 2000, the reduction is much slower (0.1% per year for the EU-15), and even a reversed trend (i.e. an increase of this intensity) was observable in some countries (e.g. the Netherlands, Portugal, Denmark and Luxembourg), along with a more rapid increase in Spain and Italy. To a large extent, this recent trend is due to the influence of the recent economic downturn.

Industrial energy use has been worldwide growing strongly in recent decades. But the growth rates are not uniform and they varied significantly between sub-sectors. For example, chemicals and petrochemicals, which are the heaviest industrial energy users, doubled their energy and feedstock demand between 1971 and 2004, whereas energy consumption for iron and steel has been relatively stable despite strong growth in global production.

In Europe, between 1990 and 2004, 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%). The two most energy intensive users are the iron and the steel and chemical industries which consume 19% and 18% of industrial energy use respectively. This is followed by glass, pottery and building materials at 13%, and paper and printing at 11%. Around 25% of the electricity used by industry is produced by industry itself. Many sectors have considerably improved their energy efficiency over the past 20 years. But 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.

Figure 12 Energy consumption in industrial subsectors in the EU15, 2004 vs 1990



Source: ODYSSEE

Steel and chemicals are the largest energy consuming industrial branches: together they made up 37% of total manufacturing industry energy consumption in 2004 in the EU-15

(42% in 1990). With the other energy-intensives 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).

3.3 European policies for improving energy efficiency in the industrial sector

Following the oil price shock during the 1970's, energy efficiency in the industrial sector improved markedly during the last 30 years. Higher productivity, quality of products and new market shares are the main reasons for the industry to invest. Policies in order to boost the industrial investments have to take into consideration the international context and the world competitiveness of the companies. In fact, the policies implemented within the European Union give priority to flexible tools, notably market mechanisms.

EU energy efficiency legislation is recent, although legislation has existed for a longer period in certain member states. The steps which industry has taken have largely been voluntary and usually driven by cost, but are also in conjunction with EU initiatives.

EU could save at least 20% of its present energy consumption in a cost-effective manner, equivalent to 60 000 million € per year. The EU has announced an EEAP (Energy Efficiency Action Plan) to save up to 20% of energy throughout the Union (about 39 Mtoe) and 27% of energy in manufacturing industries by 2020. This would reduce direct costs in the EU by 100 billiard € annually by 2020 and save around 780 million tons of CO_2 per year.

the European Directive establishing a system of exchange of greenhouse gas emissions quotas in the community, the European Emissions Trading Schemes was adopted in 2003. After the first experimental phase 2005-2007, the system entered the second phase 2008-2012. The revised EU-ETS adopted in December 2008 will apply over the period 2013-2020 and should lead to a reduction in greenhouse gas emissions of the participants in the system of 21% compared to 2005 levels. The quantity of allowances issued each year in the EU will decrease in a linear fashion, so as to reduce gradually the overall level of emissions each year. Auctioning is seen as the main instrument to allocate certificates but the industry sector was, at least partially and for a transition period, exempted from auctioning and certificates were allocated based on benchmarks (grandfathering).

In the framework of the EU-ETS, every member State sets up a "National Plan of quotas Allocation" in order to allocate the national target of greenhouse gas emission reduction among the industries. The quantity of allocated quotas is lower than the initial emissions, so every industrial firm has to reduce its own emissions or to buy quotas from another industrial firm holding surplus permits. This system became a flagship measure of the European policy concerning reduction of greenhouse gas emission and improvement of energy efficiency in the industry.

Besides the ETS, in general, there are few regulatory measures on energy efficiency in the European industrial sector. In Italy, industrial firms which have an energy consumption over 10 Mtoe must designate an energy administrator. In Portugal, Romania, Bulgaria, Lithuania, the most important energy consumers have to lead a compulsory energy audit.

Some countries give priority to tax tools, as Germany, Estonia, Italy, the Netherlands, Sweden and the United Kingdom which set up environmental taxes proportional to electrical, fossil fuels consumption and gas emissions.

Direct subsidies are also implemented, particularly to finance innovative projects which introduce new efficient technologies on the market.

Energy management (EM) programs address the way an industrial plant is managed to exploit cost-effective energy savings opportunities. Global adoption of EM measures could produce industrial energy demand savings of 3-7%. Large energy savings can also be made from light industry that consumes 30% of industrial energy use by increasing EM programs in this sector. Many countries are also continuing, or expanding, their promotion of energy management in industry. These policies commonly include the provision of energy management tools, training, energy manager certification and quality assurance. Nevertheless, there is some concern about the level of energy management support in some European countries.

The lack of formal energy management policy in France and Germany is of concern. In terms of policies for the small and medium-sized enterprises, there is a lack of benchmarking information and of appropriate incentives, which need to be implemented to encourage small and medium enterprises to make least-life-cycle-cost capital acquisition decisions.

According to the IEA, "governments should consider adopting mandatory minimum energy performance standards for electric motors in line with international best practices". Moreover, "governments should examine barriers to the optimisation of energy efficiency motor-driven systems and design and implement comprehensive policy portfolio aimed at overcoming such barriers"[14].

Concerning lighting in the industrial sector, the European programme "GreenLight" was launched in February 2000. GreenLight is an on-going voluntary programme whereby private and public organizations commit towards the European Commission to reducing their lighting energy use, thus reducing polluting emissions[15].

[14] IEA (2008) Consolidated List of Energy Efficiency Recommendations prepared by the IEA for the G8 under the Gleneagles Plan of Action.

[15] An example of this policy is shown by the workshops of Beerse Metaalwerken nv, a Greenlight Partner. This firm replaced the standard high pressure mercury lamps of their workshops with 26 mm diameter fluorescent lamps. It also installed a control system to dim the lamps' output in response to daylight availability. In its offices, 36 mm diameter fluorescent lamps were replaced with 26 mm diameter lamps. All new lamps are geared with electronic ballasts.
Besides improved visual conditions, the enterprise reported the following savings:
-lighting electricity savings: 24 919 kWh/year
-Reduction of electricity use in the areas covered: 38%
-Total running cost savings: 7 133 €/year (includes company-estimated gains in productivity)
-internal rate of return of the Investment: 20%.

