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COMMUNICATION FROM THE COMMISSION TO THE COUNCIL, THE EUROPEAN PARLIAMENT, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS

A European Strategic Energy Technology Plan (SET-Plan)

CAPACITIES MAP

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Capacities Map

for the European Strategic Energy Technology Plan

1. EXECUTIVE SUMMARY AND CONCLUSIONS

The present study aims at providing an overview of the energy research capacity in EU Member States. It is composed of a quantitative analysis of funding for energy research from the public and private sectors on the one hand and an assessment of the institutional capacity in energy research policy making and implementation on the other.

The assessment provides input into the Impact Assessment accompanying the forthcoming proposal for a Strategic Energy Technology Plan, which aims at addressing how to improve international collaboration in energy research within the EU.

It must be noted that available information is sketchy and data beyond 2005 were not available at the time of preparation, meaning that important recent developments may be missed out.

Despite these shortcomings, the study comes to the conclusion that public energy research has lost in importance over the last decades with a slight uptake in very recent years. A similar trend can be observed in the private sector, influenced by the liberalisation of energy markets. Particularly in the context of limited budgets, it is important to exploit synergies in energy R&D among Member States, which currently takes place only to a limited extent. One of the reasons hampering international energy collaboration may be the distinct institutional set-ups in energy research among Member States. Furthermore, sketchy data make it difficult to create transparency about countries' activities, which would be a precondition for an improved coordination of efforts.

The main findings of the study are summarised below.

The energy sector faces the challenge of becoming more competitive, less reliant on imported energy carriers and environmentally sustainable. Innovative technologies are important in the sector's transition. R&D investment in the energy sector is therefore crucial.

A competitive energy sector is indispensable for our economic activity. At the same time, concerns about supply security, climate change and air quality have to be addressed. This implies the need for a considerable and continuous restructuring of the sector.

Innovative energy technologies are central for making progress towards these long-term objectives. Despite an increasing energy demand of the consumers, the local air quality in the EU has improved considerably in the last couple of decades. The decoupling of energy consumption from economic growth and the significant reductions in air pollutant emissions are mainly due to past technological improvements such as the introduction of abatement techniques, fuel switch or efficiency gains.

The development and market introduction of new energy technologies face a number of barriers. The sector is prone to market inefficiencies due to its oligopolistic structure, the environmental and network externalities, the long investment horizons, and the risk for a technological lock-in with socially suboptimal technologies.

R&D is needed to accelerate the technological improvement in the energy sector. In general, the government should guarantee an attractive R&D environment for both the private and public sector. In particular, public research initiatives (e.g. R&D funding) become necessary where the actions by the private sector are insufficient.

EU Member States award a relatively low importance to energy research. The public energy R&D spending decreased during the early 1990s with some limited increases in the last couple of years. This results in a low share dedicated to energy R&D compared to overall public research budgets. Also the business sector's R&D expenditure in the energy sector is low. It is questionable whether current public and private R&D efforts are sufficient to meet the new challenges of the energy sector.

Public funding for energy R&D in the EU Member States (but excluding the significant EC funding through Research Framework Programmes and the Intelligent Energy Europe Programme) declined between 1991 and 2005, reaching around 2.2 bn EUR by 2005. However, most of this decrease happened in the early 1990s with limited increases in recent years. This compares to a more or less stable budget in the USA and a net increase in Japan over the same period. The aggregated EU Member States' energy R&D spending is even falling behind Japan's in nominal terms. These trends illustrate the low importance given to energy research in EU Member States.

Such conclusion is supported by the share of government budget appropriations dedicated to 'production, distribution and rational utilisation of energy' in the overall government budget appropriations (GBAORD). While this share would be below 3% on an EU average in 2005 (with individual Member States ranging between almost 0% and 12%), it amounts to around 17% in Japan (in 2004).

The EU trends hide large differences among the EU Member States. By 2005, France, Germany and Italy accounted for almost three quarters of the aggregated EU public energy R&D funding, while the 12 new Member States together accounted for less than 3% of the total. Nevertheless, the importance awarded to public energy R&D remains limited in all Member States with budgets being in the order of 0.01 to 0.05% of GDP. Unfortunately, a similar assessment cannot be done for public R&D efforts in transport-related sectors. However, for those eight Member States that provide data, the public R&D spending in the manufacture of cars is important.

The investment in energy R&D of the private sector shows a somewhat similar pattern as the public energy R&D funding by 2005. The energy R&D expenditure of the business sector also concentrates in few Member States (France, Germany, Sweden and Italy account for three quarters of the EU total) with a limited contribution of the new Member States. Similarly to the trends in the public funding, energy R&D expenditure of utilities and of producers of nuclear fuel and petroleum products decreased during the 1990s, with a slight recovering in recent years.

Private R&D expenditures in the manufacturing of motor vehicles and electrical machinery are relatively strong, compared to energy R&D. Around 63% of the total energy- and transport-related R&D expenditure of the business sector is allocated to the manufacture of motor vehicles. Transport-related R&D has a share of almost 25% in the total R&D expenditure by the business sector on an EU-average, compared to less than 5% for the energy R&D. This difference is even more remarkable when having in mind that the energy sector's gross value added is above that of the transport sector.

Also on a company level this trend is apparent: the R&D intensity[1] in the manufacture of automobiles reaches an average value of 4.5% for the top investing 44 EU companies compared to less than 1% for companies in the energy sectors with the exception of oil equipment and electrical components. In an international comparison, EU-based companies operating in both the energy- and transport-related sectors show a more or less similar R&D intensity compared to non-EU-based companies operating in these sectors (except for oil equipment services).

The divergence in R&D intensity among sectors of activity may be explained by the fact that electrical utilities produce an identical good (electricity) with price competition as a main success criterion. Furthermore, innovation in electricity production often is not carried out at the level of the utility itself but at the level of component suppliers. Whereas the manufacturing of cars is sensitive to a stronger innovation pressure as innovation may be one of the 'selling factors'.

The on-going deregulation of important energy sub-sectors created competition and a more liberalised market structure. On the one hand, the privatisation and liberalisation of many traditional publicly managed electricity and gas monopolistic companies may have meant that former publicly supported research activities have been shifted to the private sector, explaining in part the reduction in the public funds for energy R&D. At the same time, increased competition may have reduced the "monopolistic rents" of utilities, and therefore the company's resources for investment in R&D and returns from R&D investment.

Considering the low level of funding in both public and private energy R&D spending, it is questionable whether the challenges of the energy sector can be met adequately without a significant increase in the Member States energy R&D budget. However, it needs to be noted that in very recent years, the R&D budgets dedicated to energy have increased in some Member States, and a number of countries have already announced plans to increase further their budgets.

Energy R&D priorities vary among Member States, but some shared priorities exist in some technologies and groups of countries. Synergies should be exploited in these areas, which is of particular importance for capital-intensive technologies.

The specific research priorities vary among Member States, adding to the low overall energy R&D spending. These divergent preferences of the Member States bear the risk of insufficient resources being allocated, resulting in projects with little "critical mass", especially as energy R&D often requires an intensive capital investment. However, this diversified and broad approach may prevent the new technologies from an early technological lock-in.

Despite the variety of specific research interests, most Member States share some general priorities. These include renewable energies, energy efficiency and nuclear-related research in some Member States (yet declining in funding). For example, around 40% of the overall energy spending aggregated from the EU Member States listed in the IEA database is dedicated to nuclear energy (dominated by France that has a relatively high nuclear budget), 20% to renewable energies and some 10% to fossil fuels and energy efficiency, respectively. Renewable energy, however, is diverse and, even if generically considered as an absolute

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[1] R&D investment over net sales

priority for almost all Member States, different weights are assigned to specific technologies by individual Member States, according to their strategic interests and potentials. While a number of Member States focus on bioenergy – sometimes with a biofuel focus – and/or wind energy, there are only few countries promoting geothermal and ocean energy.

Recently, an increasing number of Member States mentions CO_2 capture and storage as a priority area for energy R&D, even though this is not yet strongly reflected in the R&D expenditure. Similarly, hydrogen and fuel cells are mentioned as being important despite the currently limited budgets in most Member States. As these technologies are characterised by a high capital investment need, they would particularly benefit from a closer European collaboration, as it is already the case for nuclear fusion.

In addition to public R&D funding, almost all EU Member States also support the market introduction of renewable energies and use efficiency standards. Furthermore, other policies, as the European Emission Trading Scheme, give an advantage to low-carbon energy sources. It is expected that the impact of such market based instruments is strengthened by the liberalisation of the energy sectors [European Commission, 2006f]. Dedicated pull instruments (like feed-in tariffs and green certificates) as well as instruments that indirectly support innovative technologies (like the ETS) help to deploy new technologies and subsequently reduce their costs through learning. However, despite the existence of such systems in all Member States, they are very heterogeneous and not always compatible with similar systems within the Member State or across the Member States.

Pan-European cooperation is hampered by diverse organizational structures in energy R&D, ranging from the institutional set-up to programmes and public private partnerships. A number of recent initiatives aim at improving both the science-industry link and international cooperation. However, current procedures remain far away from a coherent strategic priority setting at pan-European level that would enable to exploit synergies in energy R&D.

Pan-European cooperation in public energy-related research remains low even in areas of shared priorities. Energy R&D programmes vary significantly in their organisational forms and contents and national priority setting does often not take into account the research policies of other countries. In conclusion, a priority setting at EU level hardly takes place (except for EU funded programmes such as the Research Framework Programme or the Intelligent Energy Europe Programme), making it difficult to exploit synergies.

One possible barrier to the coordination in energy R&D may be the variety in the institutional structures, stemming from differences in the historic development, the energy mix, the general energy policy as well as the government structure. In many Member States the responsibility for energy R&D policy making lies with several ministries, the nature of which varies among countries. This set-up may lead to a lack of focus.

The heterogeneity of actors and responsibilities becomes even more apparent in the implementation of energy R&D policy. This can either fall directly under the responsibility of the ministry, or – more commonly – be carried out by an energy agency, by a broader technology agency, or by a major public research organisation. In some Member States, several approaches are used for different energy niches.

Also the performers of energy research vary among Member States, with precedence given to either universities or public research organisations. In many Member States, the public research organisations are extensively involved in energy research, often having their origins as nuclear research centres. Especially in the new Member States, the academies of science play a role in energy R&D.

The importance of creating a link between science and industry to guarantee the transfer of knowledge has led to public private partnerships in all Member States. The concrete design yet differs significantly among Member States, ranging from project-based industry/business cooperation to more institutionalised forms such as innovation agencies. This has been complemented by a number of innovative concepts such as technology platforms. Furthermore, some research centres that are jointly financed by the public and private sector are established, often with a clear focus on specific energy technologies. Some Member States also introduced forms of PPP with a clearly defined regional focus, such as the French "*pôles de competitivité*".

Overall, the institutional infrastructure in energy R&D is scattered and heterogeneous across Member States. Unlike in the USA, where the Department of Energy centralises all aspects of energy policy at federal level, in most EU Member States the responsibilities for energy R&D policy are shared among various ministries and different agencies. Another problem of the energy sector is its fragmentation into several sub-sectors, characterised by different technologies, products and value chains. As a result, private actors are extremely heterogeneous among the different sub-sectors of the energy sector.

However, the discrepancies in national energy R&D infrastructure do not a priori prevent international collaboration. A successful example is the Nordic Energy Research Programme that forms a joint programme among Denmark, Finland, Iceland, Norway and Sweden. Also on the European level some highly integrated initiatives exist in specialised areas, such as ITER and CERN.

There are also some more recent initiatives aiming at better pan-European energy cooperation, often initiated by the European Commission. The ERA-NETs, created under the 6th Framework Programme for Research, contribute to a better coherence in research policies among Member States. The strengthening of knowledge in a specific area is the focus of the Networks of Excellence, bringing together the critical mass of expertise on an EU level. Eventually, the EU Technology Platforms will also facilitate international information exchange, despite their focus on creating a link between industry and science. In general, the role of the EU Research Framework Programmes to connect, reinforce and synergize national capacities is widely recognised as fundamental, though insufficient in some cases.

Beyond the EU-level (but including 17 EU Member States), the International Energy Agency's Implementing Agreements bring together experts in specific technologies in order to collaborate on R&D activities. There are currently about 40 active agreements with varying members, covering various kinds of energy technologies.

Overall, it can be concluded that potential synergies among Member States efforts often remain unexploited, influenced by the heterogeneity in energy research priorities and institutional capacities. This is a shortcoming, particularly affecting those technologies that require joint research efforts due to high costs. The recent initiatives such as the ERA-NETs and Technology Platforms are an important step towards mobilising pan-European cooperation, often realised as a bottom-up approach with a clear technology focus. Nevertheless, these efforts are still far away from a common EU-wide research strategy. Such a strategic planning would need to follow a broad cross-sectoral, coordinated approach, comprising not only energy production but also large energy consumption sectors such as the transport sector.

Systematic and consistent reporting of information on R&D spending, programmes and priorities is a pre-requisite for a better coordination of energy R&D programmes among EU

Member States. Currently available information does not allow for a comprehensive and consistent overview of the R&D infrastructure and spending in public and private energy R&D.

Overall, research efforts need to be better synchronized in order to provide the technologies that will allow the energy sector to meet its long term challenges. This requires as first step transparent information on energy and transport R&D efforts among Member States, comprising both quantitative data and information on policies, programmes and responsibilities. Access to such transparent, comprehensive information is of particular importance given the heterogeneous infrastructure of energy R&D among Member States.

The report reveals that information on energy- related R&D is fragmented. This applies both to data on public as well as on private spending, with the latter usually being sketchier. Furthermore, available data sources are not easily comparable due to differences in methodology, coverage etc. In some cases, such as for the trends in energy-related public funding, even contradictory trends emerge between various data sets. Data availability for public energy-related research is much more comprehensive than data on transport-related research.

Compared to quantitative data, information on the institutional structure, programmes and policies is even sketchier. Except for a number of studies that are not regularly updated, there is little regular and structured information available on the institutional energy R&D infrastructure.

On EU level, the exchange of information between the Member States and among different national actors could be facilitated by providing a database containing a standardized set of information regarding energy R&D funding, programmes, priorities, responsibilities and structures. The success of such a measure depends on the completeness of the respective database, which may argue in favour of either a compulsory reporting by Member States or an expert-based scheme yet with secure multi-annual funding.

With respect to quantitative data on energy and transport-related R&D funding and expenditure, the Eurostat GBAORD, GERD and BERD databases may be a good starting point but currently contain too little information on the sector level or on different technologies. As they rely on Member State reporting, one option may be to make detailed reporting to Eurostat compulsory for the Member States in order to capture more comprehensively the funding trends in energy- and transport-related sectors. With regard to investment in the private sector, the EU Industrial R&D Investment Scoreboard provides important information on the R&D investment on a company level, including companies operating in the energy and transport sectors.

The collection of information on research policies, programmes and initiative within EU Member States is done as part of the Research Inventory of the web-based ERAWATCH service. This comprises also some energy- and transport related information on policy priorities and programmes, if relevant from a general research policy perspective. Energy and transport R&D policies and programmes as such, however, are not explicitly addressed.

If a voluntary and expert-based monitoring scheme is favoured, a deepened coverage of energy R&D information within ERAWATCH could be developed through a measureoriented specific extension of the research inventory.[2] It could cover a broader set of energy-related research programmes, policy documents and organisations with the existing set of specific templates, if appropriately amended by a summary field for each country on energy research policies in the country profile and a specific entry point on the ERAWATCH website. An example of another existing thematic service which follows such a coverage philosophy is the CISTRANA portal on IST research.

Of course also other forms of extension are conceivable. An exploratory study by the ERAWATCH Network during 2006 has conceived and tested an approach which provides more detailed coverage of thematic research policies and its drivers, processes and implementation mechanisms for several fields, among which energy. Such an approach would however require an additional specific thematic field template. It has turned out in the exploration that it is quite costly and requires an additional organisational layer of thematic quality assurance as well as a significant change in the web presentation. This approach is hence not suggested as preferred option. It might be considered in a later step.

[2] A theme-specific extension of ERAWATCH would require multi-annual additional funds and would be based on the general design and methodology of ERAWATCH – including information collection and provision by experts from the ERAWATCH Network.

2. INTRODUCTION

Energy production and consumption exerts a number of environmental pressures such as the emission of air pollutants and greenhouse gases. The use and production of energy accounts for more than 80% of the EU greenhouse gas emissions and the vast majority of emissions of acidifying substances, ozone precursors and particulate matter [EEA, 2006].

The EU has set the objective of reducing the level of GHG emissions by 20 % compared to 1990 levels by the year 2020 [Council, 2007]. In the longer run, even more ambitious GHG reductions in the order 60-80% may be necessary [Environment Council, 2005]. At the same time, the EU's energy import dependency is predicted to increase further, while the number of energy exporting countries will decrease, making the EU energy supply vulnerable.

Meeting these challenges requires drastic changes to energy production and consumption sectors. Particularly, domestic energy production, energy savings and low carbon carriers are likely to become more important [IPTS, 2007; IEA, 2006d]. The recently adopted 'Energy Policy for Europe' [European Commission, 2007k] consequently aims at achieving a 20% share of renewable energies in energy consumption and a 20% better energy efficiency than under a business-as-usual scenario by 2020. This target implies an accelerated effort to develop and introduce new energy technologies into the market, requiring initiatives by the government and private sector, and by enhancing international cooperation.

The forthcoming proposal for a Strategic Energy Technology Plan aims at addressing how to improve international collaboration in energy research and development especially for those technologies that need a 'critical mass'. This requires a scanning of energy technologies under development as well as the knowledge about the current national energy research efforts and the underlying infrastructure, i.e. the key players involved.

The objective of this report is to provide an overview of the energy research capacities both in the public and in the private sector in the EU Member States, and in Japan and the USA for comparison.

Following the executive summary (Chapter 1) and a brief description of the methodology in Chapter 3, the public energy research infrastructure in the different Member States is analysed in Chapter 4. The assessment shows that there is a remarkable heterogeneity in the energy R&D infrastructure, which may contribute to the lack of cooperation in European energy research. Firstly, the ministries involved in setting up national energy research priorities vary strongly. Secondly, there are large discrepancies for energy R&D spending across Member States. Thirdly, the implementation of energy R&D is rather heterogeneous, comprising dedicated energy agencies as well as technology agencies, the main national research organisations or directly the ministries themselves.

In addition to promoting energy-related research ('technology push'), governments need to create favourable conditions for deploying new energy technologies ('demand/market pull'). Currently, clean energy technologies are not competitive with the established technologies (with the notorious exception of some niche markets). All governments of EU Member States use a wide number of instruments to promote development and dissemination of new technologies, from subsidising R&D to voluntary agreements, standards, taxes and cap-and-trade systems [IEA, 2003, 2007a]. In Section 4.3., we compare the two prevailing 'demand pull instruments', i.e. the feed-in tariffs and green certificates. Other policies discussed include car scrappage programs and bio-fuel policies.

Chapter 1 has a closer look to the role of the private sector in energy R&D. Depending on the technologies, the type of their output, the production processes and their market maturity, the energy sector breaks down into different sub-sectors, each of which includes actors with specific R&D needs. Therefore, a complete picture of the private energy- and transport-related R&D efforts is difficult to draw. Nevertheless, a closer look at the list of the 1000 top performing companies in R&D investment reveals that the majority of the business sector's investment goes into the car manufacturing industry and related ancillary industrial sectors, while 'traditional' energy enterprises receive limited private investment. Similar conclusions may be drawn concerning the pattern of R&D-related employment.

The research needs and the current thematic R&D priorities are discussed in Chapter 6. Even though there are large differences in Member State's spending, revealing different priorities in energy R&D, a number of shared priorities become apparent between different clusters of countries. Such priorities include research on renewable energies, energy efficiency and nuclear-related research. Furthermore, a number of Member States mention that CO_2 capture and storage is a recent priority.

The present study systematically captures developments until 2005, as data for more recent years have not been available at the time of writing. More recent developments are thus not included in a systematic way. However, having in mind the dramatic changes in the energy sector in the last two years (such as the steep rise of the oil price), it is important to provide an indication about more recent developments. This is aimed at in Chapter 7.

Overall, we can conclude that despite the strategic importance of energy- and transport-related R&D, public funding remains limited. A better cooperation of EU Member States R&D programmes and international collaboration among Member States with shared priorities could thus help to achieve the 'critical masses' needed for the introduction of some technologies with high costs, infrastructure requirements, etc. However, the heterogeneity of Member States' institutional R&D infrastructure currently impedes a better alignment of energy- and transport-related R&D. A first step towards a better exploitation of synergies comprises a systematic gathering and exchange of information on energy R&D efforts and the related institutional structure. This could be facilitated by a database containing comparable, standardised sets of information regarding energy and transport R&D funding, programmes, priorities and responsibilities.

3. METHODOLOGY AND SCOPE

3.1. Scope of this study

In early 2007, the European Commission proposed the development of a European Strategic Energy Technology Plan. Its aim is to facilitate the innovation challenges of the energy-related sectors, which arise from concerns about climate change and supply security. The plan is expected to identify those technologies for which EU cooperation is crucial and analyze whether the existing R&D capacities in the EU Member States support such collaboration.

This report is one of the two background documents providing input to the SET-Plan. This document aims at assessing the capacities of the energy- and transport-R&D infrastructure, i.e. the institutions being involved in the policy making, the implementation and the performance of energy research, while the other document focus on a technology assessment.

A broad approach has been followed regarding energy but transport is restricted mainly to its energy-use component. Although, the different classification systems of the various databases hamper the breakdown of the sectors, this report aims to cover the following sectors to the extent possible:

- Energy sectors include the primary energy production (such as mining of coal and nuclear fuels, mineral oil and natural gas prospecting), as well as the transformation and distribution of final energy (power, industrial and domestic heat, refined liquid fuels, etc.) obtained from fossil resources, nuclear energy and renewable energy sources. Often, a distinction is made between nuclear and non-nuclear R&D.

- Other energy-related sectors comprise sectors producing electronic equipment and components. Even though this sector is extremely diverse, it is included in order to reflect R&D in energy-consuming consumer goods and components used for energy production.

- Transport-related sectors such are the developers of transport systems and the manufacturers of motor vehicles (commercial vehicles and cars).

With the focus being on structures, programmes, policies and technological priorities in Member States, initiatives on the EU-level were generally not considered. It therefore needs to be remembered that the important budgets (around €574 Mio on an annual average) of the 6th Framework Programme and the Intelligent Energy Programme (€50 Mio) are excluded from the analysis. Since 2007, these additional funds would even be more important with 7th framework programme amounting to €886 Mio/year from the EC and EURATOM Framework Programmes and €100 Mio/year from the Intelligent Energy Europe Programme[3] [European Commission, 2007e].

[3] Not all sectors have seen an increase in funding. There has be been no increase over inflation for the budget of fission-related EURATOM indirect actions, which now amounts on average to only €57 Mio/year. In addition, approximately €103 Mio/year from the EURATOM programme are for the nuclear-related activities of the European Commission's Joint Research Centre. Furthermore, not all the activities in the fission and JRC's programmes are related to energy per se, e.g. there is important research in areas such as radioactive waste management, radiation protection, nuclear safeguards, etc.

This study does not undertake new research, but mainly draws on existing studies and supranational databases. However, Member States were given the opportunity to comment on the report as part of a consultation on the SET-Plan.

As this report evaluates available information, its second purpose is to identify the future need for monitoring and evaluation that will allow a more comprehensive assessment of the energy-related R&D capacities of the public and private sectors in future SET-Plans, as the delivery of the first SET-Plan is not meant to a one-off exercise [European Commission, 2007e].

The preparation of this study has revealed significant gaps both with regard to data on R&D expenditure and funding as well as for information on the R&D infrastructure. In the following, the main sources of information are briefly introduced and some major gaps mentioned.

It must be noted that the assessment on energy research budgets and expenditures and its infrastructure does not necessarily provide a complete picture on the energy innovation capacities in Member States. This would require a more comprehensive analysis, taken into account also output indicators. Nevertheless, a quantifiable relation between R&D intensity and technological development has been shown [Doornbusch and Upton, 2007, including further references]. A strong relation between R&D expenditure and output-based indicators has also been found. On this ground, the narrow approach followed in this study can be justified.

3.2. Sources of data on R&D expenditure and funding

A reliable data basis is indispensable for estimating the energy R&D funding and expenditure and direction of energy research in the EU. At the moment, there are four supranational datasets on energy R&D funding covering (most) EU Member States, namely:

- GBAORD: Government Budget Appropriations or Outlays on R&D are all appropriations allocated to R&D in central government or federal budgets. This is collected from government R&D funders and maintained by Eurostat and the OECD[4] and follows the NABS (Nomenclature for the Analysis and Comparison of Scientific Programmes and Budgets) classification, a socio-economic nomenclature.

- GERD (Gross Domestic Expenditure on R&D). Like the GBAORD, this database is created by Eurostat/OECD on the basis of data collected from all R&D performers. It has a sectoral breakdown (BES: business and enterprise, GOV: government, HES: higher education; PNP: private non-profit)

- The BERD (Business enterprise sector's R&D expenditure) database from Eurostat contains figures on the business sector's expenditure in R&D broken down by different sectors and sources of funds. It is basically the part of GERD that is financed by the business sector.

- The IEA R&D statistics. They are collected from government R&D funders and use a scientific/technical nomenclature. The underlying 'questionnaire' and the classification

[4] There are differences in the way the collected data are treated by OECD/Eurostat but the two databases rely on the same raw data.

were recently updated (e.g. to account for new technologies) as proposed by an expert group on energy R&D statistic [European Commission, 2005h[5]].

- The EU Industrial R&D Investment Scoreboard[6] provides data on investment in R&D from 2000 companies from around the world reporting major investments in R&D. The set of companies it covers comprises the top 1000 R&D investors whose registered offices are in the EU and the top 1000 registered elsewhere. The companies are broken down by sector of activity, and to give a full picture the data presented include R&D investments, and other economic and financial data (sales, capital expenditures, profits or losses, employees) from the last four financial years.

The scoreboard is prepared from companies' annual audited reports and accounts using rigorous financial reporting practice verification processes. In order to maximize completeness and avoid double counting, the consolidated group accounts of the ultimate parent company are used.

Companies are allocated to the country of their registered office. In some cases, this is different from the operational or R&D headquarters. This means that the results are independent of the actual location of the R&D activity. Examples are EADS (the Netherlands), AstraZeneca (UK) or Royal Dutch Shell (UK).

The main limitations of the Scoreboard are due to different national accounting standards determining the information disclosure practices of companies. For companies listed in stock markets the situation will improve with the adoption of the international financing reporting standards (IFRS).

In summary, the Scoreboard is a useful tool to monitor and analyze R&D developments by business corporations although it does not specify the location and the nature of the R&D investments (place of execution and type of technological development).

Unfortunately, these databases cannot easily be compared one another, mainly due to

- Different coverages: GBAORD, GERD and the scoreboard comprise all R&D, while the IEA is restricted to energy R&D. However, a sub-classification in GBAORD and GERD covering the energy part is also available, yet often data entries are missing. Currently only few countries supply data to EUROSTAT for the sub-categories under the GBAORD category energy.

- Different geographical coverage: While the databases hosted by Eurostat comprises all EU Member States, the IEA database covers IEA Member States. This means that 10 EU Member States are not included in the IEA database, i.e. Bulgaria, Estonia, Cyprus, Latvia, Lithuania, Malta, Poland, Romania, Slovenia, and Slovakia. However, Poland and the Slovak Republic are expected to become IEA members soon.

- Different approaches: While EUROSTAT collects budget data in its GBAORD statistics and expenditure data in GERD, the IEA assembles both budget and expenditure data in its

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5 The European Commission set up an expert group on energy R&D statistics, which included members from the IEA, EUROSTAT and 10 EU Member or Associated Countries (European Commission, 2005h). They produced a number of recommendations on how to improve the data production chain and how to make energy R&D statistics more responsive to users' needs, many of which were taken into account in the updated IEA questionnaire.

6 The Scoreboard is available on-line from http://iri.jrc.es/

energy R&D questionnaire. The Scoreboard uses data from companies' annual audited reports.

- Different sectoral breakdowns: The GERD follows an institutional nomenclature, the NACE (the European statistical classification of economic sectors), while the Scoreboard classifies companies' economic sectors according to the ICB classification[7]. GBAORD follows a functional classification, which has a first level representing socio-economic objectives (SEO's), and uses varying logical structures on the lower levels. The IEA energy R&D data use a scientific/technological structure.

- Different geographical allocation: The Scoreboard refers to all R&D financed by a particular company from its own funds, regardless of where that R&D activity is performed. BERD refers to all R&D activities performed by businesses within a particular sector and territory, regardless of the location of the business's headquarters, and regardless of the sources of finances.

- Lack of coordination in data collection: Some countries collect data on budgets, others on expenditure; demonstration projects may be accounted for in different ways; some countries attribute the whole budget of a program or project to the first year, whereas others indicate actual yearly expenditures etc. [see e.g. European Commission, 2005h].

This report takes into account information from all of the above mentioned main data sources. However, as a consequence of the inherent differences between the data sources, the information taken from different sources is kept apart in Sections 4.2. and 5.2. Preliminary conclusions covering the information from the different sources are drawn at the end of those two chapters.

It should be noted that a complete overview of energy- and transport-related R&D funding and expenditure would also need to capture the upstream research and innovation expenditures as the energy sector crucially depends on research in other sectors. For example, oil and gas extraction industries depend on innovation that is carried out by mechanical engineering workshops or engineering consultancy firms [Kaloudis and Petersen, 2006]. Similarly, material research often is a pre-condition for the development of new energy technologies. However, current sectoral breakdowns do not easily allow for such task. A thorough in-depth analysis of the Scoreboard data on a company by company basis might allow for a first approach.

3.3. Sources of information on energy and transport R&D infrastructure

Consistent information on the institutions involved in the policy process to the final performance of energy- and transport-related research is sketchy. In 2007 a survey has been conducted by the European Commission among the administrations of all EU Member States in order to monitor the structure of the national R&D systems in the particular field of Energy. To this end, a questionnaire has been sent to the corresponding government departments responsible for the implementation of the energy R&D budget. The 17 replies that were received by DG TREN were a very valuable input for this report.

The issues addressed in this survey were:

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7 "Industrial Classification Benchmark" setup by FTSE and Dow Jones, replacing the FTSE classification used in previous Scoreboard editions.

- Organisation and structure of Energy R&D and innovation activities in the country
- R&D and Innovation priorities
- R&D and innovation budget and implementation schemes
- Estimates of the private investment in energy R&D and innovation activities
- Foreseen additional measures

Other important sources of information include a number of research studies that were carried out for the European Commission, and that mostly address energy-related research [European Commission, 2005b, f, g; 2006d; 2007a; i]. Information on transport-related research is also relatively patchy; a helpful information source is a report by the ERA-NET transport, which unfortunately comprises only 12 Member States [Kropf et al., 2005]. Also the Industrial R&D Scoreboard (see Section 3.2) is a valuable source of information on the main private actors involved in research in the different sectors.

Eventually, information from ERAWATCH was used. ERAWATCH has been created to provide evidence-based policy intelligence in the research field in Europe. It is a service contributing to the realisation of the European Research Area (ERA). ERAWATCH is a European web-based service that presents information on national and regional research policies, actors, organisations and programmes. ERAWATCH is targeted at those interested and active in research policy making in Europe, for example decision makers, policy analysts, researchers, NGOs.

ERAWATCH is funded through the European Community's Research Framework Programme. It is jointly run by the European Commission's Directorates-General for Research and the Joint Research Centre - Institute for Prospective Technological Studies (IPTS). The online service is provided through CORDIS[8].

A core element of ERAWATCH is the Research Inventory. Information can be accessed on a country level as well as at an aggregate EU level and through a range of advanced searches. ERAWATCH provides information on the 27 Member States of the European Union, countries associated with the European Community's Research Framework Programme, and for comparative purposes China, Japan and USA. From autumn 2007, coverage will also include India, Republic of Korea, Canada, Australia, New Zealand and Brasil. Information is collected with the support of the ERAWATCH Network of national research and consulting organisations specialised in gathering and analysing information relevant to research policy-making. Quality of information is checked in several steps by ERAWATCH Network senior policy analysts and management and by IPTS country desks.

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8 http://cordis.europa.eu/erawatch/

Box 1 – Current coverage of energy R&D policies in ERAWATCH

A core element of the EU-funded ERAWATCH is the Research Inventory. Information can be accessed on a country level as well as at an aggregate EU level and through a range of advanced searches. Currently however, ERAWATCH addresses specific thematic fields, i. e. energy research policies, only to a limited extent. In the base-load inventory, more energy-specific information is or will soon be covered in three ways:

– Two sections in the country profile which address the "Thematic research policy priorities" and "Thematic priorities and other targeted funds";

– Specific templates on relevant research programmes and partly - in countries which do not have a programme-based implementation structure - policy documents and organisations;

– A thematic search screen bringing together relevant information from country profiles and specific templates according to a classification of thematic fields which basically follows the thematic areas of the FP 7 cooperation programme, containing energy and mobility/transport as separate items.

Furthermore, ERAWATCH provide more detailed R&D country profiles, with the current coverage of energy research policies still being mixed. For Denmark and Japan, an extended scope of coverage with regard to thematic fields such as energy in the ERAWATCH research inventory can be expected by autumn 2007. It is expected that by that time one to two energy relevant specific programmes, organisations or policy document templates will be accessible for many of the EU-27 countries.

4. THE PUBLIC SYSTEM OF ENERGY-RELATED R&D

R&D in energy is considered as important and challenging due to the strategic importance of energy, the need for security of supply, its environmental impacts (in particular for climate change) and the time horizons used in this sector. In general, the government should guarantee an attractive environment for the research activities by both the private and public sector. Public research initiatives (e.g. R&D subsidies) are necessary where the actions by the private sector are insufficient (e.g. fundamental research, international cooperation, etc. – for more on the rationale for public research initiatives see Box 2).

The role of the public sector in energy-related research is twofold. A first role of the governments is to stimulate R&D in new energy technologies ("technology push"). This will help in resolving technical problems and reducing the costs that are typically above those of existing technologies. A second role for the governments is to create favourable conditions for deploying the new energy technologies ("demand pull"). Such market pull instruments contribute to the maturing of new technologies through "learning". Further, technologies that may overcome these technical and cost-competitive barriers may still face a wide range of barriers, as e.g. planning and licensing or lack of financing; nevertheless these are largely outside the scope of this study.

The public energy-related R&D infrastructure is presented in Section 4.1. The public spending on energy and transport R&D in the EU is dealt with in Section 4.2. We elaborate on the policies for market deployment of energy technologies in Section 4.3. The conclusions are listed in Section 4.4.

4.1. Public energy-related R&D infrastructure

Table 1 provides a tentative and non-exhaustive overview of the different actors involved in energy and transport R&D for all EU Member States. The table is mainly based on the Member State survey for the SET-Plan, and completed using a number of other studies[9] [e.g. European Commission, 2005f; ERAWATCH Network, 2007]. In general, the information on transport R&D capacities is less complete than for energy; and it is mainly based on ERAWATCH and the ERA-NET transport [Kropf et al., 2005]. Due to their large number of actors, universities are not included in the table, even though they include some of the most important R&D performers.

The table indicates large discrepancies in capacities and responsibilities for energy and transport R&D across the EU Member States. These will be assessed further in this chapter, and in some cases be compared with those in the USA and Japan.

[9] In some cases this information may be incomplete or outdated.

Box 2 – Why should governments invest in R&D?

The increase in R&D expenditure has become a priority of European governments in the last decade. The Barcelona European Council of March 2002 set the objective to increase the average investment in R&D in Europe from 1.9% to 3.0% by 2010, of which two thirds to be funded by the private sector [European Commission, 2002].

Why should governments (regional, national or EU) invest in R&D? And if they do, how can they contribute? One can distinguish three reasons why governments should step into R&D investment.

First, it is demonstrated that the R&D activities of private firms generate widespread benefits enjoyed by consumers and society at large. As a result, the overall economic value to society often exceeds the economic benefits enjoyed by innovating firms as a result of their research efforts. This excess of the social rate of return over the private rate of return enjoyed by innovating firms is defined as a positive externality or spillover. These spillovers imply that private firms will invest less than is socially desirable in R&D, with the result that some desirable research projects will not be undertaken, and others will be undertaken more slowly, later, or on a smaller scale than would be socially desirable. These spillovers flow through a number of distinct channels. First, spillovers occur because the workings of the market for an innovative good create benefits for consumers and non-innovating firms ("market spillovers"). Second, spillovers occur because knowledge created by one firm is typically not contained within that firm, and thereby creates value for other firms and other firms' customers ("knowledge spillovers"). Finally, because the performance of interrelated technologies may depend on each other, each firm improving one of these related technologies creates economic benefits for other firms and their customers ("network spillovers"). Governments should invest in projects that have a high social rate of return, but that would be underfunded, delayed or otherwise inadequately pursued in the absence of government support. This objective can be furthered by pursuing projects for which the gap between the social and private rates of return ("the spillover gap") is large [Jaffe, 1996].

Second, a forward-looking planning is important, which accounts for the expected demand for new capacities in order to match the appropriate 'time window', available technologies and possible developments of the energy prices and environmental legislation. Often, such time horizons exceed the planning of private investors, underlining the need for government action in energy R&D.

Third, risk, capital market imperfections and financial factors may also impede socially desirable R&D efforts. Among others, the governments can respond to this by implementing market pull instruments, in particular feed-in tariffs (which are discussed in Section 4.3.) or by giving the right incentives to 'venture capital' (see Box 3).

Table 1: Institutional framework of energy/transport research in EU Member States (Universities are not listed due to their large number)

	Ministries (or other setting energy R&D priorities)	Agencies and Intermediary organizations (Implementation)	Public Research Organizations	PPP / private institutes	Regional research	Special energy R&D programmes	Others/Remarks
Austria	Ministry for transport, innovation and technology (BMVIT) Ministry of economics and labour (BMWA) Ministry of agriculture, forestry, environment and water management Ministry for Education, Science and Culture Research Councils	Research Promotion Fund (Forschungsförderungsesellschaft)	Austrian Research Center Seibersdorf (transport division) Joanneum Research (energy and transport unit) Austrian Transport and Mobility Research Centre	A3PS – Austrian Agency for Alternative Propulsion Systems	The Länder have individual programmes	Federal Programme on Technologies for Sustainable Development with the 3 subprogrammes: - Building of tomorrow - Factory of tomorrow - Energy systems of tomorrow Transport R&D programmes, e.g. - Intelligent Transport Systems and Services	

	Ministries (or other setting energy R&D priorities)	Agencies and Intermediary organizations (Implementation)	Public Research Organizations	PPP / private institutes	Regional research	Special energy R&D programmes	Others/Remarks
Belgium	The main responsibilities for energy R&D lies with the regions In Flanders: Department of Economy, Employment, Internal Affairs and Agriculture Department of Environment and Infrastructure Department of Education and the Department of Science Innovation and Media Wallonie Region: D.G.T.R.E. (Direction Générale des Technologies, de la Recherche et de l'Énergie) Brussels Region : IBGE-BIM Federal level: Minister for Economy, Energy, Foreign Trade and Science Policy	IWT-Flanders: Institute for the promotion of innovation by science and technology in Flanders FWO Flanders: Fund for scientific research in Flanders Cogen-Sud (promotion of cogeneration)	VITO CSTC	IMEC (solar cells)	The regions are leading in energy and innovation policy, including energy R&D. The federal level, however, remains responsible for all nuclear issues.		

	Ministries (or other setting energy R&D priorities)	Agencies and Intermediary organizations (Implementation)	Public Research Organizations	PPP / private institutes	Regional research	Special energy R&D programmes	Others/Remarks
Bulgaria	Ministry of Education and Science Ministry of Economy and Energy Ministry of Agriculture and Forest National Science Council	The National Science Council consults, finances and supports implementation of research programmes	Bulgarian Academy of Sciences: Central Laboratory of Solar Energy and New Energy Sources, the Regional Black Sea Center and the Technical University Sofia. National Centre of Agrarian Sciences SVT - Institute for Energy and Technique University for Mining and Geology	Executive Agency for the Promotion of SME's		National innovation strategy	
Cyprus		The planning bureau defines and co-ordinates all government interventions in favour of research Research Promotion Foundation is a non profit independent institution used as an interface with the scientific community.	Applied Energy Centre Institute of Energy Agricultural Research Institute (ARI)				
Czech Republic	R&D Council of the Government Ministry of Education, Youth and Sports Ministry of Industry and Trade Academy of science Grant Agency	Czech Energy Agency R&D Council of the Government RVV	Academy of Sciences (with more than 50 institutes) More than 50 other research institutes, in large part drawn together in the association of research organizations AVO			Long-term Research Guidelines include priority point 3: energy sources Research Programme of the Ministry of transport 2007-11	

	Ministries (or other setting energy R&D priorities)	Agencies and Intermediary organizations (Implementation)	Public Research Organizations	PPP / private institutes	Regional research	Special energy R&D programmes	Others/Remarks
Denmark	Ministry for Transport and Energy Ministry for Science, Technology and Innovation Advisory body on Energy Research	Danish Energy Authority Danish Agency for Science, Technology and Innovation Danish Environmental Protection Agency Danish Board of technology Board of Danish Research councils plus the 6 Danish Research Councils Danish Road Directorate Fund for Advanced Technology (independent government board) TSO energinet.dk	Risoe Danish Road Institute	The system operators ELTRA and ELKRAFTSYSTEM grant subsidies to research and development projects		Energy Research Programme (by Danish Energy Authority) Strategic Research on energy and environment (Ministry of Science) Renewable Energy research Programme (Ministry of Science) Clean electricity - Public Service Obligation Research (different operators) Transport research strategy	Part of the Nordic energy research council
Estonia	Ministry of Education Ministry of Economic Affairs and Communication Research and Development Council (TAN): strategy advisory body for the Government in the field of RD&I.	Estonian Research Foundation (ETF) Estonian Technology Agency (ESTAG)	Estonian Academy of Sciences Estonian Energy Research Institute	Enterprise Estonia			

	Ministries (or other setting energy R&D priorities)	Agencies and Intermediary organizations (Implementation)	Public Research Organizations	PPP / private institutes	Regional research	Special energy R&D programmes	Others/Remarks
Finland	Ministry of Education Ministry of Trade and Industry Ministry of Transport and Communication Science and Technology Policy Council	Tekes, the National Technology Agency, finances applied and industrial R&D in Finland. The Academy of Finland finances fundamental academic research	VTT Technical Research Centre of Finland Plans to found Strategic Centers for Science, Technology and Innovation, including e.g. the area of energy and environment.				Part of the Nordic energy research council

	Ministries (or other setting energy R&D priorities)	Agencies and Intermediary organizations (Implementation)	Public Research Organizations	PPP / private institutes	Regional research	Special energy R&D programmes	Others/Remarks
France	Ministry of Finance, Economy and Industry Ministry of Higher Education and Research Ministry of Ecology, Sustainable Development and Town and Country Planning	ANR – National Research Agency AII – Agency for Industrial Innovation ADEME (Environment and Energy Management Agency) AGRICE (Agriculture for Chemistry and Energy) CEA (Atomic Energy Commission) leading R&D agency in the field of energy (15000 employees in 9 research centres)	CNRS (National Centre for Scientific research) CEA National Institute for Solar Energy IPSN – National Institute for Nuclear Protection and Safety CNRT – Energy and Environment (National Centre of Technological Research) BRGM - Geological and Mining Research Office EPST - Scientific and Technological Public Institution Institute Carnot IRSN – National Institute for Research on Radiation Protection and Nuclear Safety INRETS National Institute for Research on pollution, GHG and clean transport LCPC: National Institute for Applied Research in transport infrastructure CERTU – Centre d'etudes de reseaux, de transports, de l'urbanisme et de construction publique IFP – Institut Français du Pétrole	Pôles de compétitivité (Fond unique interministeriel) AII – Agency for Industrial Innovation OSEO Innovation IFP INRET - National Institute of Research on Transport	Regional Research and Technology Delegations DRRT Regional Consultative Committees on Technological Research and Development CCRRDT Regional Innovation and Technology Transfer Centre CRITT RT3: inter-regional cooperation initiative in transport research	National Research Strategy for Energy PREBAT (Energy research in construction; part of the climate plan 2004) Interdisciplinary energy programme CNRS: dual system as the research advisers and performers are the same PREDIT – transport R&D ANR calls	

	Ministries (or other setting energy R&D priorities)	Agencies and Intermediary organizations (Implementation)	Public Research Organizations	PPP / private institutes	Regional research	Special energy R&D programmes	Others/Remarks
Germany	Ministry for Economy and Technology BMWi Ministry of Environment and Nuclear Safety BMU Ministry of Education and Research BMBF Ministry of Transport, Building and Urban Affairs BMVBS Ministry of Consumer Protection, Food and Agriculture BMELV	Project Agency Jülich (part of Helmholtz Society) DFG – German Research Foundation (project funding at universities) German Energy Agency DENA Federal Office for Radiation Protection (BfS)	Helmholtz Society, out of which six participate in energy research (DLR; FZ Karlsruhe; FZ Jülich; GFZ; HMI; Max-Plack-Institut für Plasmaphysik) Fraunhofer Society, out of which in energy R&D are ISE; IBP; UMSICHT; IWS; ISI (Max-Planck Society) (Leibniz-society) Several so called “Forschungsverbände” or research-networks aim to coordinate the activities of non-university research centres in specific fields (see also under PPP). Federal Highway Research Institute (BASt)	German Federation of Industrial Cooperative Research associations AIF A number of institutionalised cooperations, e.g. National Hydrogen and Fuel Cell Strategy Council COORETEC,on new power station technologies) ForschungsVerbund Sonnenenergie (solar energy), Kompetenzverbund Kernenergie (nuclear energy) AG Turbo (turbines)	Within the federalist setting of the German research system, funding of R&D is organised both on the national and the federal level, with (basic) university funding mainly in the competence of Länder and more applied funding under shared competence of the federal government and the Länder. Funding of regional research centres such as ZSW, ZAE, ISFH, DEWI, ISET	Research organized with framework programmes (5th energy research framework programme): shift from nuclear to efficiency and renewables.	