4. Panel Analysis: Methodology

This section describes the techniques used in WP 5.8 to identify and characterise the energy intensity, carbon efficiency, carbon intensity and energy security determinants by means of panel econometric analyses, focusing on the following factors suggested by the literature:

- Structural changes in the economy: GDP, sectoral GDP shares changes, R&D expenditure
- Policies: national and supranational energy policies (eg. EU directives, presence of national carbon/energy taxes, etc.)
- Measures: fiscal, education/information initiatives, legislation (mandatory standards or labelling), cooperative measures, cross-cutting measures
- Energy: energy prices, energy balance sheet.

The goal is hence to assess the economic variables which could have a significant effect in improving the energy intensity, energy efficiency, energy security and carbon intensity and to identify the policies and measures (P&M) implemented in European countries which have been effective for the same purpose. A further goal is to compare the significant drivers resulting from regressions, in order to understand whether there are some factors which affect both energy intensity and energy security and if improvements in carbon intensity match with lower energy intensity.

In order to achieve these goals, we estimate econometric models which exploit the panel data format. The panel data analysis approach, indeed, allows us to combine cross-sectional data and time series data, obtaining a gain in the efficiency of estimates, thanks to the availability of a larger amount of information.

The estimates have been performed by regressing the energy intensity index (EI), the energy efficiency index (EE), the energy security index (ES) and the carbon intensity index (CI) - or CO_2 emissions pro capita in the case of the household sector, on a set of explicative variables X (such as energy prices, GDP, R&D expenditure, etc.) and policy variables PM. The EI, CI and the ES indexes have been calculated both at the aggregate level and at the sub-sector level, focusing on three main sectors, namely Industry, Other and Transport sectors. For the ES and CI a more detailed disaggregation has been carried out, splitting the Other sectors into Agriculture plus Tertiary sector and Residential sector. The EE index model has been estimated for the Residential and the Transport sectors.
The analysis therefore includes 18 general panel models, with alternative specifications for energy security[16], focusing on the EU-15 countries and Norway between the period 1980-2006[17].

The econometric models have the following form:

[16] Given the vast range of possible energy security indicators, we have tested a few alternative options. See Section 6 for details.
[17] For the EE indexes the analysis focuses on the period 1980-2004.

$$EI_{it} = \alpha_i + \lambda X_{it} + \beta_1 PM1_{it} + \ldots + \beta_K PMK_{it} + u_{it} \qquad (2)$$

$$EE_{it} = \alpha_i + \lambda X_{it} + \beta_1 PM1_{it} + \ldots + \beta_K PMN_{it} + u_{it} \qquad (3)$$

$$ES_{it} = \alpha_i + \lambda X_{it} + \beta_1 PM1_{it} + \ldots + \beta_K PMN_{it} + u_{it} \qquad (4)$$

$$CI_{it} = \alpha_i + \lambda X_{it} + \beta_1 PM1_{it} + \ldots + \beta_K PMN_{it} + u_{it} \qquad (5)$$

$$CC_{it} = \alpha_i + \lambda X_{it} + \beta_1 PM1_{it} + \ldots + \beta_K PMN_{it} + u_{it} \qquad (6)$$

In the equations above, *EI* is the Energy Intensity index, *EE* is the Energy Efficiency index, *ES* is the Energy Security index, *CI* is the Carbon Intensity index, and CC are the carbon emissions per capita. The matrix X_{it} includes the explanatory variables related to economic structural changes, society and energy market. The variables PM_J, j=1,…,K, represent instead the policies included in the regression, which are dummy variables equal to 1 if the policy is in force in the *i-th* Country and *t-th* year.
The double pointer (*i*,*t*) shows the panel structure of the dataset. In particular the index *i*=1,…,N represents the country, while the index *t*=1,…,T refers to time. The parameters λ e β_j, j=1,…,K, are constant across countries and over time, while the parameters α_i change only with the country. The parameters α_I are known as fixed effects and capture the individual heterogeneity which characterize panel data models.
The individual heterogeneity is unknown, systematic and correlated with regressors. To solve this issue we chosen a fixed-effect model, where the individual heterogeneity is modeled by means of *country-specific* constants. This class of regression models differs from random-effects models, where instead the individual heterogeneity is a random variable μ_I, included in the disturbance term, $\alpha_i = \alpha$ e $u_{it} = \mu_i + e_{it}$.
The random-effect model implies the use of a random sample of individuals. We used instead a dataset where the selection of countries under scrutiny are not random, this makes the fixed-effects models more useful for our purpose than the random-effects models.
Models (2) – (6) are special cases of Seemingly Unrelated Regression equation systems (SUR), where the coefficients λ e β_j, vary across individuals. In a model where coefficients are indexed with *i*=1,…,N, the excess of parameterization implies issues in degrees of freedom and less efficient estimates of coefficients. Considering the high number of policies used in the regression, the fixed-effects model is preferable to a SUR system.
We have tested also one-year and two-year lags for all the P&M variables, and one-year lags for the main economic variables. The approach followed consisted in testing models which cover all macro-variables and policies, as well as their lags, cutting out variables with non statistically significant coefficients. This process has been made again until a set of significant explicative variables has been obtained.
Data concern observations on 16 countries (N=16) for 27 periods (T=27), related to 69 variables overall, which 57 are dependent or explicative variables (X_{it}; PM_{it}) and 18 are endogenous variables (Y_{it}). The set of independent variables includes energy intensity, energy efficiency and energy security indexes calculated for each country as a whole and for the three macro-sectors, as well as the carbon intensity index calculated only for

the entire economy. We have created therefore 18 panel models, one for each indicator/sector and we have proceeded by regressing each endogenous variable on the set of explicative variables in order to find statistically significant regressors. In this deliverable we present the results of 8 models, that is, the 3 models related to aggregate energy use, the 3 models for industry energy use, and two alternative models providing a different specification respectively for the effect of all energy policies energy security and for industry energy policies on energy security.