	Ministries (or other setting energy R&D priorities)	Agencies and Intermediary organizations (Implementation)	Public Research Organizations	PPP / private institutes	Regional research	Special energy R&D programmes	Others/Remarks
Greece	Ministry of Development National Council for Research and Technology Ministry of Economy and Finance Ministry of Agriculture Ministry of Education Ministry of National Defence General Secretariat for Research and Technology (GSRT)	General Secretariat for Research and Technology (GSRT), which co-ordinates research National Foundation for Agricultural Research (NAGREF), Institute of Geology and Mineral Exploration (IGME)	CRES – Centre for Renewable Energy Sources Centre for Research and Technology Hellas (CERTH) Institute for Solid Fuels Technologies and Applications (ISFTA) National Centre for Scientific Research (Demokritos) Institute for Chemical Processes Engineering (CPERI) Institute of Electronic Structure and Lasers (ISEL-FORTH) Institute of Chemical Engineering and High Temperature Chemical Processes (ICE-HT)	GSRT also aims to encourage partnerships between research organisations and industry		Operational Programme Competitiveness and Innovation 2007-2013	
Hungary	Ministry of Education	The Hungarian Energy Centre	Academy of Sciences				

	Ministries (or other setting energy R&D priorities)	Agencies and Intermediary organizations (Implementation)	Public Research Organizations	PPP / private institutes	Regional research	Special energy R&D programmes	Others/Remarks
Ireland	Department of Communications, Marine and Natural Resources Irish Energy Research Council Department of Environment Department of Enterprise, Trade & Employment	Sustainable Energy Ireland (SEI)	SEI Teagasc Environmental Protection Agency Marine Institute Enterprise Ireland Economic and Social Research Institute			Energy White Paper Science Technoloy and Innovation Strategy contains energy R&D as central topic	
Italy	Ministry of Education, University and Research Ministry of Productive Activities Ministry for Environment and Territories	Ministries are directly funding research National Agency for New Technology, Energy and Environment ENEA					
Latvia	The Ministry of Education and Science Latvian Council of Sciences Ministry of Economics Ministry of Agriculture Investment and Development Agency	Latvian Council of Sciences	Latvian Academy of Science, in particular Institute of Physical Energetics				

	Ministries (or other setting energy R&D priorities)	Agencies and Intermediary organizations (Implementation)	Public Research Organizations	PPP / private institutes	Regional research	Special energy R&D programmes	Others/Remarks
Lithuania	Ministry of Education and Science Ministry of Economy Ministry of Finance Ministry of Agriculture Science Council	Lithuanian State Science and Studies Foundation Energy Agency	Lithuanian Academy of Sciences Lithuanian Technology Institute Lithuanian Energy Institute	Development Agency for SMEs		No national programme for energy R&D but plans for a future energy national research programme	
Luxembourg	Ministry of Economic Affairs	Luxinnovation National Research Fund	Henri Tudor Public Research Centre				
Malta	Ministry of Education						
Netherlands	Ministry of Education and Science Ministry of Economic Affairs Ministry of Transport, Public Works and Water Management	Senter Novem NWO (Netherlands foundation for scientific research)	Energy Research Centre of the Netherlands (ECN) TNO (Research organisation for Applied Natural Sciences) SDE (Consortium for Sustainable Energy) Wageningen UR institute for agro technology and food innovation KEMA			Energy Research Strategy of the Netherlands	

	Ministries (or other setting energy R&D priorities)	Agencies and Intermediary organizations (Implementation)	Public Research Organizations	PPP / private institutes	Regional research	Special energy R&D programmes	Others/Remarks
Poland	Ministry of Science and Higher education Ministry of Economy Ministry of Regional Development Ministry of Environment	National Energy Conservation Agency	National Technology Platforms Polish Academy of Sciences, such as its Institute of Fundamental Technological Research IPPT PAN Mineral and Energy Economy Research Institute			Energy is one of the strategic priorities of the National Framework Programme 'Technological Fishing Rod'	
Portugal	Ministry of Science, Technology and higher education Ministry of Economy and Innovation Ministry of the Environment The Ministry of Social Equipment (transport)	National Institute for Engineering and Industrial Technology (INETI) Innovation Agency (ADI) Science and Higher Education Observatory (OCES)	CEEETA - Centro de Estudos em Economia da Energia, dos Transportes e do Ambiente The Institute of Nuclear Technology (ITN) National Laboratory for Civil Engineering (LNEC)	Innovation Agency (ADI)			Plans for a new laboratory of State with a focus on energy and geosciences (LNEG)
Romania	Ministry of Research Ministry of Industry	Romanian Agency for Energy Conservation	Energy Research and Modernising Institute				
Slovak Republic	Ministry of Education Ministry of Economy	Agency for Support of Science and Technology VEGA, Scientific Grant Agency Centre for Development, Science and Technology, SARC Academy of Sciences	Slovak Academy of Sciences	VUJE Travna – a privately owned nuclear research institute		Energy R&D programme 'Application of progressive principles of production and transformation of energy'	

	Ministries (or other setting energy R&D priorities)	Agencies and Intermediary organizations (Implementation)	Public Research Organizations	PPP / private institutes	Regional research	Special energy R&D programmes	Others/Remarks
Slovenia	Ministry of Education, Science and Technology Ministry of Finances	Slovenian Research Agency Public Agency for Technology of the Republic of Slovenia	Jožef Stefan Institute Milan Vidmar Electric Power Institute National Institute of Chemistry Institute for Public Administration (Faculty of Law) Economic Institute of the Law School	Energy, Ecology and Technology Research Institute d.o.o Korona d.d. Electras Nova d.o.o ApE – Energy Restructuring Agency Ltd. ELEK d.o.o			
Spain	Ministry of Education and Science Ministry of Industry, Tourism and Trade Ministry of Environment Interministerial Commission on Science and Technology	Institute for Energy Agency for Diversification and Efficiency of Energy (IDAE) Centre for Technological Industrial Development (CDTI)	CIEMAT Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas CENER is the National Centre of Renewable Energies CIDAUT is a Centre of Research and Development in Automotive IGME – Institute for Mining and Geology High Council for Scientific Research (CSIC)		Regional research plays a limited role Example: Foundation Center of Research for Energy Resources and Consumption (CIRCE) in Zaragoza	National Plan on Scientific Investigation, Development and Technological Innovation	

	Ministries (or other setting energy R&D priorities)	Agencies and Intermediary organizations (Implementation)	Public Research Organizations	PPP / private institutes	Regional research	Special energy R&D programmes	Others/Remarks
Sweden	Ministry of Enterprise, Energy and Communications National Research Council	Swedish Energy Agency STEM National Research Council Governmental Agency for Innovation Systems Research Council for Environment, Agricultural Sciences and Spatial Planning				Energy Research Programme	Part of the Nordic energy research council
UK	Department of Trade and Industry (DTI; office of science and technology) Department of Environment, Food and Rural Affairs (DEFRA) Department for Transport UK energy research centre Energy Research Partnerships	There are 6 grant-awarding Research advisory councils; the majority of energy R&D funds come from the Engineering and Physical Sciences Research Council Energy Technologies Institute Carbon Trust Energy Saving Trust	UK energy research Centre	Energy Research Partnerships Energy Technologies Institute	Regional Development Agency		

NB: Often, a clear distinction between e.g. PRO's and Agencies and Interim organizations is not possible. Some of the table entries need thus to be interpreted with care.

Sources: ERAWATCH Network, 2007; European Commission, 2005f – annexes; ERAWATCH website http://cordis.europa.eu/erawatch/; Member States surveys

4.1.1. Institutional energy and transport R&D framework

The institutional energy and transport R&D framework can be divided into decision making and priority setting, implementing R&D policies and conducting and carrying out of research itself. A clear distinction between these divisions is very often somewhat artificial. For example, public research organisations often act both as a performer of research, but are active also in the policy implementation by allocating funds. Similarly, Research Advisory Councils are sometimes involved both in the policy making and the implementation processes.

The basic *decision making* with regard to energy and transport R&D funds is taken by ministries in the majority of Member States (see column 1 of Table 1) The responsible ministries, however, vary across Member States: they include not only ministries of energy and/or transport but also ministries of finance and economy, ministries of science or innovation.

In many Member States, energy R&D is primarily the responsibility of one or two ministerial departments (Education/Science and Industry/Energy, in some cases directly linked to the Ministry of Economy or Finance). In other countries, a large number of Ministries share the responsibility for energy research. In Germany, for example, four ministries manage energy R&D research, namely the Ministry of Economy and Technology BMWi (general energy R&D), environment ministry BMU (renewables), the Ministry on Food, Agriculture and Consumer Protection BMELV (biomass applications), with the research Ministry BMBF coordinating and managing horizontally all institutional energy research priorities and contributing to nuclear R&D.

In many Member States, an inter-ministerial body supervises the adequacy of short-term, mid-term and long-term targets to the overall R&D targets prescribed by the government (e.g. CICYT in Spain). In other countries, the strategy plan is the main responsibility of one single department: for instance, in Sweden the strategy plan depends on the Ministry of Enterprise, Energy and Communications and in Greece on the General Secretariat for Science and Technology (GSRT). In a number of Member States, Councils on Science and Research also play an important role in the decision processes (e.g. Bulgaria, Denmark, Ireland etc.).

The institutional framework for the *implementation of energy R&D* policies is even more heterogeneous, stemming from differences in the historic development, the energy mix and the subsequent importance of the respective actors, and energy policy objectives (column 2 of Table 1). There are basically four ways in which implementation is organised (analogous to European Commission, 2005f). Yet, often a clear attribution of an institute to one of the categories is difficult to make and in many Member States, several of the options are in place (e.g. for France).

- Directly falling under responsibility of the ministry. This is the case e.g. for Belgium (regional ministries), Italy, Austria and Greece. In some countries, the research activities are directly managed by the central (or federal) governmental departments, whereas in other cases, specific para-governmental agencies for the management of the R&D are created for this purpose such as the General Secretariat for Research and Technology in Greece.

- Through an agency dedicated to the energy field, such as the Czech Energy Agency, the Danish Energy Authority, or the Swedish Energy Agency STEM.

- In some countries, specific agencies exist that are mainly dedicated to the market promotion of new, emerging energy technologies or focus on energy conservation. The role of these agencies is to act in the final R&D and innovation phase, by promoting the first commercial implementation of technologies that are ready for the market. Examples are the Romanian Agency for Energy Conversation, IDAE in Spain and ADEME in France.

- The UK system is an example for a number of specific agencies for the management of the R&D. Depending on the nature of the research project, its management is channelled along a different institution: basic research is generally coordinated by the Energy Research Partnership, Research Councils and the UK Energy Research Centre itself, whereas development and demonstration programmes are managed by the recently created UK Energy Technology Institute, the Technology Strategy Board or the Carbon Trust, and the Environmental Transformation Fund or the Regional Development Agency, respectively, none of which are within a single Ministry.

- The concept of Research Councils taking an active role in the implementation of energy R&D policy can also be observed in Denmark, Latvia, the Czech Republic and Bulgaria.

- By a broader technology agency that is not limited to the energy field. Amongst them we find TEKES in Finland, INETI in Portugal, SenterNovem in the Netherlands, the French Innovation Agency AII, the Estonian Technology Agency, CDTI in Spain etc.

- Through the main national research organisation of a country in the area, which acts de facto as an agency. This approach can be found e.g. with the CEA in France, but in parts also in Spain (CIEMAT). Also in Germany, the 'Projektträger Jülich' acts as a funding organisation for institutional energy research, while it is part of one of the largest energy public research organisations, the Helmholtz society.

Additionally, a large number of other institutions are involved in the implementation of energy R&D policies. Furthermore, regional competences for energy R&D exist in Austria, Belgium, Germany[10] and Spain, which is particular important for the former two.

The *performers of energy research* in Europe are public research organisations, universities and enterprises in the private sector (column 3 of Table 1). As there are no comprehensive data on energy research by sectors, only a rough indication of the importance of the different players may be derived from a look at the gross expenditure on R&D across all topics. Universities have a high share in total research of 22%, compared to the US (14%) and Japan (14%) (see Table 2). Similarly, EU universities also employ a large number of researchers (33.6% of total researchers, compared to 14.7% in the US and 25.5% in Japan) [European Commission, 2007i].

The public research organisations often (and especially in relatively large Member States) consist of a network of energy research laboratories specifically dedicated to energy technology research according to the priorities identified by the corresponding government. They have often evolved from purely public research organisation, mostly involved in (nuclear) energy research, towards a mixed funding structure, i.e. a combination of grants,

[10] A country report prepared in the context of the study (EC, 2005f) shows that regional energy research support plays only a limited role in Germany. Yet, it needs to be noted that this depends on the sectoral definition, as, for example, this may have played a larger role with regard to energy efficient buildings.

competitive funding and paid direct contracts, and a broader range of energy-related topics Usually there are close links to industry and national authorities [European Commission, 2007i].

Reference public or semi-public national energy technology laboratories include the French CEA and IFP, the Dutch ECN, the Finish VTT, the Italian ENEA, the Spanish CIEMAT, the Greek CRES, the British UKERC. Other European excellence research Institutes although devoting significant efforts to the energy-related applications, are not strictly speaking energy research centres (e.g. VITO in Belgium). In Germany, two out of the 15 Helmholtz Research Centres are particularly involved in the energy field: the Jülich Research centre and the Karlsruhe Research centre. The Fraunhofer Gesellschaft network is also very active in energy research, but it is not entirely dedicated to it. This is also the case of the Danish RISOE Lab, and the Portuguese INETI.

Furthermore, in most of the countries, basic research related to energy is funded by bodies, equivalent to the University system or National Academy of Sciences. In many of the Eastern European Member States, the Academy of Sciences has taken over the role of public research organisations, e.g. Hungary, Czech Republic, Bulgaria, the Baltic States. In some cases, the academies of sciences also play a role in the implementation or even decision-making processes of energy R&D.

There is also a network of national/international laboratories, often of smaller size, mainly dedicated to specific research fields within the broad energy topic. Most are dedicated to renewable energy technologies, energy efficiency technologies and also energy system analysis. Amongst others, we find the German Fraunhofer ISE Freiburg, ISFH Hameln, ZSW Baden Württemberg, the Spanish Plataforma Solar de Almería, PV Centre Poland for Solar Energy Research, the European Academy of Wind Energy (a joint venture of CRES, RISOE, Kassel University and ECN), Centre for Renewable Energy Systems Technology Leicester (CREST).

4.1.2. Public private partnerships

Partnerships between the public and private sectors are an important element in transferring knowledge from research institutions to industry and – vice versa – better match research priorities to the needs of the industry. In addition, industrial actors are often involved in energy R&D policy making; this is described in more detail in Section 5.1.2.

While industry-science links exist in most Member States (see column 4 of Table 1), there are differences in its design, reaching from project-based collaboration to institutionalized cooperation including knowledge transfer offices, innovation agencies or technology platforms. On the one hand, public-private partnerships are established for clearly defined technology clusters, sometimes even with a regional focus. On the other hand, there exists the concept of (a more unidirectional) energy-related knowledge transfer, which can take the place in a more general innovation agency. In a number of Member States, these concepts are complementary.

A few examples are provided in the following [ERAWATCH Network, 2007; European Commission, 2007i]:

- Collaboration among public and private sectors in energy R&D is enhanced on a project level. For example, the German "Verbundprojekte" require at least one industrial partner in the consortium. On an EU level, project-based cooperation between industrial and public partners is fostered through e.g innovative concepts of the 6th Framework Programme for Research such as integrated projects.

- There can be a close link between industry and universities for clearly defined technologies. An example is the Danish Research Consortium on Wind Energy, which forms a collaboration between the Technical University of Denmark (DTU), Aalborg University (AAU), Risø National Laboratory, the Danish Hydraulic Institute (DHI) and the University of Copenhagen. The Danish Hydrogen and Fuel Cell Academy at Risoe National Laboratory follows a similar approach.

- Collaboration between universities and industrial partners can also go beyond narrow thematic topics and aim at capturing the broader field of energy research. E.g. in Germany, the Ruhr universities, Bochum, Dortmund, Duisburg-Essen, together with the Initiativkreis Ruhrgebiet founded a Public Private Partnership for energy research.

- On an EU level, the Technology Platforms succeeded in bringing together industry and public sector for strategic energy R&D issues. There are currently 32 technology platforms, out of which 6 directly deal with energy or transport-related topics. The aim of these platforms is to provide a framework for stakeholders, led by industry, to define research and development priorities, timeframes and action plans.

- Following this model, a number of national Technology Platforms have been created or are currently being established, for example in Austria, Belgium, Denmark, Germany, Greece, Italy, Netherlands, Poland, Portugal, Slovenia, Spain and the UK (the latter with the prominent UK Energy Research Partnerships) [European Commission, 2007i].

- In 2004, France introduced the 'pôles de compétitivité' (competitiveness clusters) under the Directorate General of the Ministry of Industry. The logic of Competitiveness Clusters is to create regional poles of excellence in a certain research area in accordance with regional strengths. The objective is to make work together on a small territory three types of partners (enterprises, training centers and research units) on a common innovating project with an international dimension. The concept experienced a fast uptake and there are currently 66 clusters, an important number of which relate to energy- and transport sectors.

- Technology excellence clusters may sometimes have a regional focus, making participation easier for smaller enterprises. Germany, for example, established a number of competency networks ('Kompetenznetze') aiming at regional networking, four of which are in the energy field. France has a number of regional clusters in the field of energy and transport (e.g. EnRRDIS in Rhone-Alpes focusing on energy in buildings, Normandy motor valley, electrical energy sciences in Region Centre).

- Eventually, there exist some research centers that are funded jointly by universities and industry. The RWTH Aachen and the E.ON AG, for example, are currently founding together a new energy research institute in Aachen. Also the Austrian Christian Doppler Laboratories strongly involves industrial partners.

- In some Member States, energy is one of several areas covered by innovation agencies, such as the Portuguese Innovation Agency ADI, the French Agency of Industrial Innovation AII and OSEO Innovation. The role of these agencies is to foster R&D activities within the entrepreneurial fabric, often putting particular emphasis on small and medium enterprises, by providing assistance to innovation, budgetary support and in some cases also guaranteeing external financing provided by banks and credit institutions.

- Knowledge transfer often also forms a task of the public research organization. This is the case for the French CEA that has set up 93 new high-technology companies since 1984 [European Commission, 2007i]. In Germany, the Fraunhofer-Gesellschaft cooperates closely with industrial partners; the French 'Institut Carnot' works in a similar way.

4.1.3. Energy R&D programmes within EU Member States

Dedicated energy R&D programmes are one important factor in coordinating energy research. By the end of 2003, all EU-15 Member States (except Luxembourg) had such a programme, while they were lacking in the new Member States [European Commission, 2005f]. However, this has changed in some Member States such as the Slovak Republic, and others are working on plans for the future (e.g. Lithuania).

Nevertheless, the organizational form of the programmes (separate energy R&D programme; part of a broader research strategy; linked to national energy policy strategy; broad or sectoral/technological approach) varies strongly among different Member States [European Commission, 2005f]. For example, Sweden and Denmark as well as the UK and Germany have multiannual energy R&D programmes with well-defined running times, budgets and clear objectives. In a number of other Member States, energy R&D plays a role in national research programmes with a broader scope (e.g. Poland, Austria, Spain). Thirdly, most Member States have programmes that address a specific energy/transport sector, sometimes including a regional focus.

Even more important differences can be observed among the technological priorities of national energy R&D programmes. Based on the IEA R&D database and the survey of the European Commission accompanying the Strategic Energy Technology plan, an overview of energy research priorities in different EU Member States has been produced in Chapter 6. It clearly shows the large differences among national energy R&D priorities. This is certainly influenced by the historic and current energy mix of the country, its domestic resources and/or public perception of e.g. nuclear power, as well as the specific problems the energy sector faces (e.g. environmental pollution; high import dependency).

On the other hand, a number of shared priorities among a significant number of Member States can be observed. This is the case particularly for R&D in renewable energies, yet with differences in the importance awarded to the various renewable technologies. Such areas would form a good starting basis for a better alignment of national energy-related research programmes. However, there is still little coordination among national energy research programmes and national programmes are opening up only slowly for international participation [European Commission, 2005f; 2005i].

Recently, there are some initiatives that strive for a better coordination of research (policies) among EU Member States:

- The ERA-NETs, which were created under the 6th Framework Programme for Research, aim to improve coordination of national and regional research programmes. In the long run, this will help to contribute to a greater coherence in research policies among Member States. An important element of the ERA-NETs thus includes the networking activities. There are a number of ERA-NETs in the energy and transport areas. The ERA-NET transport, for example, currently consists of 13 EU Member States and associated counties and aims at the whole land-based transport sector.

- The 6th Framework Programme for Research also introduced the Networks of Excellence (NoE) and the Integrated Projects, both of which require participants from at least three different Member States. The objective of the former is to strengthen scientific and technological excellence on a particular research topic by integrating at European level the critical mass of resources and expertise. A number of energy-related NoEs have been created. Integrated projects focus more on integration of industrial and public partners but also contain an element of international collaboration.

- The International Energy Agency's Implementing Agreements bring together experts in specific technologies in order to collaborate on R&D activities. There are currently about 40 active agreements with varying members, covering all kind of energy technologies such as clean coal, different renewable energy technologies and advanced motor fuels. However, 10 EU Member States do not belong to IEA and IEA also comprises very important non-EU countries for energy R&D[11]. Regardless this mismatch, IEA's Implementing Agreements constitute important R&D clusters that generate very interesting R&D spillovers for the EU energy R&D system.

- The Nordic Energy Research is an institution which operates under the auspices of the Nordic Council of Ministers since 1999. It comprises Denmark, Finland, Iceland, Norway and Sweden. The Nordic Energy Research Programme is aimed primarily at supporting research and development activities through grants, mobility support, network and project funding and supporting seminar and course activities.

- Even though the primary objective of the European Commission Technology Platforms is the better alignment of public research efforts to the needs of the industry, they bring together stakeholders from many Member States in a specific research area. This naturally entails information exchanges and the identification of competitive advantages amongst the members of the platform, and can therefore have a role in European coordination of research efforts.

- Some pan-European research organisations also exist for a number of specialised energy technologies, such as CERN and ITER.

- The European Academy for Wind Energy is another example of international collaboration of research institutes and universities in a specific field. It consists of four partners from Denmark, Germany, Greece and the Netherlands.

4.1.4. Energy R&D infrastructure in Japan and the USA

4.1.4.1. The US Public system of Energy R&D and Innovation

The first noticeable characteristic of the US public system of Energy R&D and Innovation is the existence of a dedicated Energy Ministry (DoE). This means that, from the administrative point of view, a single governmental department centralises all the aspects of energy policy at federal level. This is obviously a remarkable difference, since independent, energy-dedicated ministerial departments are not at all common within EU Member States. The DoE in the US was created in 1977 as a response to the first oil crises and since then it has consolidated its

[11] The following EU Member States are IEA members at the same time: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden, the UK. Poland and the Slovak Republic are expected to become member of the IEA soon.

role within the governmental structure of the US. The DoE is responsible for energy policy and nuclear safety. Its portfolio includes programmes on energy conservation, energy-related research, radioactive waste disposal, and domestic energy production and the associated regulatory and normative bodies for electricity, gas and other energy carriers. It supervises also all nuclear-related policies, including the military ones and the provision of the nuclear reactors for the US navy.

The DoE sponsors more basic and applied scientific research than any other US federal agency, most of this is funded through its system of United States Department of Energy National Laboratories. The DoE Office of Science is the steward of 10 national laboratories that support the missions of its science programs. The national laboratory system, created 50 years ago, perform research and development that is not well suited to university or private sector research facilities because of its scope, infrastructure, or multidisciplinary nature, but for which there is a strong public and national interest.

The Office of Science coordinates the activities of the following 10 national laboratories, whose activity portfolio goes well beyond strictly speaking energy issues:

- Ames Laboratory (materials science, solid state physics and computing sciences)
- Argonne National Laboratory (nuclear engineering, transportation R&D, energy systems)
- Brookhaven National Laboratory (high energy physiscs, computational biology)
- Fermi National Accelerator Laboratory (fundamental physics, astrophysics)
- Thomas Jefferson National Accelerator Facility (fundamental physics, astrophysics)
- Lawrence Berkeley National Laboratory (genomics, geology, engineering, computing)
- Oak Ridge National Laboratory (nuclear engineering, biology, advanced materials,
- Pacific Northwest National Laboratory (microbiology, environmental sciences, sensing & metrology)
- Princeton Plasma Physics Laboratory (fundamental physics)
- Stanford Linear Accelerator Center (fundamental physics)

In addition, the Office of Science funds research and development projects conducted at these additional national laboratories, which are overseen by other DoE offices:

- Idaho National Laboratory – for the Nuclear Energy office (nuclear generation IV, security, environment, etc)
- Lawrence Livermore National Laboratory – for the Nuclear Energy office (primarily security)
- Los Alamos National Laboratory – for the Nuclear Energy Security Agency office (primarily security)
- National Energy Technology Laboratory – for the Fossil Energy office (fossil fuel-related technologies)

- National Renewable Energy Laboratory – for the Energy Efficiency and Renewables office (renewable energy technologies)

- Sandia National Laboratories – for the Nuclear Energy Security Agency office (primarily security)

Despite stable or even mildly shrinking during the last years, the total R&D funding of the DoE is very high, amounting about 8 000 million $, notwithstanding the fact that this budget also includes a large share devoted to security and military applications.

4.1.4.2. The Energy R&D & Innovation System in Japan

The Council for Science and Technology Policy (CSTP) is the high-level political body that set up the overall R&D strategy for Japan. The Prime Minister himself coordinates it, and it includes the Ministers of Education, Culture, Sports, Science and Technology, and the Ministry of Economy, Trade and Industry; as well as other experts from academia, including the Science Council of Japan (SCJ) and selected experts from industry. The sectoral priorities prescribed at CSTP are then implemented by the various governmental departments and Agencies.

The Japanese Third Science and Technology Basic Plan (2006-2010) points out four primary and four secondary prioritised R&D areas[ERAWATCH, 2007]. The four primary areas are:

- Life Sciences (7 strategic priorities)

- Information and Communications (10 priorities)

- Environment (11 priorities)

- Nanotechnology and Materials (10 priorities)

Whereas the four secondary areas are:

- Energy (14 priorities)

- Manufacturing Technologies (2 priorities)

- Social Infrastructure (4 priorities)

- Frontier Science (4 priorities)

Although the CSTP plays the role of a central coordination office of R&D efforts, the public or semi-public agencies that implement the R&D programs (the so-called Independent Administrative Institutions, IAIs) benefit from a good level of autonomy, several of which are of specific relevance for the energy R&D and Innovation system:

The Institute for Chemical and Physical Research (RIKEN) conducts comprehensive research in science and technology and disseminates the results of its scientific research and technological developments. RIKEN carries out high level experimental and research work in a wide range of fields, including physics, chemistry, medical science, biology, and engineering, covering the entire range from basic research to practical application. RIKEN was first organized in 1917 as a private research foundation, and reorganized in 2003 as an independent administrative institution under the Ministry of Education, Culture, Sports, Science and Technology. The role of RIKEN in specific energy R&D is not clearly defined, since it is primarily a basic R&D institution. The budget is 600 M€, and the research staff is about 2400 (in 2005).

National Institution of Advanced Industrial Science and Technology (AIST) conducts research programmes focusing on environmental protection, strengthening the industrial competitiveness of the Japanese economy, with a focus on the exploitation of local technological resources and to support the industrial policy priorities prescribed by the government. Energy and environment is one of the 7 R&D priority lines of AIST, but some other like nanotechnologies, material sciences and manufacturing, geological sciences and life sciences have also an energy R&D component. Its total budget is around 838 M€, and the research staff is about 2300 people (in 2005).

The New Energy and Industrial Technology Development Corporation (NEDO) is a specific energy-focused research institute, originally established to develop alternative oil technologies. Since then, NEDO has diversified its activity portfolio and now conducts energy-oriented R&D in several strategic fields: in 2005 about 19% of the budget was dedicated to biofuels (mainly bioalcohol), 7% to hydrogen and fuel cells, 14% to energy-saving machinery and electronics, 8% to environmental protection technologies and 6% to new energy developments and superconductors. NEDO mainly plays the role of pure technology developer, promoting research and development for next generation technologies that are difficult for the private sector to perform due to the risk and uncertainty over outcomes and the need for multidisciplinarity. It does not carry out deployment financing projects.

The Japan Atomic Energy Research Institute (JAERI) is the public R&D institute centralising the nuclear R&D activities in Japan. Its 2000 researchers mobilise a year budget of about 700 M€, mainly dedicated to R&D in neutronics, photonics, nuclear reactor physics' & safety as well as new, advanced nuclear energy concepts. The role of fusion research in JAERI is particularly relevant.

Beyond public R&D institutes, the energy R&D and innovation system in Japan is largely based on R&D agencies financed by industrial corporations, which are described in Box 4.

4.2. Public spending on energy and transport R&D

As this report focuses on the energy R&D capacity in Member States, the funding from the EU though the 6th and 7th framework programme and the Intelligent Energy Europe Programme is not included. Prior to 2007, these programmes would add around €600 Mio to the EU figure for energy research. With FP7 and the new Intelligent Energy Programme, additional fundings will amount to €986 Mio on an annual average after 2007 [European Commission, 2007e].

The following comparison of public R&D spending is based on a number of different sources, namely GERD and GBOARD from Eurostat and the Energy R&D database from the International Energy Agency. Private sector spending is dealt with in Section 5.2, based on the Industrial Scoreboard and BERD. Unfortunately, as described in Section 3.2, the databases are not (easily) comparable.

4.2.1. Total spending (public and private) on overall R&D

Research spending largely varies among the EU Member States and the 6 biggest spenders account for 80% of total R&D spending in the EU. Furthermore, the EU as a total lags behind the US and Japan in terms of research spending relative to GDP and the number of researchers.

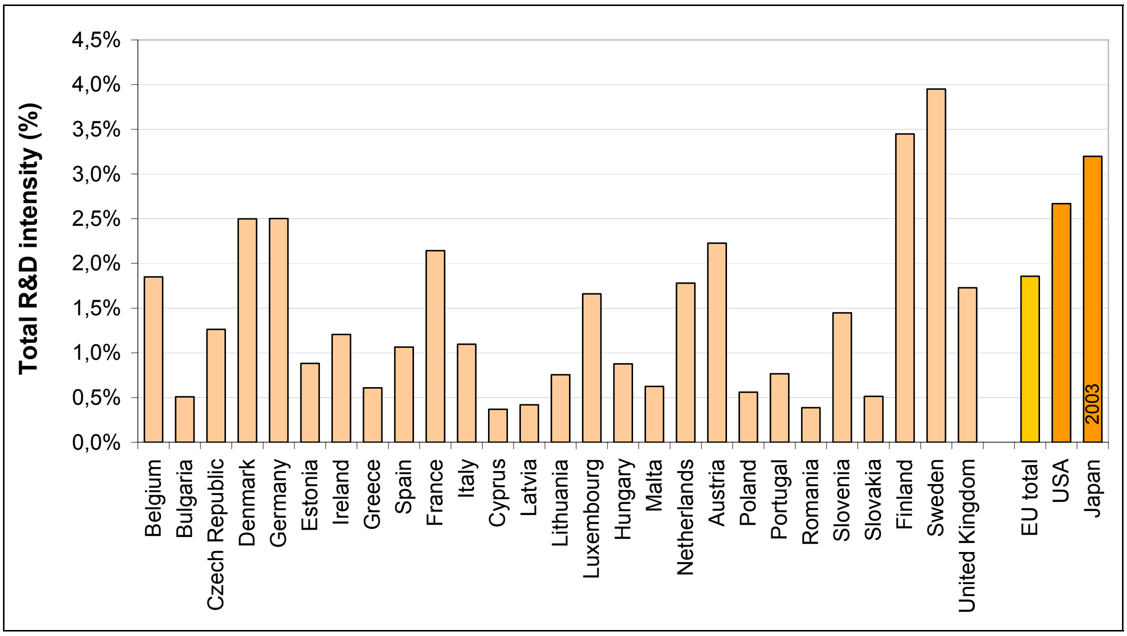
Total research funding in the EU (Gross Expenditure on R&D, GERD, based on Eurostat) focuses to a large extent on a limited number of Member States. In 2004, Germany accounted for 28.5% of EU funding, followed by France (18.3%), the UK (15.4%), Italy (7.9%), Sweden (5.7%), Spain (4.6%) and the Netherlands (4.5%). This contrasts with the cumulated funding from the 12 new Member States amounting to 2.2%.

The R&D intensity (measured as GERD relative to GDP) in the EU remained below 2% by 2005, which is 0.6 % – 0.85% less than in the US and between 1.0%-1.3% less than in Japan. So far, not much progress has been made towards the EU R&D investment target of 3% of GDP (two thirds of which to come from private sources) since this objective was set in 2002 [European Commission, 2007i]. Furthermore, the gap in R&D expenditure between the EU-25 and the USA does not seem to be narrowing.

There are also significant differences in R&D intensity among Member States. Sweden and Finland are taking the lead with an average higher than 3% of GDP. Austria Belgium, Denmark, Germany, France, the Netherlands, Luxemburg and the UK form the second group with an R&D intensity of 1.5-2.5%. The 12 new Member States have a significantly lower level of investment, which is on the whole far below 1% of their GDP, with Slovenia and the Czech Republic being the exceptions. In some Member States R&D intensity has decreased during the past couple of years, namely France, Sweden and the UK. In the Netherlands the R&D intensity decreased until 2002, but increased thereafter.

This heterogeneity in R&D intensity among EU Member States also holds true for the R&D expenditure relative to population. Here, Denmark also joins Finland and Sweden as a leading country. Similarly, the EU as a total falls well behind the US and Japan.

Figure 1: Total Gross Expenditure for R&D relative to GDP in 2004



Note: 2004 data were used as they were more complete than 2005 data; data for Japan refer to 2003.

As illustrated in Sections 4.1 and 5.1, many institutions and organisations are involved in research funding and performance. The most important actor both in the funding and performance of research is the private sector. Table 2 and Table 3 show the relative importance of the "business enterprise sector (BES)", "government (GOV)", "higher education sector (HES)" and "private non-profit sector (PNP)" for the sources of funds and the performance of research. The outstanding role of the business and enterprise sector becomes obvious in the EU with the sector funding more than half of the overall research expenditures and performing almost two thirds. However, compared to Japan and the USA, the business sectors in the EU contribute relatively less in research funding and performance.

Table 2: Gross Expenditure on R&D by sector of performance

	BES	GOV	HES	PNP
EU-27 (2005)	64%	13%	22%	1%
USA (2004)	70%	12%	14%	4%
Japan (2003)	75%	9%	14%	2%

Table 3: Gross Expenditure on R&D by sources in different regions, 2003

	BES	GOV	HES	PNP	Abroad
EU-27	54%	35%	1%	1%	9%
USA	61%	30%	3%	4%	-
Japan	75%	18%	6%	1%	0%

Source: Eurostat GERD

Unfortunately a detailed analysis of the overall (public and private) R&D spending in the energy sector is not possible, as the category "production, distribution and rational utilization of energy" of Eurostat's GERD database contains too many gaps, including the large spenders Germany and France. The fragmented data available indicate that the share of energy R&D in total GERD is in the order of 1-4% for the countries included, with more important contributions in Slovenia (8.6%) and Romania (6.1%).

4.2.2. Public spending for energy and transport R&D

4.2.2.1. Eurostat: Government budget appropriations or outlays for energy R&D (GBAORD)

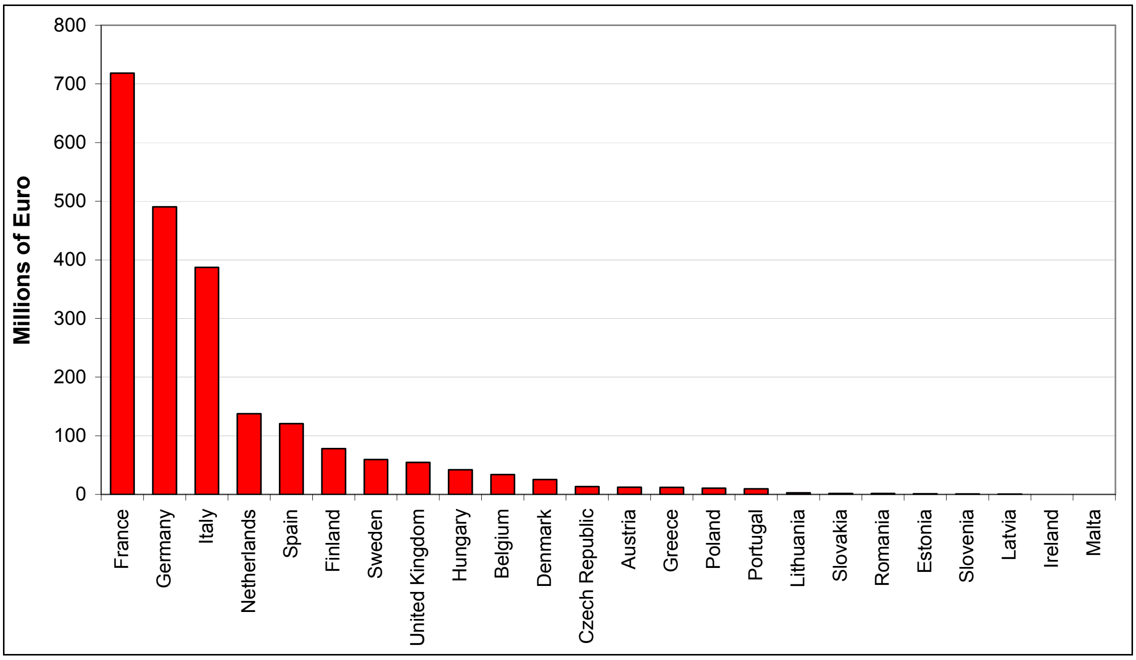
The GBAORD data concentrate on the government budget, which means that it complements the before presented GERD data by offering more detailed information on government funding on R&D. However, it is difficult to compare and analyze the GERD and GBAORD data in a comprehensive way, due to a lack of harmonised information and irregularity of reporting by the Member States (see Section 3.2).

Unfortunately, an (almost) complete dataset is available only for the energy sector (i.e. distribution and rational utilisation of energy). Data on public R&D budget in energy-related sectors (electronic and related industry) and transport-related sectors (manufacture of motor vehicle and other means of transport) remains patchy. The following section thus focuses on the energy sector and provides some limited information on the other sectors at the end.

The government budgets for the energy sector are shown in Figure 2. The absolute spending for energy research by 2005 was dominated by France, Germany and Italy, accounting for 73% of the cumulated EU Member State spending. On the other hand, the new Member States account for less than 3% of the total EU spending[12].

[12] Excluding Bulgaria, Cyprus and Luxembourg due to lack of data

Figure 2: Absolute government budget appropriations for production, distribution and rational utilisation of energy, 2005

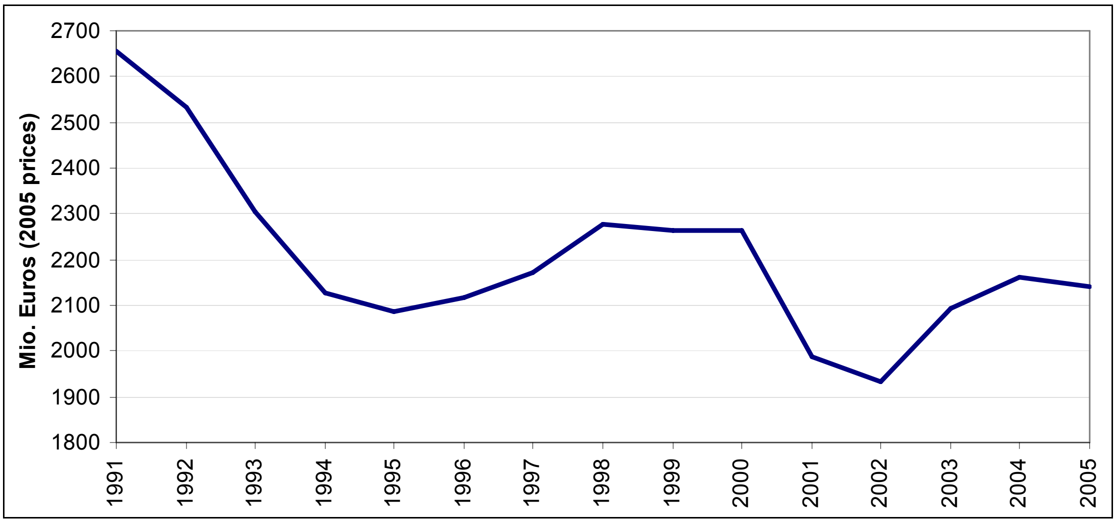


Note: Funding from the EU through the research framework programmes and the Intelligent Energy Europe Programme are not included in the EU-figure (see chapter 3); data for Poland relate to 2004; no data for Bulgaria, Cyprus and Luxembourg

Source: Eurostat GBAORD

The aggregated R&D budget of the EU-15 Member States allocated to distribution and rational utilisation of energy experienced a drastic decrease in the early 1990s, followed a more stable, yet fluctuating trend (see Figure 3). By 2005, government budget appropriations dedicated to energy R&D amounted to €2139 Mio in the EU-15 and €2194 Mio in the EU-27. The decline in public energy R&D budgets between 1991 and 2005 was very pronounced in the UK, Germany and Italy [Doornbusch and Upton, 2006], yet with some budgets rising again in recent years. One reason may have been the privatisation of a number of formerly nationalised energy industries during this time period.