5. Panel Analysis: Data

For the estimates of the energy indexes and the economic variables we have combined a set of different data sources. The Energy Intensity index has been computed drawing from the IEA[18] database for energy final consumption data and EUROSTAT[19] and from the OECD[20] databases for the estimates of sectoral value added. Energy Security indexes have been obtained employing data extracted from ENERDATA[21] and IEA. Data for the Carbon Intensity index have been extracted from the ENERDATA[22] and EUROSTAT/OECD databases, while per capita CO_2 emissions for the residential sector have been computed by combining data from WDI[23] and ENERDATA.
The EI index is defined as the ratio between energy consumption and an indicator of activity measured in monetary units (e.g. GVA). Energy consumption can be classified as primary and final. By primary energy consumption it is meant the energy of combustible fuels and natural sources (oil, coal, etc.) whose transformation generates the energy used for final consumption. In this study we consider final energy consumption to calculate the EI index. The IEA energy balances provide information on primary and final energy consumption by country, energy product and sector. Regarding the indicator of economic activity, used both in the energy intensity and in the carbon intensity indexes, we have chosen the GVA in US dollars at constant prices, calculated at PPPs using the 2000 as base year, which allows us to make a more careful international comparison. The indexes have therefore the GVA, rather than the GDP, as denominator since that taxes and subsides, included in the GDP, are not relevant for our purpose. EUROSTAT database includes the monetary values of all goods and services produced by a given country. These values represent the GDP at an aggregate level and the value added produced in each sectors, at a sectoral level. We have chosen the EUROSTAT database because it allow the disaggregation of GVA in 32 subsectors.
The indexes have been calculated by sectors, aggregating production activity for three macro-sectors, namely industry, other and transport, where the sector *other* includes public and private services, as well as agriculture and residential. We focus the analysis on EU-15 Countries and Norway for the period 1980-2006.

The Energy Efficiency indexes have been computed by combining data extracted from IEA and MURE-Odyssee databases. IEA energy balances provide data on final and sectoral energy consumptions (Mtoe), while Odyssee (MURE) database includes the data on unit consumption, (physical/technological data).

The economic time series are been obtained from different sources, mainly World Development Indicators (WDI), EUROSTAT[24] and IEA[25]. Energy prices data have been

[18] IEA World Energy Statistics and Balances - Extended Balances Vol 2008 release 01.
[19] EUROSTAT - National Accounts by 6 and 31 branches - aggregates at current prices.
[20] OECD.Stat - *Gross domestic product (output approach) US $, constant prices, constant PPPs, OECD base year (2000), millions.*
[21] Enerdata – World Energy database, 2007.
[22] Enerdata – EmissionStat, 2007.
[23] World Development Indicators, The World Bank, 2008.
[24] Eurostat - Statistics on research and development - R&D expenditure at national and regional level.

extracted from IEA, R&D expenditures have been obtained from EUROSTAT, while the WDI has provided information on the remaining macro variables.

For the policy measures, the MURE[26] project database have been used. MURE (*Mesures d'Utilisation Rationnelle de l'Energie*) indeed provides information on energy efficiency policies and measures that have been carried out in the Member States of the European Union. The MURE Database is divided into five sections, which contain the energy efficiency measures relevant to the four main energy demand sectors, namely household, transport, industry and tertiary. A fifth database contains information on general energy efficiency programs and on general cross-cutting measures. Dummies variables have been created by subcategory of policy, that is, the dummy variable is equal to 1 if any kind of policy included in the same subcategory is been implemented in a certain county during the period considered. Annex I provides a glossary of data with a description of economic variables and policy dummies.

[25] IEA - Energy Prices and Taxes – Vol. 2009 release 02.
[26] http://www.isisrome.com/mure/

6. Panel Analysis: Results

In this Section we illustrate the result of the panel analyses, whose methodology and dataset has been described in the previous sections.

As mentioned there, our aim is to check whether the implementation of energy efficiency policies has had an effect in EU (EU15+Norway) countries on indicators of energy efficiency, carbon efficiency and security of supply. In particular we are interested in checking whether some policies had a sort of "double dividend" by having a positive effect on more than one of these indicators. Besides policy dummies, we also look at the effect of the macro drivers (GDP, prices, R&D, etc.).

In this section we analyse such effects for the European economy as a whole (in subsection 6.1) and for the industry sector (in subsection 6.2). The regressions' results are reported in Table 7. Subsection 6.3 discusses briefly these results.

6.1. Panel analyses of energy polices in the EU for the whole economy

The energy intensity at the aggregate level is affected by a number of policies. It is interesting to note that besides general cross cutting policies about energy efficiency, promotion of renewables or climate change mitigation, (particularly if using marked based instruments), also sector-specific policies, have a beneficial effect on overall energy intensity. In the residential sector, mandatory standards for electrical appliances and the deployment of grants, subsidies or soft loans have proven particularly effective. Measures supporting information, education and training in the industrial sector and tax exemptions in the tertiary sector also seem to improve overall energy intensity.

As expected, increasing the residential electricity price induces a small but significant reduction in overall energy intensity. An analogous effect, both in terms of sign and in terms of magnitude, has the share of industry on value added. GDP reduces energy intensity, hinting that richer economies, at least in Europe, tend to use their energy more efficiently, while a somewhat puzzling, perverse but significant effect have R&D expenditures. Note however that the R&D variable does not capture R&D in the energy sector, but overall R&D. It is thus not implausible that these expenditures steer the overall economy towards a slightly more energy intensive configuration.