Figure 3: EU-15 aggregated public budget appropriations for production, distribution and rational utilisation of energy between 1991 and 2005



Note: GDP deflators have been used to adjust for inflation. Funding from the EU through the research framework programmes and the Intelligent Energy Europe Programme are not included in the EU-figure

Source: Eurostat GBAORD

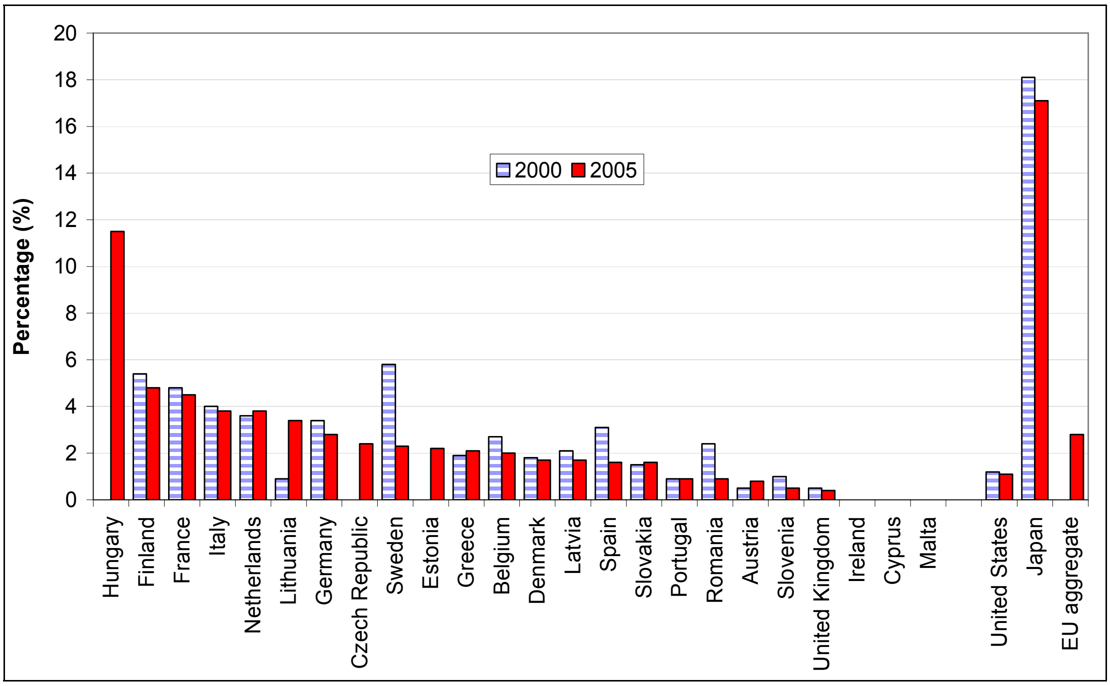
The relative budget appropriations for energy R&D compared to the total government R&D budget provides an even clearer indication for the importance of energy research in a specific country (see Figure 4). It becomes obvious that this share was by far highest in a non-EU country, Japan (17% by 2004), followed closest by Hungary only. Among the EU Member States (figures for 2005), Hungary allocates the largest share of its R&D budget to energy (12%) followed by Finland, France and Italy (4-5%). Compared to the year 1980, the share of public energy R&D in overall public R&D budget has decreased in the broad majority of Member States.

The EU average was 2.7% in 2005, while this share remains even smaller for many other Member States. This compares to a relative share of around 10% in the early 1980s, and 3.5-4% in the early 1990s (in the EU-15). However, it should be noted that the contribution of the Gross Value Added of the energy sector to GDP is of a similar order.

Relative to GDP (see Figure 21 in Annex), the budget for production and utilisation of energy amount to in-between 0.01% to 0.03% in most Member States, with only Hungary, Finland and France reaching 0.04-0.05%.

Overall, the small and decreasing share of energy-related R&D funding in overall R&D fundings shows the low importance that is given to public energy research by most Member States. However, the stabilisation and even small increase in absolute energy R&D budgets in the past decade – following the steep decrease in the decade before – may signify a change in trends.

Figure 4: Government budget appropriations for production, distribution and rational utilisation of energy relative to overall GBAORD, 2005



Note: Funding from the EU through the research framework programmes and the Intelligent Energy Europe Programme are not included in the EU-figure; data for Japan and Poland relate to 2004; no data for Bulgaria, Cyprus and Luxembourg

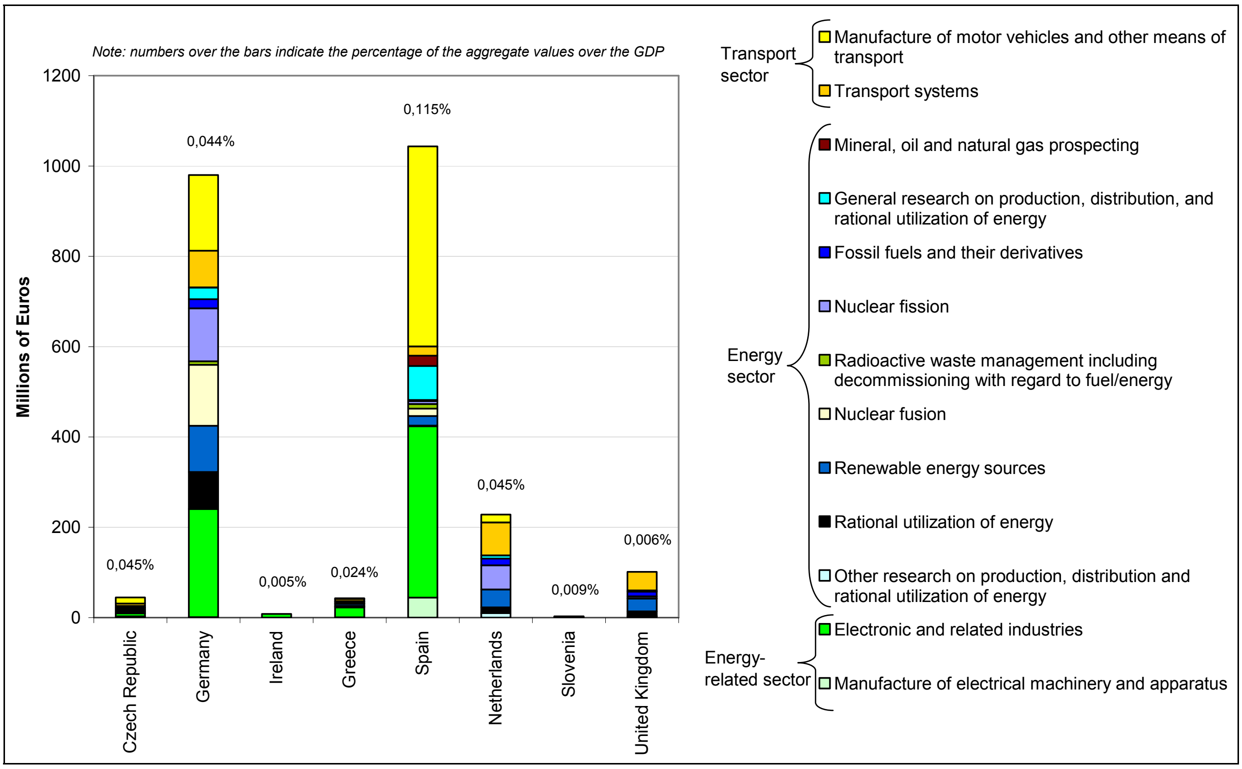
Source: Eurostat GBAORD

As mentioned before, data on transport- and energy-related sectors are sketchier. Among the Member States for which data is available (yet not all for 2005), Germany and Spain had the by far largest overall R&D spending for the total of energy and transport sectors by 2005, followed by the Netherlands and the UK (see Figure 5). This ranking is the result of a converging trend with German funds being reduced by more than 40% since 1995 while Greece doubled its spending and Spain experienced five-fold increase; smaller increases could also be seen in the Dutch and UK funds.

Even though the limited database does not allow for an assessment, it is interesting to observe that research funding into the transport sector constituted the most important part of the overall fund of the 8 Member States included. Research in the area of transport accounted for around half of the aggregated energy- and transport budget of the eight Member States. It was particularly important for Spain and the Czech Republic, where it amounts to 6.6% and 2.5% of total GBAORD, respectively. Also research support to energy-related sector (the manufacture of electrical machinery and electronic industries) was strongly pronounced in Spain (5.7% of total GBAORD), followed by Greece (4%).

A more detailed breakdown of the energy sector (i.e. production, distribution and rational utilisation of energy) reveals the importance of public spending reveals the direction of large part of funds towards nuclear, renewable energies and the rational utilization of energy. These trends are in line with the IEA data that are presented in the following.

Figure 5: Public spending in energy and transport related research fields in 2005



Note: There are only a limited number of Member States providing detailed data on a three-digit level; some data were taken from 2003 and 2004.

Source: Eurostat GBAORD

4.2.2.2. Database of the International Energy Agency

The International Energy Agency collects data on government R&D spending for energy and provides a detailed breakdown by energy sources. Unfortunately, only 17 out of 27 EU Member States are IEA members and thus included in the database (see Chapter 3 and Footnote 11). Moreover, the IEA data set does not contain any data on transport R&D spending. The database also contains gaps especially for spending in detailed subcategories in more recent years.

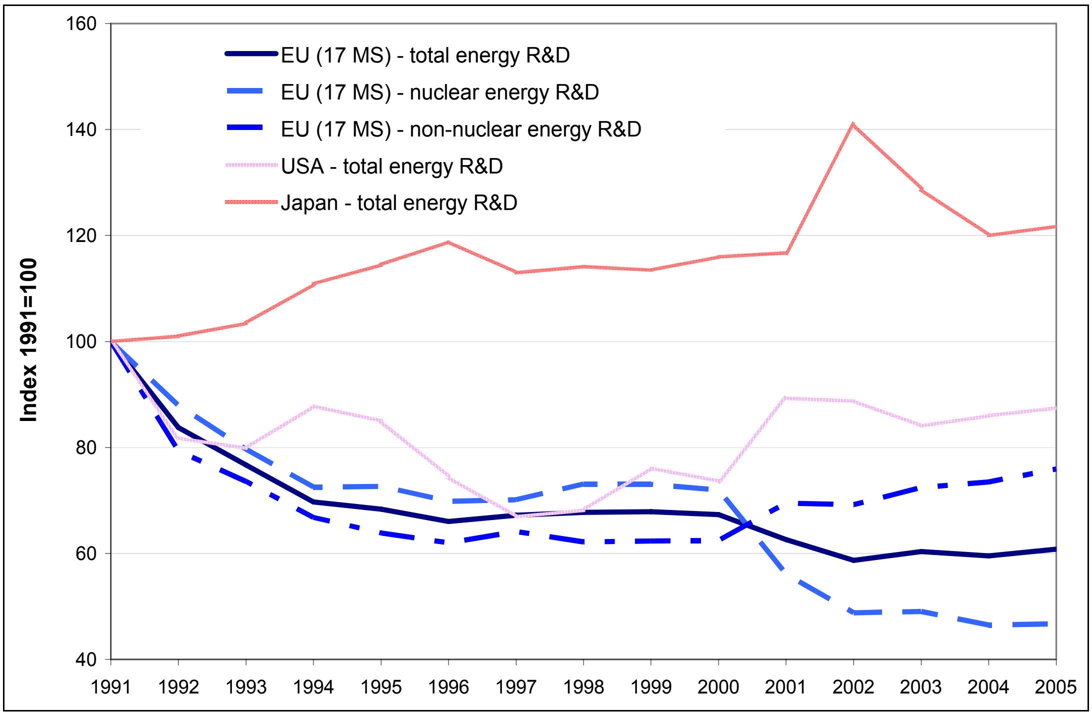
According to the IEA database, the aggregated spending for energy R&D in the EU Member States included decreased by about 40 % between 1991 and 2005.[13] Much of this trend happened in nuclear research (-53%), following increasing concerns in public perception on nuclear and a number of phase-out policies, and technologies related to fossil fuel extraction and transformation. In general, non-nuclear energy research budgets were increasing again after 2000 after a sharp decline in the 1990s. The Member States with the most significant decline in energy R&D spending were Portugal, Spain, the UK and Italy.

While funds for energy R&D also declined in the USA since 1991, yet less significantly than in Europe, Japanese spending experienced an increase of more than 20%. This meant that by

13 The timeline is not totally consistent with the GBAORD data provided for the EU-15 Member States's budget for research in the production, distribution and rational utilization of energy. It must therefore be interpreted with care.

2005, public spending for energy R&D in Japan was 60% above the aggregated spending of 17 EU Member States (excluding the European Commission funding). Using GBAORD data, this gap would be even more pronounced with Japanese funds reaching twice the EU level.

Figure 6: Development of public spending on energy R&D in selected EU Member States, the USA and Japan



Note: The IEA database considers only 17 EU Member States. Furthermore, 2005 data were not available for a number of Member States. In the cases of Finland and the Netherlands, the 2003 data were thus used; similarly, 2004 values were used for Austria. For the years 1992 and 1999, data for Italy were missing but due the importance of Italy in the overall budget, these gaps were filled, taking into account the data for the previous and coming years. Belgium, Czech Republic, Luxembourg and Greece are not included due to data gaps for more recent years. The effect of the changes in the French methodology was not taken into account.

Source: IEA database; modified as explained above

The largest spending in absolute figures occurs in France[14], followed by Germany and Italy. It needs to be emphasized that France is a very particular case with around 62% of overall energy R&D spending dedicated to nuclear energy research, while it accounts for in-between 0% and one third in most other Member States (see Figure 22 in annexes). Considering non-nuclear energy research only, the largest absolute spenders remain France, Germany, Italy and the Netherlands, yet with different priority spending areas (see below and Chapter 6; a

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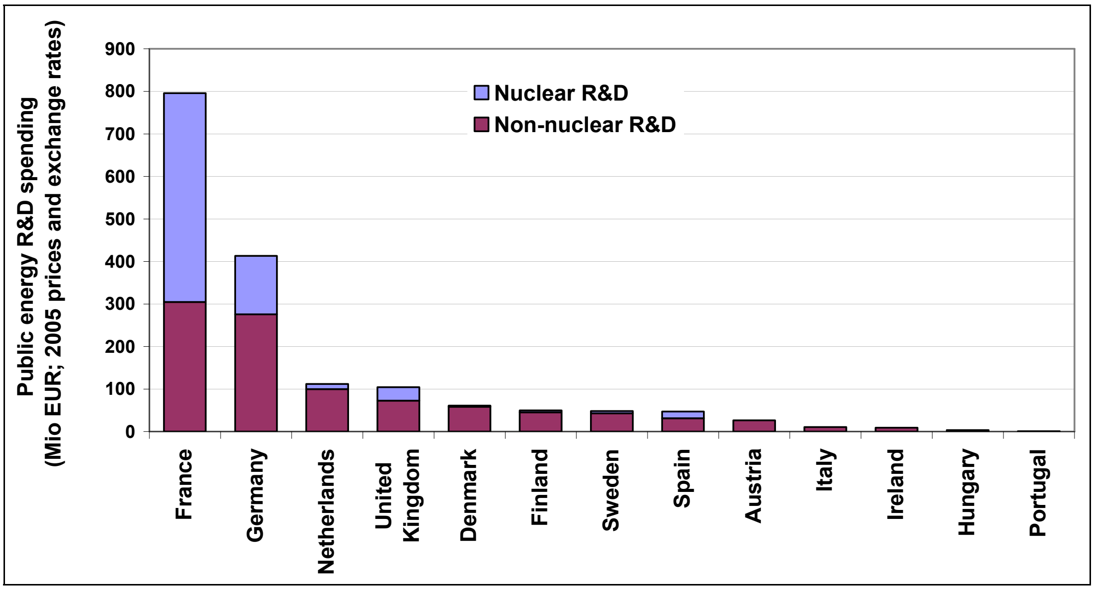
[14] France recently changed the methodology for reporting on public R&D expenditure, which has a large impact on the overall amount of spending, For example, French energy R&D expenditures in 2002 amounted to €421.3 Mio according to the old methodology, while they would have been €802.6 Mio under the new methodology. This is due to the fact that a number of institutes were not taken into account in the old methodology (see http://www.industrie.gouv.fr/energie/recherche/alcimed.htm). The figures used in this report are based on the new methodology for the years 2002-2005. When showing a timeline, indices were therefore used and adjusted.

detailed analysis of non-nuclear energy research is also provided in [European Commission, 2005f]).

The total public spending of the EU Member States for which data is available in the IEA database amounts to around €1953 Mio[15] by 2005. About 40% of this is dedicated to nuclear energy research. The respective figures in the USA and Japan are €2429 Mio (nuclear 15%) and €3144 Mio (nuclear 64%).

Figure 7: Public spending on nuclear and non-nuclear energy R&D in 2005



Note: Nuclear contains nuclear fission and fusion. For most countries, 2005 figures were used. However, there are a number of countries for which another year had to be used due to data shortcomings in more recent years: for Austria, 2004 figures are applied. In the case of Finland and the Netherlands, figures for 2003 were used. Belgium, Czech Republic, Luxembourg and Greece are excluded due to data gaps for more recent years.

Source: IEA database; France: Ministry of Industry

A different ranking occurs when energy-related (nuclear and non-nuclear) public R&D funds are reported in relation to GDP. In that case, especially France and the Nordic Member States Finland and Denmark as well as the Netherlands have the highest relative spending (0.03% - 0.055 % of GDP). This corresponds to 0.086% and 0.024% of GDP for Japan and USA in 2005, respectively.

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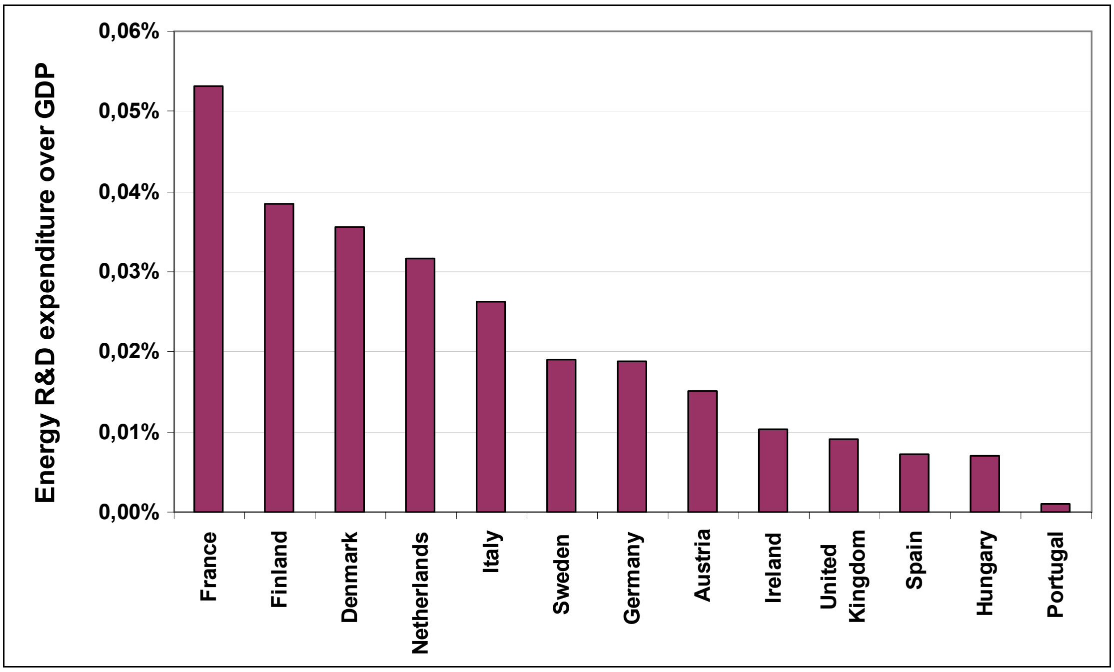
15 excl. EC funding under the 6th (and now 7th) Research Framework Programme and the Intelligent Energy Programme; 2003 or 2004 figures for some Member States.

Figure 8: Energy public spending relative to GDP (2005)



Note: See note to Figure 7.

Source: IEA database; France: Ministry of Industry

Large differences among Member States occur not only in the absolute or relative spending for energy R&D, but also in the priority setting. This is dealt with in more detail in Chapter 6. Instead of a wide spread of funds among a large number of energy technologies, as usual in most Member States, some countries are rather specialised spenders. For example, Austria and the Netherlands spend about 60% of their budget on energy efficiency and renewables compared to some 30% on an EU average. Denmark and Spain spend 16% and 15% of their total budget on wind energy, respectively; research in solar heating accounts for 52% of the Portuguese funds; and 75% of the Hungarian funds are dedicated to research in bioenergy. Denmark also focuses on research spending in hydrogen and fuel cells; due to this specialisation, the total Danish spending for research in hydrogen is the second largest in the EU after Germany, despite the overall budget ranking only on rank six. The specialisation of some smaller countries in the European Research Area (ERA) is important for the construction of an ERA in non-nuclear energy R&D [European Commission, 2005f].

On an overall EU level, most of the funds are dedicated to nuclear research, followed by renewable energies, fossil fuels and energy efficiency. Compared to the USA, a much larger share is thus spent on nuclear energy but also on renewable energies at the expense of research on fossil fuels. Also in comparison with Japan, the EU Member States (listed in the IEA database) give a much higher priority to spending on renewable energies both in absolute and relative terms.

Box 3 – On Venture Capital and R&D

Venture capital is a form of financial intermediation particularly well suited to support the creation and growth of innovative, entrepreneurial companies. It specializes in financing and nurturing companies at an early stage of development (start-ups) that operate in high-tech industries. For these companies the expertise of the venture capitalist, its knowledge of markets and of the entrepreneurial process, and its network of contacts are most useful to help unfold their growth potential. By contrast, when venture capital is applied to companies at a later stage of their growth, or in companies which operate in technologically mature industries, it has less of an opportunity to 'make a difference' [Da Rin et al., 2006].

The European Commission made the increase of the supply of risk capital one priority of its policy towards innovation and capital markets [European Commission, 1998, 2003], and in 2001 it transformed the European Investment Fund (EIF) into Europe's largest venture investor with an injection of more than €2 billion [EIF, 2002]. The Risk Capital Action Plan adopted by the European Commission in 1998, subscribed to this view and greatly influenced national policies in the late 1990s [European Commission, 1998]. This approach is shared by many national programmes, from Germany's federal and regional schemes for innovative companies [German Federal Ministry for Economics and Technology, 1999], to the French 'Plan Innovation' [French Ministry of Industry, 2003], to the transformation of the Danish Growth Fund into a public venture fund in 2001 [Danish Growth Fund, 2003], and to the creation of the UK High Technology Fund [HM Treausury, 2003].

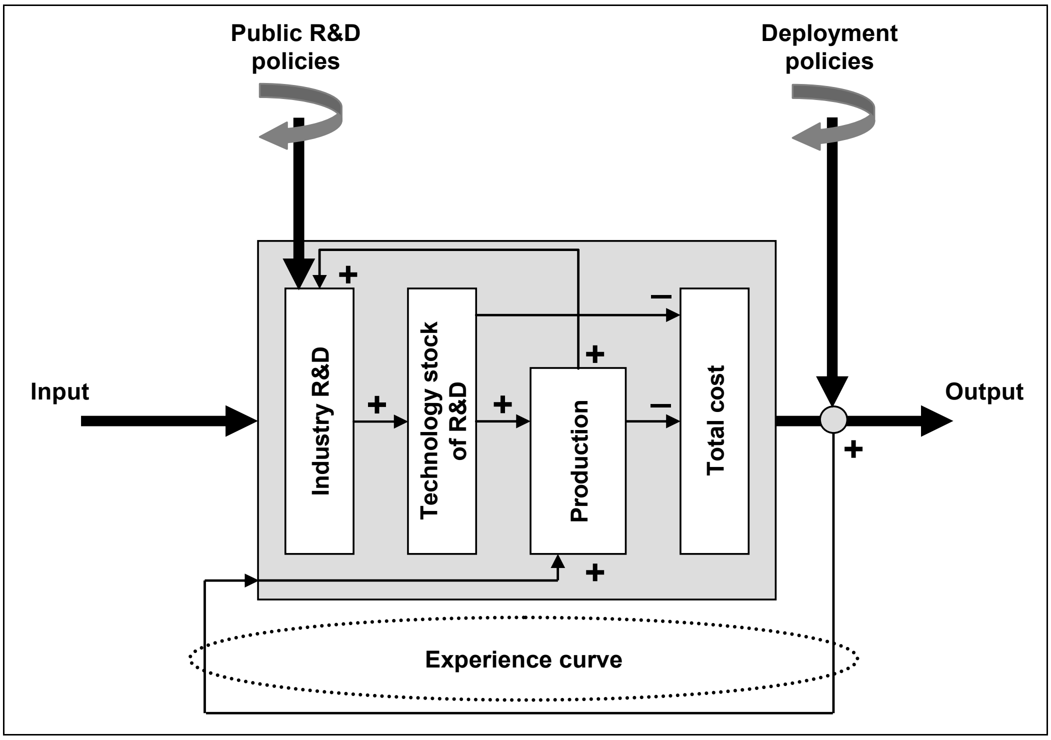
Other policies have also been tried out in Europe. Several forms of taxation have undergone a broad trend towards reduction [EVCA, 2003]. For example, investment vehicles with a favourable taxation have been introduced in 1995 in the UK ('Venture Capital Trust') and in 1997 in France ('Fonds Communs de Placement dans l'Innovation-FCPI). Reductions in effective taxation have also been enacted in Germany (1998 and 2000), the Netherlands (1996), Spain (1996 and 2001). Corporate and personal income taxes have also been reduced [European Commission, 2002].

Policies aimed at improving regulatory design have been part of a broad trend towards deregulation in Europe over the 1990s, as documented in a series of OECD studies reviewed in [Nicoletti and Scarpetta, 2003]. In particular, several countries have made an attempt to reduce regulatory barriers to entrepreneurship, with results which have been favorably assessed by recent empirical analyses [Alesina et al., 2005; Klapper et al., 2004].

4.3. Policies for market deployment of energy technologies ("market-pull")

Policies aiming at technological innovation include, on the one hand, technology push instruments, such as R&D policies, and, on the other hand, market-pull instruments (or demand-pull instruments). A successful introduction of new technologies into a mature market crucially depends on both elements and their correct timing in the process; this has been observed for a number of technologies [IEA, 2000].

Figure 9: Influences on the learning system from public policy



Source: IEA, 2000

Market-pull instruments can include stringent and ambitions command-and-control targets for energy efficiency or renewable energy generation ("renewable portfolio standards"), combined with financial support schemes, covering the higher cost of renewables and energy-efficient goods.

The main rationale behind these market-pull instruments is to stimulate the market for new energy technologies, such that they can mature and, at the end, can compete with the existing technologies without any specific support. In that sense, market-pull instruments are complementary to technology push instruments.

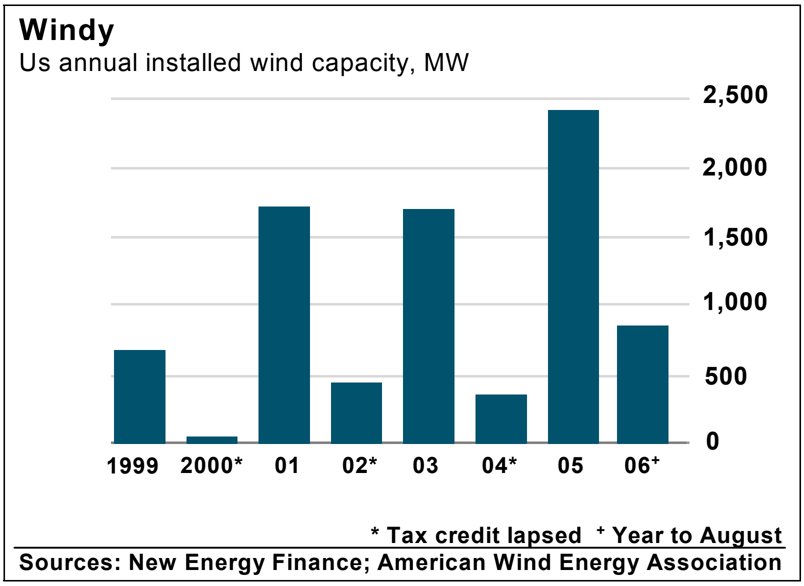
4.3.1. Deployment policies for renewable energies

The promotion of renewable energies and higher energy efficiency is at the heart of the energy policies of the European Union and most industrial countries in the world. Analysts at Goldman Sachs reckon that 49 countries have policies on renewables in place, including all EU member states, Japan, the United States and emerging economies such as Brazil, China and India.

This maturation of new energy technologies using market-pull instruments has already taken place in Japan, where the subsidies for solar power, introduced in 1994, were phased out in 2005 and Japan became the first market where customers have continued to buy solar systems without subsidy. This is (partially) thanks to the high retail electricity prices in Japan making it relatively easy for solar power to compete. Similarly, in Brazil, ethanol is competitive thanks to a 30-year-old policy of promoting fuel derived from home-grown sugar cane. Its cost of sugar production is so low that ethanol can compete with petrol even with oil prices at €26 a barrel, about half the price in 2007. However, the export of ethanol is limited as both the EU and US impose stiff tariffs on Brazilian ethanol favouring homegrown bio-diesel from rapeseed and corn.

The wind and solar power businesses are experiencing an unprecedented acceleration thanks to subsidies and regulatory incentives in Europe, the United States and many other countries. The cost of wind-power generation has come down from €0.06-€0.08 to €0.02-€0.03 per kWh since 1990 because of better turbines and higher volumes. Solar-power prices have dropped too. The first cells, in satellites, cost about €150 per watt of generating power. By 2006 the price had fallen to about €2 per watt, whereas the efficiency of silicon-based solar cells improved from 6% to an average of 15%. It is assessed that for every doubling in cumulative production volume, the cost of modules has declined by about 20%. That translates to an annual reduction in manufacturing costs of about 5%. As price decreases come with the volume of output, the market-pull instruments (and other type of support) are there to help to speed the process up by stimulating extra sales.

Figure 10: US annual installed wind capacity, MW



Source: The Economist (2006b)

In 2005 Germany was the world leader in wind power (18,430 MW of installed capacity), solar photovoltaics (1400 MWp of installed capacity), production of bio-diesel (1.9 billion liters), and, with China, overall investment in renewables. In 2005 Spain ranked second in the world in total installed wind power capacity (10,030 MW), and was among the top three in newly installed wind capacity [REN21 Renewable Energy Policy Network, 2006].

Although the cost gap between energy generated in conventional ways and that generated by alternatives has shrunk, it still exists. Burning natural gas is still a cheaper way of generating power than using wind turbines, and coal is in many cases the cheapest option without the internalization of external costs. For the time being, clean energy is competitive in only a few countries in certain specific instances (e.g. Japan and Brazil). Moreover, although the growth is strong, the industry of renewables remains vulnerable to policy decisions and external events. In the US, the tax break for wind generation expired periodically, causing the industry to loose momentum until the credit was renewed again (see Figure 10). Similarly, in the summer of 2006 the shares of European clean-energy firms fell, along with the price of permits to emit carbon dioxide within the EU.

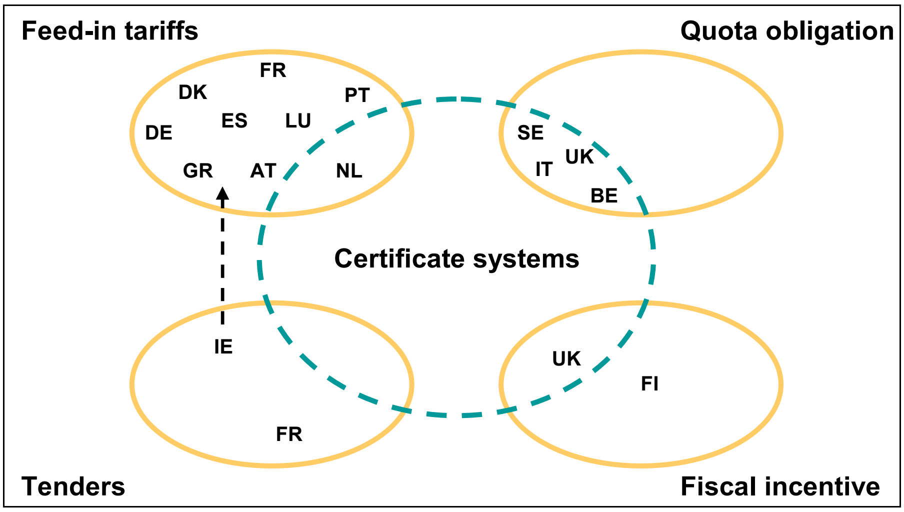
Moreover, stimulating renewables using market pull instruments or other ways of subsidies or support is not without problems. Too generous subsidies may allocate to much capital and human resources to some nominated technologies to the detriment of other, possibly better or necessary, technologies. Similarly, innovation is seen as a dynamic, cumulative, systemic and uncertain process, giving rise to path dependency and the potential for lock-in of technological and institutional systems. In other words, once a technology is chosen and the related industry has been built up to a competitive level, it is very difficult to leave this technology aside for a new technology. Unruh [2000, 2002] states that industrial countries have become locked-into fossil fuel-based energy systems through path dependent processes driven by increasing returns to scale. This lock-in of fossil fuel-based technology hampers the emergence of renewables and other new energy technologies.

The fundamental question that policymakers are confronted with is how to create market pull without creating excessive costs for society, in other words how to speed up the development of new technologies in a cost-efficient way?

In Europe five types of support models on the supply side of electricity seem to have sprung up, notably, feed-in tariffs, quota obligation, fiscal incentives, tenders and green certificates. In the remainder of the text we analyze the feed-in tariffs and the certificate systems, which are the two prevailing ones.

Further, we discuss the policy measures taken to speed up the energy efficiency of consumer goods. Most notably, we look at cars, domestic appliances and buildings.

Figure 11: Support systems for Renewables in EU-15



Source: Business Insights (2006)

Table 4: In-exhaustible summary of renewable energy policies across EU Member States (up to 2005)

Country	Main Support Schemes	Comment
Austria	Feed-in tariffs (now terminated) combined with regional investment incentives.	Feed-in tariffs have been guaranteed for 13 years. The instrument was only effective for new installations with permission until December 2004. The active period of the system has not been extended nor has the instrument been replaced by an alternative one.
Belgium	Quota obligation system / TGC combined with minimum prices for electricity from RES.	The Federal government has set minimum prices for electricity from RES. Flanders and Wallonia have introduced a quota obligation system (based on TGCs) with the obligation on electricity suppliers. In Brussels no support scheme has been implemented yet. Wind offshore is supported at federal level.
Bulgaria	Combination of feed-in tariffs, tax incentives and purchase obligation.	Relatively low levels of incentive make penetration of renewables especially difficult as the current commodity prices for electricity are still relatively low. A green certificate system to support renewable electricity developments has been proposed. Bulgaria recently agreed upon an indicative target for renewable electricity, which is expected to provide a good incentive for further promotion of renewable support schemes.
Cyprus	Grant scheme for the promotion of RES (since February 2004) financed through an electricity consumption tax of 0.22 E/kWh (since Aug. 2003).	Promotion scheme is fixed only for a 3-year period.
Czech Republic	Feed-in tariffs (since 2002), supported by investment grants Revision and improvement of the tariffs in February 2005.	Relatively high feed-in tariffs with 15-year guaranteed support. Producer can choose between a fixed feed-in tariff or a premium tariff (green bonus). For biomass cogeneration, only the green bonus applies.
Denmark	Premium feed-in tariffs and tender schemes for wind offshore.	Settlement prices are valid for 10 years. The tariff level is generally rather low compared to the previously high feed-in tariffs.
Estonia	Feed-in tariff system with purchase obligation.	Feed-in tariffs paid for up to 7 years for biomass and hydro and up to 12 years for wind and other technologies. All support schemes

Country	Main Support Schemes	Comment
		are scheduled to end in 2015. Together with relatively low feed-in tariffs this makes renewable investments very difficult.
Finland	Energy tax exemption combined with investment incentives.	Tax refund and investment incentives of up to 40% for wind, and up to 30% for electricity generation from other RES.
France	Feed-in tariffs.	For power plants < 12 MW feed-in tariffs are guaranteed for 15 years or 20 years (hydro and PV). For power plants > 12 MW a tendering scheme is in place.
Germany	Feed-in tariffs.	Feed-in tariffs are guaranteed for 20 years (Renewable Energy Act). Furthermore soft loans and tax incentives are available.
Greece	Feed-in tariffs combined with investment incentives.	Feed-in tariffs are guaranteed for 10 years. Investment incentives up to 40%.
Hungary	Feed-in tariff (since January 2003) combined with purchase obligation and tenders for grants.	Medium tariffs (6 to 6.8 ct/kWh) but no differentiation among technologies. Actions to support RES are not coordinated, and political support varies. All this results in high investment risks and low penetration.
Ireland	Tendering scheme. It has been announced that the tendering scheme will be replaced by a feed-in tariff scheme.	Tendering schemes with technology bands and price caps. Also tax incentives for investment in electricity from RES.
Italy	Quota obligation system / TGC. Anew feed-in tariff system for photovoltaic valid since 5th August 2005.	Obligation (based on TGCs) on electricity suppliers. Certificates are only issued for new renewable electricity capacity during the first eight years of operation.
Latvia	Quota obligation system (since 2002) combined with feed-in tariffs.	Frequent policy changes and the short duration of guaranteed feed-in tariffs result in high investment uncertainty. The high feed-in tariff scheme for wind and small hydropower plants (less than 2 MW) was phased out in January 2003.
Lithuania	Relatively high feed-in tariffs combined with a	Closure of the Ignalina nuclear plant will strongly affect

Country	Main Support Schemes	Comment
	purchase obligation. In addition good conditions for grid connections and investment programmes.	electricity prices and thus the competitive position of renewables as well as renewable support. Investment programmes limited to companies registered in Lithuania.
Luxembourg	Feed-in tariffs.	Feed-in tariffs guaranteed for 10 years (for PV for 20 years). Investment incentives also available.
Malta	Low VAT rate for solar.	Very little attention to electricity from renewables so far.
Netherlands	Feed-in tariffs.	Feed-in tariffs guaranteed for 10 years. Fiscal incentives for investment in RES are available. The energy tax exemption on electricity from RES ended on 1 January 2005.
Poland	Green power purchase obligation with targets specified until 2010. In addition renewables are exempted from the (small) excise tax.	No penalties defined and lack of target enforcement.
Portugal	Feed-in tariffs combined with investment incentives.	Investment incentives up to 40%.
Rumania	Subsidy fund (since 2000), feed-in tariffs.	Normal feed-in tariff modest, but high tariff for autonomous small wind systems (up to 110-130 €/MWh). Romania recently agreed upon an indicative target for renewable electricity, which is expected to provide a good incentive for further promotion of renewable support schemes.
Slovak Republic	Programme supporting RES and energy efficiency, including feed-in tariffs and tax incentives.	Very little support for renewables. The main support programme runs from 2000, but there is no certainty as to the time frame or tariffs. The low support, lack of funding and lack of longer-term certainty make investors very reluctant.
Slovenia	Feed-in system combined with long-term guaranteed contracts, CO_2 taxation and public funds for environmental investments.	None.
Spain	Feed-in tariffs.	Electricity producers can choose between a fixed feed-in tariff or a premium on top of the

Country	Main Support Schemes	Comment
		conventional electricity price, both are available over the entire lifetime of a RES power plant. Soft loans, tax incentives and regional investment incentives are available.
Sweden	Quota obligation system / TGC.	Obligation (based on TGCs) on electricity consumers. For wind energy, investment incentives and a small environmental bonus are available.
UK	Quota obligation system / TGC.	Obligation (based on TGCs) on electricity suppliers. Electricity companies which do not comply with the obligation have to pay a buyout penalty. A tax exemption for electricity generated from RES is available (Levy Exemption Certificates which give exemption from the Climate Change Levy).
Source: European Commission (2005k)		

4.3.1.1. Supply Side

Table 4 provides an overview of the support policies for electricity from renewables (RES) across EU Member States as of 2005. It shows that the main instruments are either feed-in tariffs or tradable green certificates (TGC), which are discussed in more detail in the following.

Feed-in tariff

Feed-in tariffs are a price-based policy which set the price to be paid for renewable energy per kWh generated (in the form of guaranteed premium prices). This is often combined with a purchase obligation. Typically the costs are borne either by consumers or by the public budget. Certain solar projects in Germany will receive as much as €0.57 for each kilowatt-hour of electricity compared to around €0.05 for dirtier power. In Spain, solar thermal-power generation got a boost with a feed-in tariff of €0.22 per kWh for 500 MW of thermal electricity.

Feed-in tariffs rarely stand alone and are combined with other policy measures. E.g. in Spain, the feed-in tariffs of wind technology are complemented with low-interest loans, capital grants and support for manufacturing of turbines.

Ringel [2006] shows that feed-in tariffs are used across various EU countries for different types of renewable power generation, including biomass, photovoltaic solar, thermal solar, geothermal, small hydro, tidal, onshore wind, and offshore wind. In some countries feed-in tariffs are also used for cogeneration and here cogeneration may contribute more than a quarter of total electricity production.

A first advantage of the feed-in tariff over a long time is that it can partly remove the financial insecurity and risk involved with a massive deployment of a new technology. The highest costs of the innovation system appear on the point of market introduction. That is the time when important investments are needed with large financial risks. These initial costs can be reduced as guaranteeing revenue stability allows the investor to borrow at lower interest rates. The profits are therefore expected in a later phase of deployment. This predictability of policy support is important to encourage the private sector involvement and allow market actors to carry out resource allocation plans on safe grounds; e.g. in Germany the feed-in tariff is fixed for 20 years declining over time. In other Member States, a long term favourable tariff is granted but with annual adjustments, which allows to take into account changing conditions.

Another advantage is that feed-in tariffs may be easily differentiated across technologies in order to stimulate various technologies at different stages of maturity. Obviously not every technology is in the same phase; e.g. wind energy on land is almost competitive with fossil fuels, whereas hydrogen and the fuel cell have a long way to go before they are ready for massive deployment. This is illustrated in the high degree of differentiation of German feed-in tariffs between technologies. Tariffs above €0.50 for photovoltaics and below €0.10 for wind illustrate the difference in commercial maturity between the two technologies.

The previous experiences show that feed-in tariffs – if appropriately designed- are well suited to foster the use of renewable energy sources quickly. In 2000 more than 80% of the new wind power installed in the EU was put in countries with guaranteed prices, notably Denmark, Germany and Spain. However, the feed-in tariffs are not free of problems.

First, the feed-in tariffs, as other support schemes, tend to distort the market significantly. Due to its geographical situation, Germany would not be a first choice to install solar power compared to sunnier countries. Moreover, the country does not have problems of grid accessibility; a condition that normally makes solar power more attractive. But thanks to generous feed-in tariffs, it is the biggest solar market in the world.

Second, the on-going electricity liberalization process makes that consumers more and more are able to choose between competing offers and are likely to switch to suppliers with lower prices. In a cross-European energy fully liberalized market the question would arise on how to harmonize the national or regional feed-in tariffs in order to avoid transboundary and/or cross-sectoral distortions. In countries like Germany the regional network operators with a large number of –expensive- renewable energy had a competitive disadvantage, as their consumers switched to the lower prices of operators with more conventional energy generation. However, this was addressed by the Renewable Energy Act that balances these expenses among different operators. Further, the level and longevity of feed-in tariffs must be tailored carefully to insure against the impact of significant drop in overall prices.

A third drawback of the feed-in tariff system relates to the fact that, being a price-based incentive, policymakers can not precisely predict the amount of renewable energy production in a given time period, if the feed-in tariff is not accompanied by a purchase obligation. On the other hand, tradable Green Certificates seem better suited to policies focused on quantities rather than on prices.

Tradable Green Certificates

Tradable Green Certificates (TGC) are tradable commodities proving that electricity is generated using renewable energy technology. The TGC can be traded separately from the electricity produced and they belong to the group of flexible market instruments for environmental policy.