A similar picture characterises **carbon intensity**. Household electricity prices and GDP have roughly the same effect as on energy intensity, both in terms of sign and in terms of order of magnitude. R&D expenditures and industry's share in value added have no significant effect, while energy production slightly worsens this indicator (although the significance of this variable is weak).

A number of sector-specific policies improve this indicator: legislative or informative measures for the industry sector, mandatory standards for household electrical appliances, cooperative measures in the household and tertiary sectors, and cross cutting policies.

As to **energy security**, there is a vast array of possible indicators to choose from, as illustrated in Deliverable 1.1. For this study, after testing various candidates, we have chosen to focus on two indicators for aggregate energy security (total energy imports/TPES and oil consumption/GDP) and two indicators for the sectoral contribution to energy security (oil consumption/GDP and gas consumption/GDP).

The first aggregate indicator displays a relatively low sensitivity to energy efficiency policies. In fact, only cross-cutting measures (legislative and cooperative) and, curiously, information initiatives in the tertiary sector have a significant beneficial effect, reducing the imports of energy as expected, energy production reduces import dependence, while it is less clear why a similar effect is produced by increasing R&D expenditures. Higher GDP and higher household energy prices stimulate imports, not unexpectedly.

If instead, vulnerability is assessed by looking at how important is oil in the economy, EU-15 countries have some more tools at their disposal to reduce it: general cross cutting measures, soft loans for the adoption of renewables and efficiency improvements in the transport and tertiary sectors, grant subsidies and again informative measures in the tertiary sector. Increases in electricity and industrial production, which are not very oil intensive in western Europe, tend to reduce the weight oil has on the economy and hence the vulnerability of the latter. Also, there is a significant positive relationship between higher level of GDP per capita and higher energy security of the overall economy, as oil gets increasingly substituted with other energy sources.

The impact of GDP on energy system vulnerability therefore seems to be twofold, depending on the indicator we use to measure the aggregate energy security. On the one hand, indeed, an increase in GDP reduces the dependence on oil improving the security of energy supply, while on the other hand it increases imports, strengthening the dependence on foreign energy suppliers. Looking at the regression coefficient values, however, the effect of decreasing the consumption of oil in favour of a less vulnerable energy mix seems to be more significant.

			Dependent variables								
			Unit	Energy intensity		Energy security				Carbon intensity	
				Eifin	eiind	esfin1*	esfin2§	esind1^{+}	esind2°	Cifin	ciind
Coefficients	Macro Drivers	Energy Price	US$/unit	-0.0009	-	0.0047	-	-	-	-0.0024	-0.003
		GDPppp	US$	-0.0203	-0.096	0.3333	-22.412	-20.434	3.447	-0.0675	-0.054
		R&D	mio_pps	0.0166	0.0515	-0.1	6.843	-	-	-	-
		Share Industry	%	-0.002	-0.0061	-	-0.473	-0.388	-0.436	-	-0.007
		Energy Production	ktoe	-	-0.012	-0.1781	-11.1977	-12.641	10.049	0.0341	-
	Industry Policy Variables	In03		-	-	-	-	-	-	-0.0602	-
		In06							-8.294		-
		In08		-0.0124	-0.0135	-	-	-	-	-	-
		In09		-	-0.0094	-	-	-	-	-	-0.026
		In10		-	-	-	-	-7.3016	-4.693	-	-
	Household Policy Variables	Hh04		-0.02	-	-	-	-	-	-0.0431	-
		Hh06		-0.011	-	-	-	-	-	-	-
		Hh07		-0.010	-	-	-	-	-	-	-
		Hh11		-	-	-	-	-	-	-0.0304	-
		Hh12		-	-	-	-	-	-	-0.0194	-
	Transport Policy Variables	Tr11		-	-	-	-12.59	-	-	-	-
	Tertiary Policy Variables	Te05		-	-	-	-3.29	-	-	-	-
		Te06		-	-	-	-9.126	-	-	-	-
		Te07		-0.012	-	-	-	-	-	-	-
		Te08		-	-	-0.041	-3.878	-	-	-	-
		Te09		-	-	-	-	-	-	-0.0175	-
	Cross-Cutting Policy Variables	Cc01		-0.0056	-	-	-	-	-	-	-
		Cc02		-	-	-0.0421	-	-	-	-	-
		Cc05		-	-	-0.0754	-	-	-	-	-
		Cc06		-0.007	-	-	-	-	-	-	-0.034
		Cc07		-0.009	-0.0145	-	-5.379	-6.453	-	-0.0196	-0.03
R^2				0.72	0.45	0.64	0.71	0.67	0.44	0.67	0.54

Notes:
All reported coefficients are statistically significant. Negative numbers indicate an improvement in energy security or reduction in energy intensity and carbon intensity and vice-versa
* esfin1 = Total import/TPES
§ esfin2 = Total oil consumption/GDP
\+ esind1 = Total oil consumption/GDP
° esind2 = Total gas consumption/GDP

Table 7. Econometric Results of the Energy Intensity, Energy Security and Carbon Intensity Indicators

6.2. Panel analyses of energy polices in the EU for the industrial sector

The energy intensity in the industrial sector is also affected by a number of policies. General cross-cutting policies about energy efficiency have a beneficial effect in this case, as the policies targeted at the industrial sector, in particular measures supporting information, education and training and cooperative measures are effective.
In this case, no energy price seems to have a significant impact: probably on one hand sunk costs related to investment constrain the possibility of fuel switching in the short term in response to price swings; on the other hand firm can put in place hedging strategies to sterilise, at least partially, the effect of energy price variations on their balances. Also in this case GDP reduces energy intensity, as does the share of industry on value added. The puzzling effect of R&D expenditures noted for the overall energy intensity is confirmed also in the industry's case.

As to **carbon intensity**, the industrial sector appear to be particularly sensitive to sector specific cooperative measures and again cross cutting policies, in particular those related to marked based instruments. Macro drivers behave in a slightly different way than in the overall economy case: energy prices, the share of industry and GDP per capita both have a beneficial effect, while energy production has no significant effect.

To assess the sector's **energy security**, we have chosen to look at two indicators: oil intensity (oil consumption on GDP) and gas intensity. Note that we consider the aggregate value for these indicators, but we regress them on sector-specific policy variables. The idea behind this strategy is that we want to look at the effect of policies designed for the industrial sector, or cross cutting policies affecting the industrial sector, on energy security indicators that are likely to be relevant for this sector. We do not compute a sector specific energy security indicator, because its meaningfulness would be questionable.
The regression of the first indicator confirms that the higher the weight of industry in the economy, the less vulnerable the latter is to disturbances and threats coming from the oil market. The effects of other macro drivers are the same as those described for the economy as a whole, (bar R&D, that displays no significant effect here). In terms of policies, this indicator appear to be influenced by cross cutting policies, both of general application and with sector specific characteristics.
The second indicator gives a slightly different picture: in this case also fiscal measures in the industry sector, along with the same cross-cutting measures with sector-specific characteristics, highlighted for the previous indicator, reduce vulnerability. However, general cross-cutting policies are no longer effective. With the exception of the share of the industrial sector in the economy, macro variables have a markedly different impact: both increasing electricity production and GDP pro capita leads to more vulnerability: this makes sense, because natural gas has had an increasing share in gross electricity generation (recall **Figure 7**), and gas is a superior good compared to oil and coal for household heating purposes.

6.3. Discussion

Overall, the analyses performed displayed a reasonably good fit, with R^2 ranging from 0.44 to 0.72.

A number of policies prove to have a beneficial influence across EU countries on specific policy target indicators. There is however very little overlapping among policies in terms of their effectiveness on both energy efficiency indicators and energy security indicators. This seem to confirm the traditional economic policy wisdom dating back to Jan Tinbergen (1952, 1956) that multiple policy objectives require multiple instruments. However, there is an exception to this general rule in our case: general cross cutting policies appear to have beneficial effects on both aggregate energy intensity, carbon intensity and energy security.

Between energy intensity and carbon intensity the overlaps are more widespread, and also some sector-specific policies improve the performance of both indicators. This is hardly surprising, given the high correlation between the two indicators, and holds in particular for the household sector, but also cooperative measures in the industry sector affect both carbon and energy intensity at the aggregate level.

7. Conclusions

In this first Deliverable of SECURE's WP5.8 we have explored the relationships between energy efficiency and energy security, both for the economy in general and for the industrial sector in particular in the EU 15 and Norway.

To this purpose we have provided a descriptive analysis of a few energy efficiency indicators and of the energy potentials in the industrial sector. The most original contribution of this WP, however, is the development and the application of an econometric approach to a dataset of policies and measures in the EU that applies panel analysis methods to test the effect of such policies on energy efficiency, carbon efficiency and energy security.

The descriptive analysis of sections 2 and 3 have highlighted a fairly convergent trend in the EU 15 towards a more efficient configuration of energy use, both at the aggregate level and in the industry sector, albeit with varying results in terms of performance and speed across countries and sectors. Our survey of energy efficiency policies in the EU has shown that there is indeed a significant commitment both at the EU level and at the national level, to devise and implement policies and measures to promote energy efficiency. What has been perhaps lacking is an effective coordination among member states inspired by a shared strategy in the field of energy policy. This is a quantum leap whose urgency is clearly felt, and the recent developments in the EU energy policy appear as serious if not completely successful attempts to build it.

The current situation is thus the result of a complex evolution towards not fully achieved but increasing coordination between energy efficiency policies among member states, in which EU directives have played a major role as catalysts and harmonizing devices, but in which some significant heterogeneity is still present. It is thus interesting to draw on this diversity across countries to look at the effectiveness of energy efficiency policies in different national contexts and in terms of different indicators. A panel analysis is the ideal tool to explore this issue as it exploits a large amount of heterogeneous information by combining cross-sectional data and time series data, to obtain a gain in the efficiency of estimates.

Our panel analyses covers energy efficiency indicators, carbon efficiency indicators and energy security indicators. In this deliverable, we looked both at the economy as a whole and at the industry sector. It turns out that quite a number of policies had a beneficial impacts on energy efficiency and carbon efficiency, measured respectively as energy intensity and carbon intensity, at the aggregate level. However only one category of these policies (general cross-cutting policies), have proven also useful to improve the performance of aggregate energy security indicators. Restricting our focus to the industry sector, we notice that, again, sectoral energy efficiency and carbon efficiency have been improved significantly by a number of policies. However, none of these policies had an impact strong enough to improve also energy security, although there have been beneficial policies for energy security implemented in the industrial sector that had no significant effect on energy efficiency indicators.

The main lesson to be drawn from this analysis is that energy efficiency policies in the EU do work, but there is no silver bullet able to successfully address different policy objectives, unless it is a policy so general that naturally encompasses different sectors and modes of energy use. Thus only broadly defined cross cutting policies seem to have this double effect. The other seemingly surprising lesson is that there are policies, designed to improve energy efficiency, that are more effective in terms of improving energy security than in terms of their original goal. This may have to do with our choice of energy security indicators: we may have focused on the consumption of fuels that are more sensitive to certain policies, but may have not enough weight to improve the efficiency of the overall or sectoral energy mix. This is the case for instance of cross cutting policies focused on the transport sector, which have a significant effect on discouraging the consumption of oil products and therefore improve the performance of the energy security indicator that measures the dependence of the economy from oil.

Taking a more general perspective, what seem to work is the policy mix rather this or that policy in insulation: the good news then are that currently in Western Europe a policy menu is in place that has produced significant improvements in energy efficiency, has reduced the amount of carbon emissions generated by the economic system, and has contributed to a more secure energy supply for Europe.