In the TGC scheme, each electricity company gets a quota for the amount of electricity derived from renewables. For each 'green' unit delivered to the grid the company receives a green certificate in addition to the electricity price. Companies that do not generate enough energy from renewables can buy the certificates from companies that have certificates in excess. This generates more competition in the supply of renewable-generated electricity, favouring the lower-cost suppliers (and technologies). The TGC schemes may stimulate the development of green power if the imposed shares of green power in total sales are significant and if the fine level of non-compliance is high enough to enforce the quota.

In the EU, national or regional TGC markets are used in the Netherlands, Sweden, Italy, Belgium and the UK (see Figure 11 and Table 4). The establishment of these national/regional TGC markets is very much in line with the fixed targets for renewables adopted by the Member States under the EU renewables directive. The use of TGC schemes in various EU markets opens the opportunity of constructing a unified TGC system covering all EU countries. The trade in certificates across the EU member states would ensure a more cost-effective policy of renewables. The renewable technologies would be established in countries with the lowest cost to produce renewable energy. These low-cost countries may sell their excess certificates to high-cost countries in short of green certificates. However, the different countries have chosen for different concepts of TGC and the integration of these national TGC systems may not be straight forward. Before an effective European TGC market can be established, the participating countries will have to agree on common market stabilisation mechanisms (e.g. maximum and minimum prices), common banking and borrowing rules, technologies eligible for certification, etc.

However, the use of TGC may increase the financial risks of the potential investors as the prices of TGC may fluctuate. In addition, a TGC system seems less efficient in stimulating the development of new renewable energy technologies. A TGC would fail, in principle, to differentiate between the different technological stages corresponding to different technologies. This may lead to a technological lock-in of mature, established renewable technologies. This is an argument for also having supplementary feed-in tariffs at early stages of technological development. Taking a dynamic innovation perspective on renewables, one can argue that feed-in tariffs and certificate markets should be seen as complementary regulatory instrument targeting subsequent steps in the product innovation cycle. The feed-in tariff only exposes the technology to a benchmark cost model for the relevant technology, whereas the TGC market stimulates a cross-technology competition improving efficiency.

4.3.2. Energy efficiency

Regulation does not only stimulate the generation of renewable energy on the supply side, but it also enhances the energy-efficiency on the demand side. New products tend to be more efficient than old ones, being one reason why the energy intensity in the EU decreased on an average annual level of around 1.2% between 1990 and 2003. Companies do not only invest in energy-efficient products and processes because the governments have changed the regulation, they also do so because they believe that more energy regulation is to come and look for first-mover advantages. The management of these expectations in terms of credibility and affordability is a fundamental task for the Administration, in order to turn them into virtuous self-fulfilling prophecies. An additional incentive for companies to embark in energy-efficiency programs is gaining influence in the policy-making process as companies without green credentials will not be invited to participate in the policy consultations. In this section the regulation initiatives for the energy-efficiency of cars, domestic appliances and buildings are discussed.

4.3.2.1. Cars

Transport is in the core of the energy and climate debate in the EU. This is reflected in the ambition to produce more bio-fuels, EU regulation forcing the car-industry to become more energy-efficient and less polluting, better inspection and maintenance, retrofitting of catalysts equipped vehicles, tax breaks for EURO 3 and 4 cars, and national and EU policies focusing on the scrappage of high emitting vehicles.

Bio-fuels

The PREMIA project undertook a detailed analysis of support measures for biofuels and found that despite the heterogeneity among Member States, the market is in the process of becoming a more mature resulting from the combination of different support policies on the EU and Member State level [Wiesenthal et al., 2007].

Biofuels are supported by several individual Member States and at EU-level. The cornerstone of the EU biofuels policy is the Biofuels Directive 2003/96/EC, which sets 'reference values' of 2% and 5.75% of transport fuels to be met by 2005 and 2010, respectively. In order to achieve these targets, Member States are allowed to exempt biofuels from taxes, and to cultivate non-food crops on set-aside areas up to a certain amount. Besides, premiums for energy crops were introduced to support the cultivation of bioenergy feedstock.

In early 2007, the Commission proposed a binding minimum target of 10% for the share of biofuels in transport in the context of the "renewables roadmap" that envisages a 20% share of all renewable energy sources in total energy consumption by 2020. The Spring Summit of the European Council has accepted this proposal in March 2007.

On a Member State level, the introduction of biofuel tax exemption schemes has been most common. Recently, however, there is an increasing number of Member States that moved towards obligations for fuel suppliers to supply a certain amount of biofuels, including German, Austria, the Netherlands and Poland as well as France with a mixed system and the UK introducing an obligation by 2008. This change is mainly motivated by the important direct revenue losses for the governments, caused by tax exemptions.

Additionally, collaboration with car manufacturers took place in Member States with a successful deployment of biofuels. This was accompanied by the rapid development of national standards ensuring a consistent biofuel quality.

As a result of this support, consumption of biofuels increased substantially in the EU over the past decade. Production volumes of biodiesel and bioethanol grew by a factor of 4.5 and 3.1 between 2000 and 2005, with biodiesel remaining the dominant biofuel in the European with 81.5% of total biofuel volumes. Also on a global scale, the EU is by far leading the biodiesel market, while the European share in bioethanol is limited compared with Brazil and the USA.

But even though countries like Germany, France or Sweden played a pioneer role and established a significant and stable market for biofuels in their transport fuels, the average EU biofuel market is lacking behind expectations. On an EU average, biofuels reached a share of about 1% of all transport fuels sold by 2005, and the indicative 2005 target of the biofuels directive was met only by Germany and Sweden. It seems also unlikely that the current policies and measures will stimulate biofuel consumption to the extent needed to meet the 2010 target.

Fuel-efficiency

In terms of improving the efficiency of cars on a EU level, a central measure formed the voluntary commitments of the European, Japanese and Korean car manufacturers to reduce the emission of the newly sold vehicle fleet. The first agreement (signed in 1998) aimed at achieving an average performance of 140 g/km of CO_2 by 2008 for new passenger vehicles sold by the association's cars in Europe. Besides the agreement with ACEA (which manufactures 86,4% of car sales in Europe), the European Commission also closed agreements with the Japan Automobile Manufacturers Association (JAMA) and Korea Automobile Manufacturers Association (KAMA). The objective was a 25% reduction from the 1995 level (185 g/km), implying a fuel economy of 5,8 l/100 km or 5,25 l/100 km for petrol and diesel engines respectively.

National and regional governments try to improve the fuel-efficiency and lower the emissions by speeding up the rejuvenation of the car fleet using car scrappage programmes.

The reduction of emissions is not the only objective of the scrappage of older and more polluting cars. The car scrappage programmes also improves transport safety, as older cars tend to be more accident prone than newer cars. Moreover, countries with a large national car manufacturing industry (e.g. France or Italy) also use scrappage policies to boost new car purchases and enhance the car sector or boost their tax revenues from car sales.

Countries in Europe, having implemented scrappage schemes include Greece (1991-1993), Hungary (1993-2004), Denmark (1994-1995), Spain (1994–2000), France (1994-1996), Ireland (1995-1997), Norway (1996), Italy.

The programmes were generally based on a bonus if cars older than 8/10/12 years were replaced by cleaner cars. Typically the programmes scrapped 4-12% of the car fleets. E.g. the Danish scrappage scheme replaced approximately 6% of the car fleet, and the emission reduction was estimated to be 0.6-1%. Hungary and Greece started their scrappage programmes in their capitals and extended it to the remainder of their countries in a later phase.

Some concerns have been raised about the effectiveness and efficiency of scrappage programmes. Ideally, the eligibility for the programme should be based on actual emissions of vehicles scrapped rather than the age in order to be cost-efficient. However, this approach unintentionally may create a moral hazard in that car owners allow their vehicle to fall into disrepair in order to qualify.

Another concern is that the scrapped vehicles are near the end of their useful life, and hence, would disappear very soon anyway. Car scrappage policies seem to have therefore a limited impact on the evolution of the emissions [Dixon and Garber, 2001]. Furthermore the scrapped car may migrate to other parts of the world, contributing to a net increase of emissions on a global level. In addition, boosting the car scrappage rate may have negative environmental impacts through the acceleration of the car life cycle (production, dismantling and recycling).

Small and Van Dender [2007] state that policy makers typically underestimate the rebound effect for motor vehicles, by which improved fuel efficiency (of the new car) causes additional travel. The more fuel-efficient the cars are; the cheaper driving an additional kilometre becomes. Hence, people tend to drive more kilometres. The rebound effect of energy-efficiency policies for cars does not only offset the environmental gains, but – paradoxically- also exacerbates mobility problems.

Finally, the scrappage programmes can have unintended consequences for the entire vehicle market. Adda and Cooper [2000] analyse the short- and long-run effects of the scrappage policies in France. These policies not only intended lower emissions but also tried to stimulate new car sales. Adda and Cooper found that a change in the distribution of the car age can have an important impact on the economic activity of the car sector. In France (and Italy) the short-run bursts of activity in the car industry caused by the introduction of the scrapping and replacement subsidies were soon followed by dramatic reductions in car sales following the end of the policy. Further while these car replacement subsidies increase government revenues in the short-run, revenue in the long-run are lower relative to a baseline without intervention.

4.3.2.2. Domestic appliances

The energy efficiency of many electric appliances has improved significantly over the last decade, mostly due to minimum efficiency standards and labelling schemes. The broadening and tightening of these standards is being discussed at the EU level, as large energy saving potentials remain to be realised.

The cost of efficient appliances is the additional cost that more efficient appliance may have compared to the conventional products. In many cases this cost is small and the payback periods are very short. Lack of awareness of these cost-benefit ratio and the higher initial costs are the main barriers to energy-efficient appliances. The minimization of the energy consumption is not an important motivation in the purchase decision.

Policies can help to increase the energy-efficiency of the appliances, by prescribing performance standards, introducing labelling programmes and fostering voluntary programmes. Continued technical improvements in the efficiency of large electrical appliances are recorded in the last years; a decrease in average specific consumption of 1.5 % per year in the case of refrigerators, freezers, washing machines, dishwashers, TVs and dryers.

Nevertheless, so far the technical progresses have been outweighed by the increased use of e.g. electrical appliances (air conditioning, lighting, IT equipment, etc.) and the advent of new electrical devices, leading to electricity being the fastest growing energy form in the EU with an increase of 27.3% between 1990 and 2003 [EEA, 2006].

4.3.2.3. Buildings

Energy efficiency in buildings is an area where important savings can be made. Buildings are responsible for 40% of the energy consumption in the EU. The implementation of the Directive on the energy performance of buildings (2002/91/EC) is estimated to gain some 40 Mtoe (Megatons of oil equivalent) between 2006 and 2020. Around 30 European (CEN) standards have been developed, and Member States apply these standards on a voluntary basis. Should voluntary compliance with these standards not be sufficient, then mandatory standards may be considered in a future amended version of the buildings directive [European Commission, 2005j].

In many EU countries, including Belgium, Czech Republic, Denmark, Germany and Sweden, the energy efficiency of housing is an important issue in the energy plans. Interestingly, in many countries mainly regional governments are responsible for energy-saving policies in buildings (e.g. Germany, Belgium), reflecting the competencies of these regional governments in housing, construction and land management. Policies measures in buildings include subsidies to solar photovoltaics integrated in buildings, demonstration projects and assured sales of technology procurement (e.g. Sweden).

4.4. Conclusions

Institutional energy R&D capacities vary enormously among the Member States at all levels of decision making, implementation and research performance. Furthermore, there are also wide differences in Member States' priorities in energy research. This variety reflects different historical developments, the overall structure of the public sector and the energy situation of a country.

The heterogeneity with regard to actors, responsibilities and priorities makes it difficult to exploit synergies among Member States. The fact that energy R&D is often managed by energy or environmental agencies or by energy, environment and economic ministries may also have the consequence that the role of research in solving the problems facing the energy sector may not be fully appreciated [European Commission, 2005f].

Nevertheless, despite the apparent heterogeneity of the energy R&D and Innovation systems at Member State level, there are remarkable coincidences in the structure of these organizations among selected Member States. In many Member States, large Public Research Organizations play a preponderant role; particularly in many Eastern European countries, the Academies of Sciences often fulfill this role. In other Member States, a number of dedicated agencies implements energy research and is often also involved in the decision making process. Lastly, the principle of research councils being involved in the implementation and decision making process is very common particularly among the Nordic Member States but also in the UK and some Eastern European Member States.

Furthermore, an increasing number of Member States have dedicated energy research programmes, even though these may take different organizational forms. However, they often do not take into account energy programmes of other Member States despite the existence of a number of shared priorities with regard to specific energy technologies.

Improving international cooperation in energy research therefore is the objective of some recent approaches. These include the ERA-NETs, the IEA implementing agreements and the Technology Platforms as well as the Nordic Research Council. This international collaboration among Member States with similar research priorities and research capacities/infrastructure opens the scope for other country clusters within the EU.

At the same time, there a number of initiatives in most Member States to improve the science-industry link. While private-public cooperation is often realized on a project level, institutionalized partnerships have been created in many Member States, often around one specific cluster of technologies and sometimes with a regional focus.

In average the government budget in the EU allocated to energy R&D for the production and rational use was limited to around 2.8% of the total public R&D spending. This compares with 17% for Japan. In most EU Member States, the government spending for energy R&D stays on a relatively low level, while it even decreased in some Member States.

The question thus arises whether sufficient public funding is provided for a sector that combines a high importance for the economy and people's welfare with major challenges to ensure the long-term environmental sustainability and supply security [Kaloudis and Pedersen, 2006]. According to the IEA, "it is unlikely that the technological challenges facing the energy sector can be addressed without significant increases to R&D budgets in IEA member countries." [IEA, 2006d].

Despite significant information missing and some inconsistencies among the databases used, the data analyzed clearly indicate a wide discrepancy in public spending for energy research and development. This occurs not only in the total overall level of funds, with only three Member States (France, Germany, Italy) accounting for almost three quarters of the EU's aggregated public spending on energy research, but also in terms of spending relative to GDP, ranging from almost 0% to 0.055%.

Furthermore, there is a different approach in spending across Member States. A closer look to the energy R&D figures shows that some Member States tend to specialise in a limited number of areas, while others support a broader number of research fields. Major differences occur with regard to nuclear energy: while this significantly prevails within the French energy R&D expenditure, other Member States exclude nuclear R&D from their figures.

Finally, there is not only a large heterogeneity in the energy priorities and in the energy R&D ('market push') of Member States, but also in the choice and the design of the market pull instruments, with the feed-in tariffs and the green tradable certificates being the most prominent ones.

5. PRIVATE ENERGY AND TRANSPORT R&D

5.1. Industrial energy and transport R&D infrastructure

In this chapter, the energy R&D infrastructure in the private sector is discussed. A priori discarding any claim for exhaustiveness, the aim is to provide a notional snapshot of the main characteristics of the corporate activities in R&D within the energy sector including large energy intensive sectors and in particular the transportation sector. In addition to the broad interpretation of the energy sectors covered, the large heterogeneity of actors and industrial profiles in the various technologies hampers the comprehensiveness of this chapter.

5.1.1. Industrial actors

The business actors in the energy sector vary strongly across the different technological sub-sectors (even more than the public sectors do). These sub-sectors depend on the technologies, their market maturity[16], the final energy output and production processes, leading to specific R&D needs.

The EU Industrial R&D Investment Scoreboard provides a good overview of the companies with the highest investments in R&D. Among the 1000 top investing companies that are based within the EU, 73 operate in energy (i.e. oil producing, services, electricity etc) and energy-related sectors (i.e. the manufacture of electronic equipments) and 70 operate in transport-related sectors. A detailed list of the companies included is shown below in Table 5 to Table 7, with companies ranked according to their R&D investment. The assessment of their R&D investments is provided in Section 5.2.2.

Table 5: EU-based companies operating in energy sectors listed in the Scoreboard

European companies by energy sectors in the Scoreboard 2006				
No/ Sector	Oil & gas producers	Oil equipment, services & distribution	Electricity	Gas, water & multiutilities
1	TOTAL (FR)	Compagnie Generale de Geophysique (FR)	AREVA (FR)	RWE (DE)
2	Royal Dutch Shell (UK)	Tenaris (LUX)	Electricite de France (FR)	Suez (FR)
3	BP (UK)	Technip (FR)	Vattenfall (SW)	Gaz De France (FR)
4	ENI (IT)	Sondex (UK)	British Nuclear Fuels (now British Nuclear Group Sellafield) (UK)	Veolia Environnement (FR)

16 See the Energy Technology Map for more information on the maturity of different energy technologies.

5	Repsol YPF (ES)	SBM Offshore (NL)	Energie Baden (DE)	E.ON (DE)
6	OMV (AU)	Vetco (UK)	Union Fenosa (ES)	National Grid (UK)
7	BG (UK)	KBC Advanced Technologies (UK)	Pohjolan Voima (FI)	BWT (AU)
8		Expro (UK)	Enel (IT)	Severn Trent (UK)
9			Fortum (FI)	MVV Energie (DE)
10			CEZ (CZ)	Northumbrian Water (UK)
11			British Energy (UK)	United Utilities(UK)
12			Verbund (AU)	
13			International Power (UK)	
14			Energi E2 (DK)	
15			Ocean Power Delivery (UK)	
16			Terna (IT)	
Source: Scoreboard data, 2006				

Table 6: EU-based companies operating in the sector 'electrical components and equipment' listed in the Scoreboard

European private companies in the sector of "Electrical components & equipments" in the Scoreboard 2006			
No	Companies	No	Companies
1	Siemens (DE)	17	TT electronics (UK)
2	Schneider (FR)	18	Vacon (FI)
3	ALSTOM (FR)	19	Intelligent Energy (UK)

4	Legrand (FR)	20	SolarWorld (DE)
5	Vestas Wind Systems (DK)	21	Xaar (UK)
6	Spectris (UK)	22	Basler (DE)
7	Nexans (FR)	23	Elexis (DE)
8	Leoni (DE)	24	Dialight (UK)
9	NKT (DK)	25	Chloride (UK)
10	Austriamicrosystems (AT)	26	Technotrans (DE)
11	Laird (UK)	27	Ensto (FI)
12	Somfy International (FR)	28	Ceres Power (UK)
13	Morgan Crucible (UK)	29	Austria Technologie & Systemtechnik (AT)
14	SGL Carbon (DE)	30	Evox Rifa Group (FI)
15	Dometic International (SE)	31	Targetti Sankey (IT)
16	Gewiss (IT)		
Source: Scoreboard data, 2006			

Table 7: EU-based companies operating in transport-related sectors listed in the Scoreboard

European private companies by transportation sectors in the Scoreboard 2006			
No\ sector	Industrial transportation	Automobile & parts	Commercial vehicles & trucks
1	Deutsche Post (DE)	DaimlerChrysler (DE)	Volvo (SE)
2	SNCF (FR)	Volkswagen (DE)	Scania (SE)
3	BAA (now part of Airport Development and Investment) (UK)	BMW (DE)	Wartsila (FI)
4	Finland Post (FI)	Robert Bosch (DE)	Claas (DE)
5	La Poste (FR)	Renault (FR)	Jungheinrich (DE)

European private companies by transportation sectors in the Scoreboard 2006			
6	Bollore Investissement (FR)	Peugeot (PSA) (FR)	JCB Service (UK)
7	Autostrade (IT)	Fiat (IT)	Same Deutz-Fahr (IT)
8	BBA (UK)	Valeo (FR)	LDV (UK)
9	Vossloh (DE)	Continental (DE)	JCB Compact Products (UK)
10	ASF (now part of VINCI) (FR)	Michelin (FR)	Manitou BF (FR)
11	Strategic Rail Authority (UK)	ZF (DE)	Rocla (FI)
12		Autoliv (SE)	Rosenbauer International (AT)
13		Hella (DE)	CAF (ES)
14		Behr (DE)	Pinguely-Haulotte (FR)
15		Pirelli (IT)	Ponsse (FI)
16		Rheinmetall (DE)	
17		GKN (UK)	
18		Burelle (FR)	
19		Trelleborg (SE)	
20		ZF Lenksysteme (DE)	
21		Eberspaecher (DE)	
22		Grammer (DE)	
23		Haldex (SE)	
24		Beru (DE)	
25		Porsche (DE)	
26		IMMSI (IT)	
27		Brembo (IT)	
28		MGI Coutier (FR)	

European private companies by transportation sectors in the Scoreboard 2006			
29		ElringKlinger (DE)	
30		Ducati Motor (IT)	
31		EYBL International (AT)	
32		Miba (AT)	
33		Carraro (IT)	
34		Avon Rubber (UK)	
35		Wagon (UK)	
36		Matador (SK)	
37		Nokian Tyres (FI)	
No\ sector	Industrial transportation	Automobile & parts	Commercial vehicles & trucks
38		Torotrak (UK)	
39		BBS Kraftfahrzeugtechnik (DE)	
40		Zytek (UK)	
41		Pankl Racing Systems (AT)	
42		Gevelot (FR)	
43		Opcon (SE)	
44		Antonov (UK)	
Source: Scoreboard data, 2006			

Participation in the EU technology platforms could be used as another indicator of the interest of industrial actors in a specific technology. However, these EU technology platforms do not necessarily include all interested industries, and may miss out smaller very innovative enterprises

One of the most diverse sub-sectors can be found in the area of hydrogen and fuel cells. This is due to the large variety of potential end-uses as well as production pathways. The Hydrogen and Fuel Cells Technology Platform, for example, includes in its advisory council – besides representatives from the public sector – car and engine manufacturers, producers of alternative fuels, electric equipment manufacturers, fuel cell manufacturers, power and gas companies, oil companies, etc. However one may expect a consolidation of the actors in hydrogen and fuel cells when the technologies reach a higher degree of maturity.

The steering committee of the European Photovoltaics Technology Platform has 20 high-level members, of which 9 represent the industry, 5 belong to the R&D sector and 6 to the policy sector. The private sector members include mainly photovoltaic manufacturers, but also glass manufacturers, oil companies, consultancies as well as architects.

A different composition of members can be observed in the Advisory Council of the Technology Platform of Zero Emission Fossil Fuel Power Plants. Here, power companies are strongly represented, but it includes also oil companies and power plant equipment manufacturers.