This study is based on the most up-to-date data we were able to recover, and employs state of the art techniques. However, the analysis performed here could in principle be extended and refined. In particular it would have been interesting to look to more countries, to use continuous, instead of binary, policy variables.

The main limitation has been data availability. In particular, policy indicators and energy efficiency indicators for new accession countries were not available or available for a decade or less of observations. For policy variables, the MURE database is mostly qualitative, and reports the presence and the category of the policies and measures implemented in a given country, but it does not provide systematically quantitative information about these policies (such as the funds earmarked for a given policy or the financial impact of a given tax). Future analyses can be pursued by investigating the country-specific P&Ms that contributed to energy efficiency improvements. We have looked at such P&Ms at the regional level (EU-15 plus Norway), but analyses of single countries can help to understand if selected policies are more effective in different countries than others.

Another limitation is that the policy database covers only efficiency- and carbon emissions-related policies, while the policy areas related to competitiveness and market liberalization are not captured. This is potentially a problem given that a more competitive market can in principle spur efficiency through more correct price signals. An indirect hint that the market reforms of the EU energy markets may have had a role also from the energy efficiency point of view, is the significant impact of prices on energy efficiency.

Finally, given the unavoidable lag in data collection, the effects of the recent economic crisis could not be incorporated into this analysis. The crisis has resulted into a noticeable decrease in energy consumption, thus temporarily reducing the case for policy support to energy efficiency and carbon emission reduction. On the other hand it also has temporarily reduced the momentum of the investment process in new technologies, thus slowing down the penetration of efficiency improving technologies, particularly in the industrial sector and in new infrastructures. The strong commitment of the EU to climate change mitigation confirmed at the

15th COP in Copenhagen, suggests that the positive consequences of the crisis will not result in a relaxation of these policies in the EU.

Although the studies described in this deliverable have already produced, in our view, policy relevant insights, further work is awaiting. The contribution of the residential and the remaining economic sectors will be dealt with in Deliverable 5.8.2, with the exception of the district heating, analyzed in Deliverable 5.8.3, and the transport sector, analyzed in Deliverable 5.8.4.

References

ADEME (2008), "L'efficacité énergétique dans l'Union Européenne: panorama des politiques et des bonnes pratiques", Paris, France.

CONFINDUSTRIA (2008) "Efficienza energetica in Italia. Tendenze e prospettive", Mimeo.

EUROPA Gateway to the European Union (2008), Synthèse du Plan d'action pour l'efficacité énergétique de l'Union Européenne (2007-2012)", Brussels, Belgium.

European Commission (2006) "Green Paper "Energy", COM(2006) 105 final. Brussels, Belgium.

European Commission (2009), "Study on the Energy Savings Potentials in the EU Member States, Candidate Countries and EEA Countries", Brussels, Belgium.

Geller H., P. Harrington, A.Rosenfeld, S. Tanishima and F. Unander (2006) "Policies for Increasing energy Efficiency: thirty years of experience in OECD countries" *Energy Policy*, 34, p.556-573

Greening, L.A. and Green, D.L., (1998). "Energy use, technical efficiency, and rebound effect: review of the literature". Conference Proceedings, Vol I. In: , 21st Annual International Conference of IAEE, Quebec, Canada, pp. 321–330.

IEA (2006), "Light's Labour's Lost – Policies for Energy Efficiency Lighting", Press Release, Paris, France.

IEA (2007), "Industry: Tracking industrial Energy Efficiency and CO_2 Emissions", Paris, France.

IEA (2008), "Assessing measures of Energy Efficiency Performances and their Application in industry", Information Paper, in support of the G8 Plan of Action, Paris, France.

IEA (2008), "Energy Efficiency Policy recommendations", Paris, France.

IEA (2008), "Energy Efficiency Requirements in Building Codes, Energy Policies for New Buildings", Information Paper, in support of the G8 Plan of Action, Paris, France.

IEA (2009), "Progress with implementing energy efficiency policies in the G8, Paris", France.

ISIS (2008), "MURE II Project. Best Available Technologies in Housing. Italian case study", Rome, Italy.

Markandya, A., Pedroso-Galinato, S. and Streimikiene, D., (2006). "Energy intensity in transition economies: Is there convergence towards the EU average?" Energy Economics 28, 121-145.

Odyssee (2007), "Evaluation of Energy Efficiency in the EU-15: indicators and policies", ADEME/IEEA, Paris, France.

Schipper, L., Meyers, S., Howarth, R., (1993), "Energy intensities in OECD countries: an historical analysis". International Journal of Global Energy Issues 5(2/3/4), 76}89.

Tinbergen, J. (1952), "On the Theory of Economic Policy, Amsterdam, North-Holland.

Tinbergen, J. (1956), "Economic Policy: Principles and Design, Amsterdam", North-Holland.

Tipping, P., Antonelli R., Boonekamp, P., Donkelaar Kroon M., Longstaff T. McLeod K., Srinivasan G., Tigchelaar C. (2006) "Impact Assessment on the Future Action Plan for Energy Efficiency" (CLWP: 2006/TREN/032), ECN, The Netherlands (http://www.ecn.nl/docs/library/report/2006/e06041.pdf)

Trégouët, R. (2008), "L'efficacité énergétique: un enjeu économique et écologique majeur pour la France et l'Europe", www.enerzine.com.

World Energy Council (2008) "Energy Efficiency Policies around the World: Review and Evaluation" (2008), World Energy Council, London, United Kingdom

Annex I – Data Dictionary

Variable	Description
Country	EU15 countries + NO
Year	1980 – 2006
EIfin EIind EIoth EItra	Energy intensity index; Final (all sectors) Energy intensity index; Industry sector Energy intensity index; Other sectors Energy intensity index; Transport sectors
EEhouOdy	Energy efficiency index; Residential sector; 1980-2004, Odyssee data
EEtraOdy	Energy efficiency index; Transport sector; 1980-2004, Odyssee data.
ESfin1	Energy security index (Total Imports/TPES); Final (all sectors)
ESfin2	Energy security index (Total Oil Consumption/GDP); Final (all sectors)
ESind1	Energy security index (Total Oil Consumption/GDP); Industry sector
ESind2	Energy security index (Total Gas Consumption/GDP); Industry sector
ESoth	Energy security index (Gas Import/Gas Consumption); Other sectors
ESagter	Energy security index (Gas Import/Gas Consumption); Agriculture & Tertiary sectors
EShou	Energy security index (Total GAS Consumption/GDP); Residential sector
EStra	Energy security index; Transport sectors;
CIfin CIind CIoth CIagter Citra CO2hou PReleHH PReleIND PRdiesel ShINDwdi R&Dpps GDPppsCur EnProdWdi	Carbon intensity index; Final (all sectors) Carbon intensity index; Industry sector Carbon intensity index; Other sectors Carbon intensity index; Agriculture & Tertiary sectors Carbon intensity index; Transport sectors Per capita CO_2 emissions; Residential sector Price in US$ of electricity residential (incl. taxes); Total Price (US$/unit) Price in US$ of electricity industry (incl. taxes); Total Price (US$/unit) Price in US$ of diesel (incl. taxes); Total Price (US$/unit), Household Industry, value added (% of GDP) (NV.IND.TOTL.ZS) WDI Total intramural R&D expenditure (GERD). Millions of PPS (Purchasing Power Standard). All sectors. EUROSTAT GDP per capita, PPP (current international $) (NY.GDP.PCAP.PP.CD), WDI Energy production (kt of oil equivalent) (EG.EGY.PROD.KT.OE), WDI
PMhhT1 PMhhT2 PMhhT3 PMhhT4 PMhhT5	P&Ms Household sector - Mandatory Standards for Buildings P&Ms Household sector - Regulation for Heating Systems and hot water systems P&Ms Household sector - Other Regulation in the Field of Buildings P&Ms Household sector - Mandatory Standards for Electrical Appliances P&Ms Household sector - Legislative/Informative

PMhhT6	P&Ms Household sector - Grants / Subsidies
PMhhT7	P&Ms Household sector - Loans/Others
PMhhT8	P&Ms Household sector - Tax Exemption / Reduction
PMhhT9	P&Ms Household sector – Tariffs
PMhhT10	P&Ms Household sector - Information/Education
PMhhT11	P&Ms Household sector - Co-operative Measures
PMhhT12	P&Ms Household sector - Cross-cutting with sector-specific characteristics
PMtrT1	P&Ms Transport sector - Mandatory Standards for Vehicles
PMtrT2	P&Ms Transport sector - Legislative/Informative
PMtrT3	P&Ms Transport sector - Grants / Subsidies
PMtrT4	P&Ms Transport sector – Tolls
PMtrT5	P&Ms Transport sector - Taxation (other than eco-tax)
PMtrT6	P&Ms Transport sector - Tax Exemption / Reduction / Accelerated Depreciation
PMtrT7	P&Ms Transport sector - Information/Education/Training
PMtrT8	P&Ms Transport sector - Co-operative Measures
PMtrT9	P&Ms Transport sector – Infrastructure
PMtrT10	P&Ms Transport sector – Social Planning/Organisational
PMtrT11	P&Ms Transport sector - Cross-cutting with sector-specific characteristics
PMinT1	P&Ms Industry sector - Mandatory Demand Side Management
PMinT2	P&Ms Industry sector - Other Mandatory Standards
PMinT3	P&Ms Industry sector - Legislative/Informative
PMinT4	P&Ms Industry sector - Grants / Subsidies
PMinT5	P&Ms Industry sector - Soft Loans for Energy Efficiency, Renewable and CHP
PMinT6	P&Ms Industry sector - Fiscal/Tariffs
PMinT7	P&Ms Industry sector - New Market-based Instruments
PMinT8	P&Ms Industry sector - Information/Education/Training
PMinT9	P&Ms Industry sector - Co-operative Measures
PMinT10	P&Ms Industry sector - Cross-cutting with sector-specific characteristics
PMteT1	P&Ms Tertiary sector - Mandatory Standards for Buildings
PMteT2	P&Ms Tertiary sector - Regulation for Building Equipment
PMteT3	P&Ms Tertiary sector - Other Regulation in the Field of Buildings
PMteT4	P&Ms Tertiary sector - Legislative/Informative
PMteT5	P&Ms Tertiary sector - Grants / Subsidies
PMteT6	P&Ms Tertiary sector - Soft Loans for Energy Efficiency, Renewable and CHP
PMteT7	P&Ms Tertiary sector - Tax Exemption / Reduction
PMteT8	P&Ms Tertiary sector - Information/Education/Training
PMteT9	P&Ms Tertiary sector - Co-operative Measures
PMteT10	P&Ms Tertiary sector - Cross-cutting with sector-specific characteristics
PMccT1	P&Ms Cross-cutting - General Energy Efficiency / Climate Change / Renewable Programmes

PMccT2	P&Ms Cross-cutting - Legislative/Normative Measures
PMccT3	P&Ms Cross-cutting - Fiscal Measures/Tariffs
PMccT4	P&Ms Cross-cutting - Financial Measures
PMccT5	P&Ms Cross-cutting - Co-operative Measures
PMccT6	P&Ms Cross-cutting - Market-based Instruments
PMccT7	P&Ms Cross-cutting - Non-classified Measure Types

Annex II. Literature about security of supply in the industrial and residential sectors[27]

Security of supply can be defined as an uninterrupted flow of energy to meet the demand in an environmental sustainable manner and at a price level that does not disrupt the course of the economy. Security of supply of energy is key element for the functionality of the modern societies. Due to this security of supply issue has got high importance throughout the world. However it is a very complex problem dependent on many factors and difficult to analyse.

Security of supply is a term which covers the entire range of energy carriers e.g. oil, gas, renewables and electricity. Security of supply can be energy specific, time specific (as well as both short-term security of supply to long-term), technology specific, consumer specific etc.

The purpose of this survey was to conduct a review of studies that have been done on the security of supply in residential and industrial sectors.

Search and Results

Survey was carried out with focus on four journals' databases:

Oxford Journals - division of Oxford University Press, publishing over 200 academic and research journals covering social sciences, humanities, computer science, mathematics and statistics.

Jstor - there are 1542 titles in the archive; the majority of its content is journal literature, but it is possible to find here some other materials such as conference proceedings, transactions, pamphlets, monographs, manuscripts etc.

Science Direct – database with more than 2,500 journals and more than nine million full-text
articles. From this appr. 340 journals are in the field of business economics, social sciences and computer science. ScienceDirect is a part of Elsevier, world’s leading publisher of science and health information.

[27] This survey has been prepared by Ramboll.

SpringerLink – one of the world's leading interactive databases with 2109 journals in the field of economics, statistics, mathematics, information technology, legislation, environment and, natural sciences.

During conducting the survey following keywords combinations were used to identify relevant articles:

- security supply household
- security supply residential
- security supply industry
- security supply industrial

After preliminary search, most of the sources reviewed were not related directly to the subject of this survey. Due to this, searching was focused on the presence of listed above keywords in the title of the article.

After applying all of the mentioned above criteria, only one article was accepted as relevant:
"Households' willingness to pay for safeguarding security of natural gas supply in electricity generation" written by D. Damigos, C.Tourkolias and D.Diakoulaki from National Technical University of Athens, December 2008.

The authors bring up the problem of European dependence on fossil- fuel import and continuous rise in energy demand, which can affect the security of energy supply. Assurance of this security gives additional costs that have to be paid by society. The idea of the survey was to find out about households' perception and willingness to pay for supporting public investments that would enhance security of supply. This study focuses on the security of natural gas supply in electricity generation. Survey was carried on in Greece, which heavily depends on imported energy, since the only significant fossil fuel source in this country is lignite. The empirical study was conducted on 793 households from all the regions of Greece, using the contingent valuation method. Among the other there were questions checking the knowledge of fuels used in electricity production, knowledge of natural gas supplier to Greece and attitude to increasing payments because of environmental reasons (natural gas is more environmental friendly for electricity sector that lignite). According to the responses Greeks are not conscious about natural gas usage in electricity production (2, 6% respondents) but they know at least one of Greece's gas suppliers. Respondents are concerned about environmental impacts and they disagree with a potential reduction of electricity prices at the cost of increase in risk for environment. The results indicate that consumers are willing to pay a premium on their electricity bills. Based on the results authors concluded that security of energy supply holds an important economic value that could justify public support for adopting appropriate measures towards this direction.

When the mentioned above criteria was applied in other electronic databases, an article was found:
"*Energy security in the residential sector"* written by Larry Hughes from University in Halifax, Canadian centre for policy alternatives; Canada; March 2008.

The author focused here on heating emergency that can occur if heating fuel costs rise too rapidly or there are shortages of energy supply. Governments must ensure their citizens are protected in case those emergencies, because they can compromise the health and wellbeing of anyone. The report has identified a number of approaches that governments can take in these situations, including subsidies and rationing. In the most extreme cases, when individuals and families are unable to either pay for the energy they need or there are shortages of energy, it will be necessary to find safe, secure, and warm shelters for those affected.

While searching in all the available databases, by using the mentioned above keywords without specifying where the keywords should appear, a higher number of articles was found. The most relevant for the subject of the survey are listed below:

"The value of supply security. The costs of power interruptions: Economic input for damage eduction and investment in networks", authors Michiel de Nooij, Carl Koopmans, Carlijn Bijvoet, January 2005

"The British Gas market 10 years after privatisation: a model or a warning for the rest of Europe?" Written by Jonathan P. Stern, Royal Institute of International Affairs, 1997

"Seasonal fluctuations of demand and optimal inventories of a non-renewable resource such as natural gas" written by Eirik Schrarder Amundsen, University of Bergen, Norway, January 1991

"Rhetoric versus reality Russian threats to European energy supply"; author: Andreas Goldthau, RAND Corporation, USA; August 2007

"Demand Response in the Residential Sector: A Critical Feature of Sustainable Electricity Supply in New Zealand" by Samuel. Gyamfi, Susan. Krumdieck, Larry. Brackney, December 2008

"Electricity and energy policy: French specificities and challenges in the European context" written by Observatoire de l'énergie, November 2006

"EU and Ukraine Security of Energy Supply, Comparative Analysis"; UNDP Blue Ribbon Analytical and Advisory Centre- Energy Policy Team report from September 2007

"Europe's current and future energy position; Demand – resources – investments"; Commission of The European Communities, November 2008

"Security of supply for Bornholm; Integration of fluctuating generation using coordinated control of demand and wind turbines" by Ea Energy Analyses; October 2007

Those articles are not focused on security of supply for residential sector and industry; however they contain information in this subject. Some of them give detailed information about the energy demand in electricity in both households and industry.

Conclusions

This survey has shown that security of energy supply is a subject of numerous discussions and articles but most of them are related to the upstream (security of supply for specific geographical region or single country). Besides, the majority in those discussions is about natural gas. Nevertheless it is possible to find information about nuclear energy, wind as well as get some overview of usage of other primary energy sources. When searching was specified for residential sectors and industry not many results were obtained.

Although this survey covered a relatively small number of articles it gave overview of the interest in this subject. In most cases articles are written by university scientist. However different governmental and European Union- related organizations provide high number of reports. The above listed articles concern security of energy supply in European countries as well as in Canada or New Zealand.