Besides R&D carried out on the industrial sites, some joint research centers are entirely or partly financed by industry (see also Section 4.1.2). This is particularly the case for institutions with clearly defined research areas. Examples are the newly founded energy research institute between E.ON and RWTH Aachen in Germany, the Christian Doppler Laboratories in Austria or the Spanish Center for Renewable Energy (CENER). In Belgium, the Energy Institute, an inter-disciplinary institute of the Katholieke Universiteit Leuven, is a partner in both public as private industrial projects.

In other Member States, industry established grants for R&D funding. In Denmark, for example, the system operators ELTRA and ELKRAFTSYSTEMS grant subsidies to R&D projects in their work area, which may be a result of the research obligation that applies to public service providers in Denmark (see Section 5.1.2).

Box 4 – Private sector energy R&D infrastructure in Japan

In other world regions where energy R&D plays an important role, the idea of privately financed (or publicly co-financed) research institutions is more widespread. In Japan, for example, the energy R&D and innovation system is largely based on R&D agencies financed by industrial corporations beyond public R&D institutes. Amongst them are the Japan Coal Energy Center (JCOAL), the Energy Conservation Center (ECCJ), the Central Research Institute of Electric Power Industry (CRIEPI), the Heat Pump & Thermal Storage Technology Center of Japan (HPTCJ), the Research and Development Association for Future Electron Devices (FED), the International Superconductivity Technology Center (ISTEC), Research Institute of Innovative Technology for the Earth (RITE), the Japan Research and Development Center for Metals (JRCM), the Japan Bioindustry Association (JBA), and the Japan Institute of Energy (JIE). The Japan Automobile Research Institute (JARI) conducts R&D in the transport sector.

The Central Research Institute of Electric Power Industry (CRIEPI) was established in 1951 as a comprehensive research organization for the electric utility industry. Its mission is to conduct research focusing on the needs of the electric industry, similar to the role played in the USA by the Electric Power Research Institute (EPRI). Its priorities include socioeconomic research on energy issues, energy economics, environment, energy services for customers, power delivery, nuclear power, fossil fuel power generation and new energy technologies. CRIEPI also finances research on the construction and preservation of electric facilities. CRIEPI employs about 800 researchers and has a budget of around €250 M.

The Japan Coal Energy Centre (JCOAL) promotes R&D and demonstration projects to foster the efficient and environmentally sustainable use of coal as a primary source of energy, including coal upgrade to more efficiently usable energy carrier and the advanced and environmentally friendly coal techniques to reduce the global environment loads such as CO_2 emissions. The development of these techniques aims at improving the advantage of the coal that has advantages in terms of cost performance and supply reliability.

The Institute of Energy Economics, Japan was established in June 1966. The aim of this establishment is to carry on research activities specialized in the area of energy from the viewpoint of the national economy as a whole. The main activities include the analysis of energy markets, as well as the provision of basic data, information and reports necessary for the formulation of policies to develop in a bid to contribute to sound development of the Japanese energy-supplying and energy-consuming industries.

The Japan Automobile Research Insitute (JARI) conducts R&D activities to develop low-pollution, environmentally sustainable vehicles. They focus not only on new vehicle concepts like electric vehicles and hydrogen-fuelled fuel cell vehicles, but also on the environmental impact of existing technologies (e.g. emissions, pollutants, ultra-low diesel engines, etc), intelligent transport system, active safety, crash safety and economic analysis. JARI plays a crucial role within the Japan Hydrogen and Fuel Cell Demonstration Project (JHFCDP). To provide an idea of the relative importance given by the Ministry of Economy, Trade and Industry to the Hydrogen and Fuel Cell R&D, it is interesting to note that the corresponding budget has been increased from €56 M in 2000 to €230 M in 2006.

5.1.2. Private sector involvement in R&D policy making

Besides carrying out energy research on its own, the private sector is also involved in preparation, implementation and evaluation of public energy R&D. A number of examples in which industry was involved are given below [taken from European Commission, 2005f, pp 47]:

- In Denmark, the industry takes part in strategy development via their representation in the Advisory Committee for Energy Research and consultation with Danish Energy Authority. Besides, there are programmes ("public service obligation") that are designed and implemented by Danish utilities (after approval of the Energy Agency). Industry is also involved in submitting R&D proposals and acts as an evaluator for proposals.

- In France, R&D priorities for renewable energies are established together with industry. Regarding fossil fuel research, the Institut Français du Pétrole (IFP) ensures the link between private and public R&D. A number of research networks in the area of fuel cells and transport R&D include industrial partners.

- In Finland, the industry is consulted during the preparation of national energy research funding programmes.

- In Ireland, industry is strongly represented in the main energy R&D funding agency and contributes particularly to the preparation and implementation phase. Various industry-oriented research programmes are initiated in different areas of sustainable energy.

- In the Netherlands, industry covers an important share of the overall non-nuclear energy R&D. However, it is not strongly involved in the priority setting process. Nevertheless, it was consulted for the energy research strategy. Private industry R&D is supported by tax credit for research, and the voluntary agreement between the government and various industrial sectors to reduce GHG emissions.

- In Sweden, industry associations/foundations commission important parts of the R&D portfolio to universities, institutes etc.

- In the UK, the Engineering and Physical Science Research Council supports energy R&D projects. As half of its members are from industry, industry's influence is important.

On that basis, [European Commission, 2005f] concludes that in some Member States, industry is a driving force for non-nuclear energy R&D, such as in Denmark and the Netherlandsfor some themes. In many other Member States, (France, Spain, new Member States) non-nuclear energy R&D is strongly driven by government initiatives. Private sector involvement in the new EU Member States is generally weak. Recently, a number of energy R&D roadmaps have been published, defining the long-term strategies and involving the industry sectors.

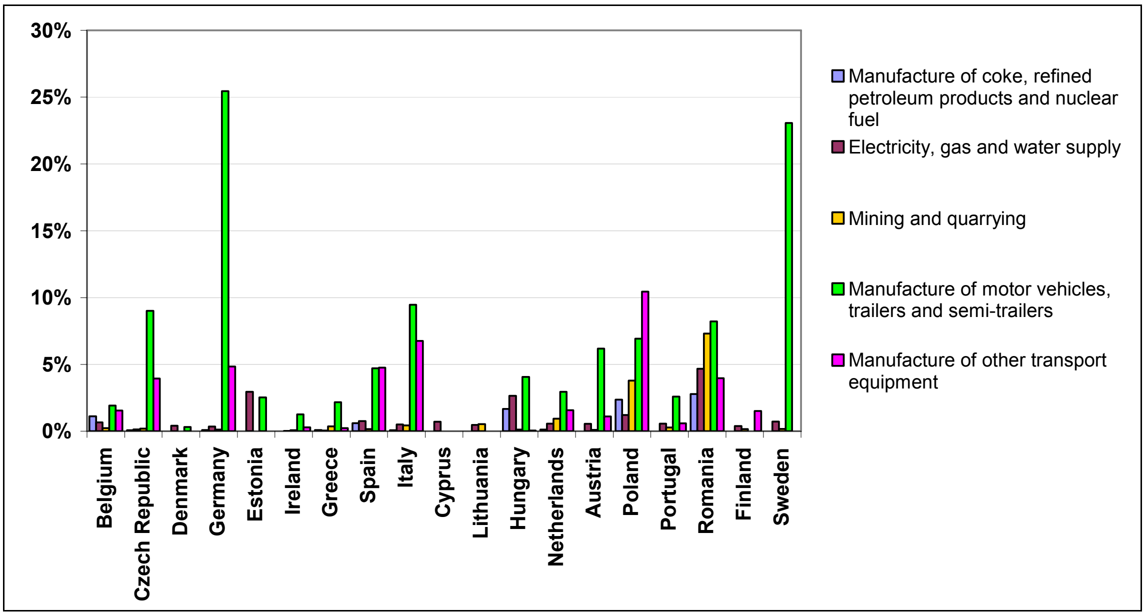
5.1.3. Private sector labour demand in energy and transport-related R&D

Unfortunately, there is very few data available for the sectoral breakdown of personnel in the business sector that works energy- and transport-related R&D[17]. The following assessment thus needs to be interpreted with care.

Available data suggest that there are major discrepancies among Member States in the share of R&D personnel in the energy- and transport-related sectors compared to the total R&D employment in the business sector (see Figure 12). This share is lower or in the order of the contribution of the energy sector to total employment, with some exceptions (particularly Finland, Portugal, Hungary and the Netherlands). On the other hand, in the transport sector the share of R&D personal compared to overall R&D personnel is often more important than this sector's contribution to total employment, such as in Germany, Finland, the Czech Republic and Portugal.

17 E.g. no data for France, UK are available.

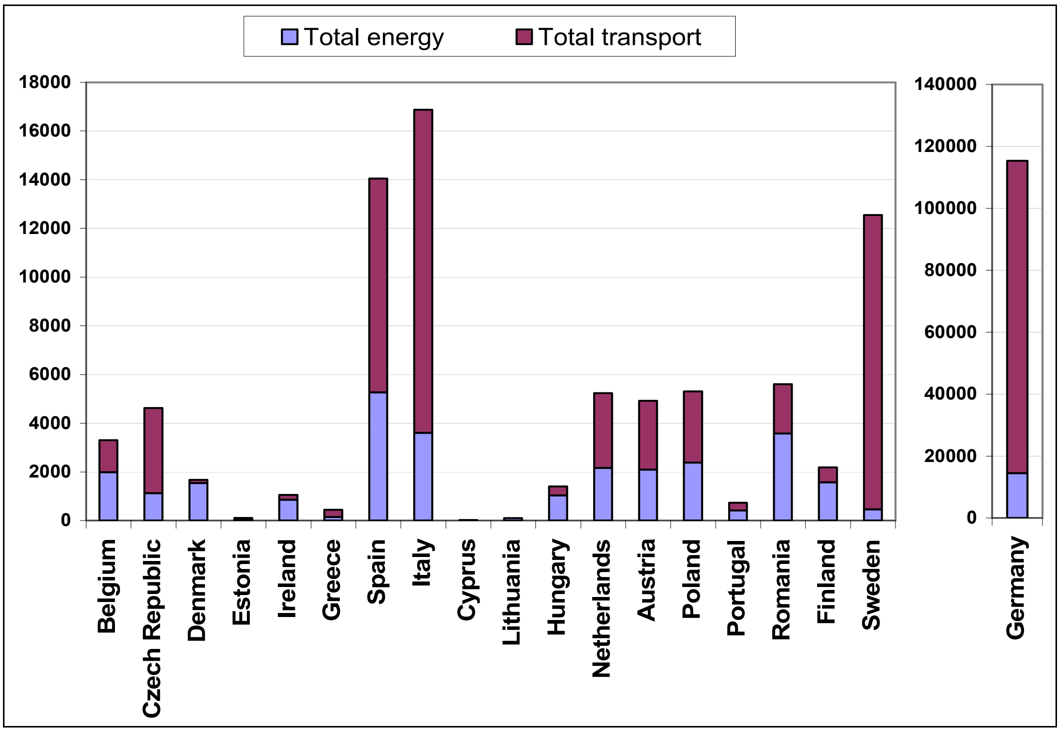
Figure 12: Relative importance of personnel in energy- and transport-related R&D compared to overall research personal in BES



Source: Eurostat; data for 2004 and 2003 respectively

Also in absolute terms, there are large differences in research personnel of the private sector among Member States (see Figure 13). Germany shows the largest number of R&D personnel in the private sector in the energy- and transport related sectors, particularly in the latter. This reflects the importance of car manufacturing and related industry in Germany, and is in line with the scoreboard data (see Section 5.2.2).

Figure 13: Total personnel in energy- and transport-related R&D



Source: Eurostat; data for 2004 and 2003 respectively

5.2. Private sector investments in energy and transport R&D

The business sector plays a major role in conducting research. By 2005, they accounted for 64% of overall EU R&D (see Table 2). This compares to 70% and 75% in the USA and Japan, respectively, since in these countries the entrepreneurship seems to be more R&D-oriented than in the EU. Unfortunately, the lack of consistent data hinders a reliable breakdown of spending for energy and transport-related research.

However, there are two main data sources on private sector R&D expenditures whose analysis may enable some conclusions (see Chapter 3): the BERD, a database hosted by Eurostat[18], and the EU Industrial R&D Scoreboard collecting data on a company level.

5.2.1. Eurostat: Business and enterprise sector expenditure on energy and transport R&D (BERD)

The BERD database contains figures on the business and enterprise sector's expenditure in R&D broken down by different sectors. Energy- and transport-related R&D expenditures comprise the following sectors:

- Electricity, gas and water supply sector
- Manufacturing sectors related to the energy field
    - Manufacture of coke, refined petroleum products and nuclear fuel
    - Manufacture of electrical machinery and apparatus
- Manufacturing sectors related to the transport field
    - Manufacture of motor vehicles, trailers and semi trailers
    - Manufacture of other transport equipment
- Land transport; transport via pipelines; water transport; air transport; supporting and auxiliary transport activities; activities of travel agencies; post and courier activities.

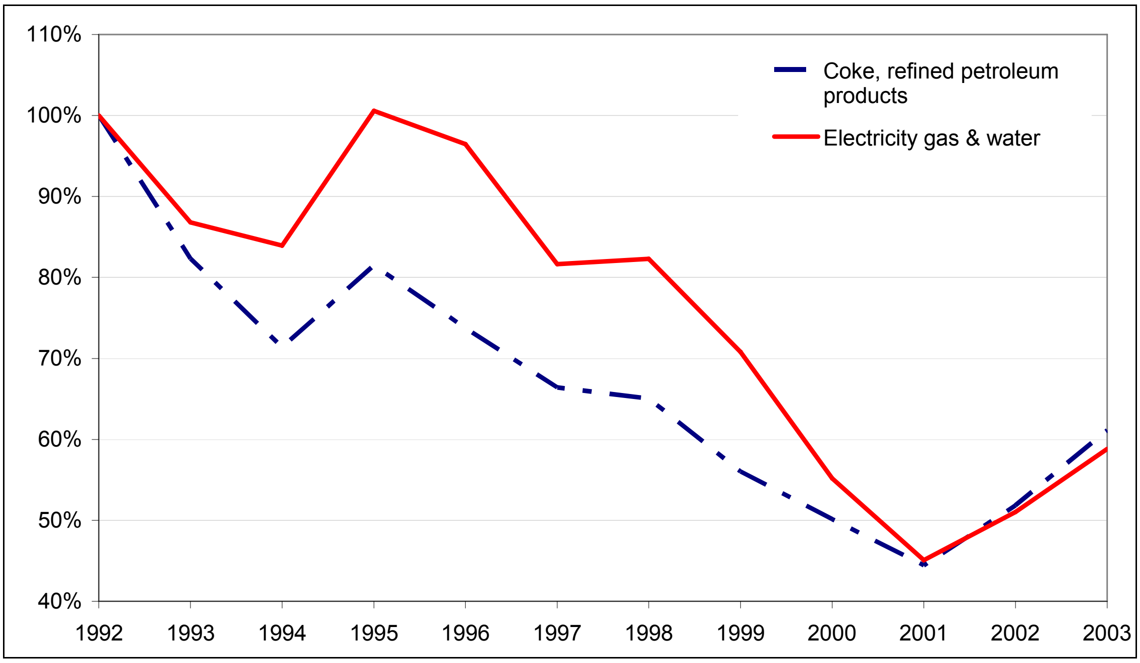
To the extent possible, data for the year 2005 are used. However, as datasets for the period 2002 to 2004 contain the highest number of observations for some sectors, in some cases it was more appropriate to use this data. The incompleteness of the dataset emphasizes the lack of R&D reporting, which hampers the analysis of the EU energy and transport R&D system.

In order to obtain an indicator of the business' sectors energy R&D expenditure over time (Figure 14), gap-filled data from the ANBERD database were used instead of the official Eurostat BERD database. Between 1992 and 2003, the R&D expenditure in electricity, gas and water supply and the manufacture of coke and petroleum products decreased substantially (see Figure 14). However, similar to the trends in public energy R&D funding, there is a re-increase in R&D expenditure in energy industries in more recent years.

18 The GERD, another database hosted by EUROSTAT, represents the Gross Domestic R&D expenditures, including the public and private expenditures. GERD is discussed in Section 4.2.1.

The overall decline may have been influenced by the recent liberalisation in these sectors. This may have reduced the "monopolistic rents", and therefore the company's resources for investment in R&D. With the introduction of competition, companies may also have diverted resources committed to longer term R&D to lower risk market-oriented projects [Doornbusch and Upton, 2006].

Figure 14: EU-15 aggregated expenditures of the business and enterprise sector for electrity, gas and water supply and the manufacture of coke

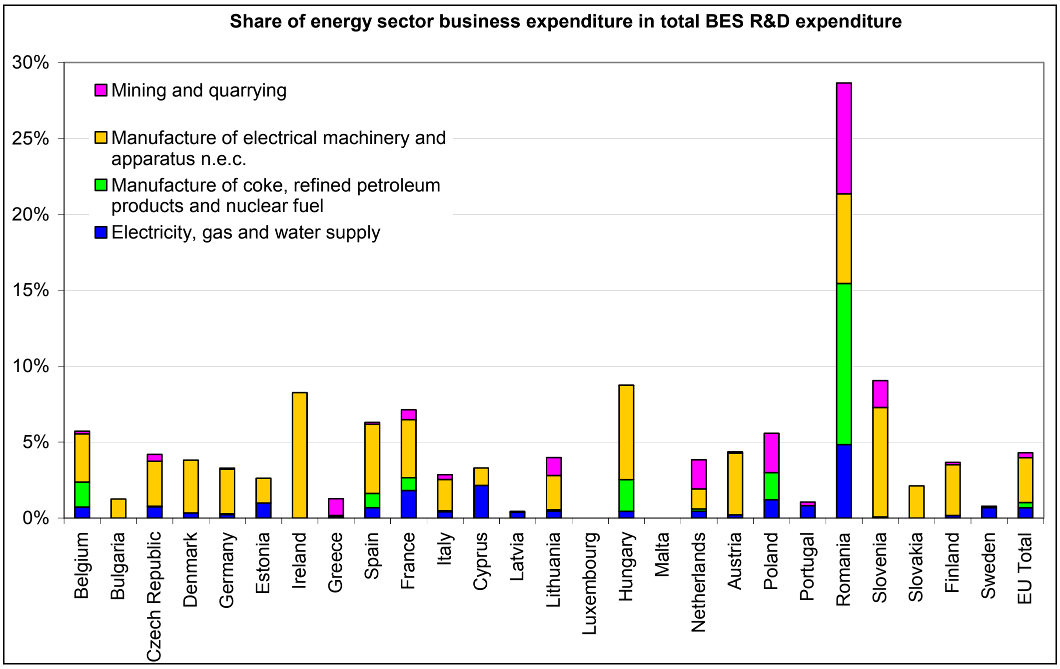


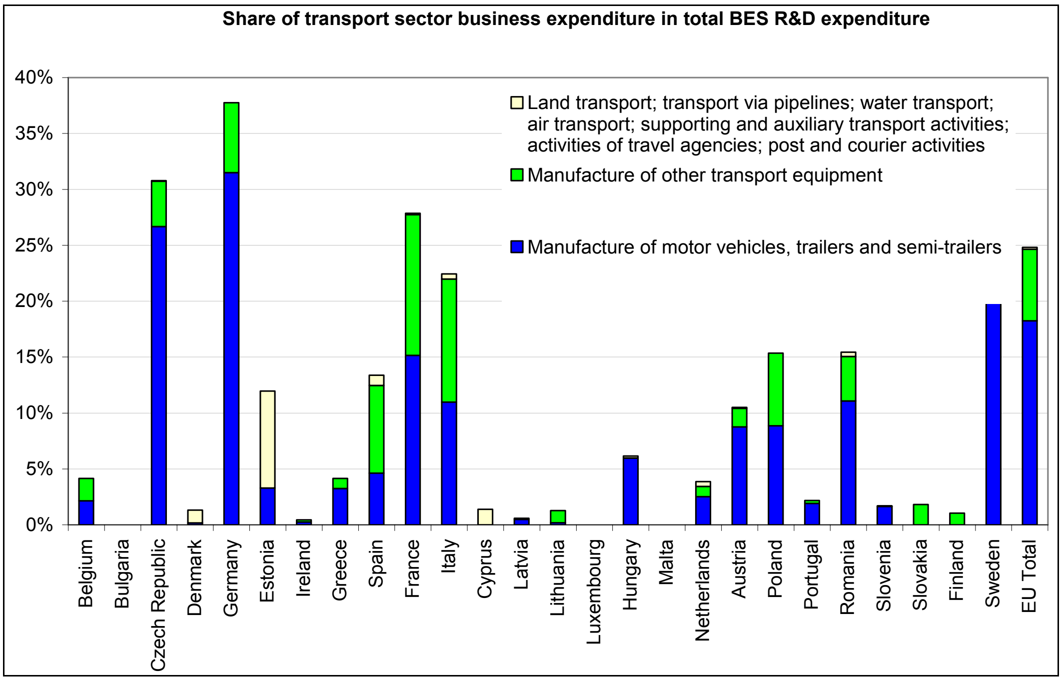
Note: The GDP deflator was used in order to obtain real values. No data for Austria, Luxemburg

Source: OECD, ANBERD Database (DSTI/EAS Division), 2006

The EU aggregated figure hide that the share of the various energy- and transport-related private R&D expenditures in total BERD expenditure varies widely among Member States, indicating the differences in importance of energy- and transport related research (see Figure 15). Despite these differences, some general observations can be made that apply to most Member States. Among the energy-related sectors, the lowest priority is awarded to mining and electricity; the majority of R&D expenditure is directed towards the manufacture of electrical components. In general, investments in transport-related research, and particularly in the manufacture of cars, are more important than those in energy-related sectors. This is the case in particular for those Member States with a relevant car industry. Furthermore, in a number of Member States, the importance of the energy-related R&D expenditure in total private R&D expenditure remains below these sectors' contribution to GDP, while the opposite applies for transport-related sectors.

Figure 15: Share of energy- and transport-related business and enterprise expenditures in total BES R&D expenditure, 2005



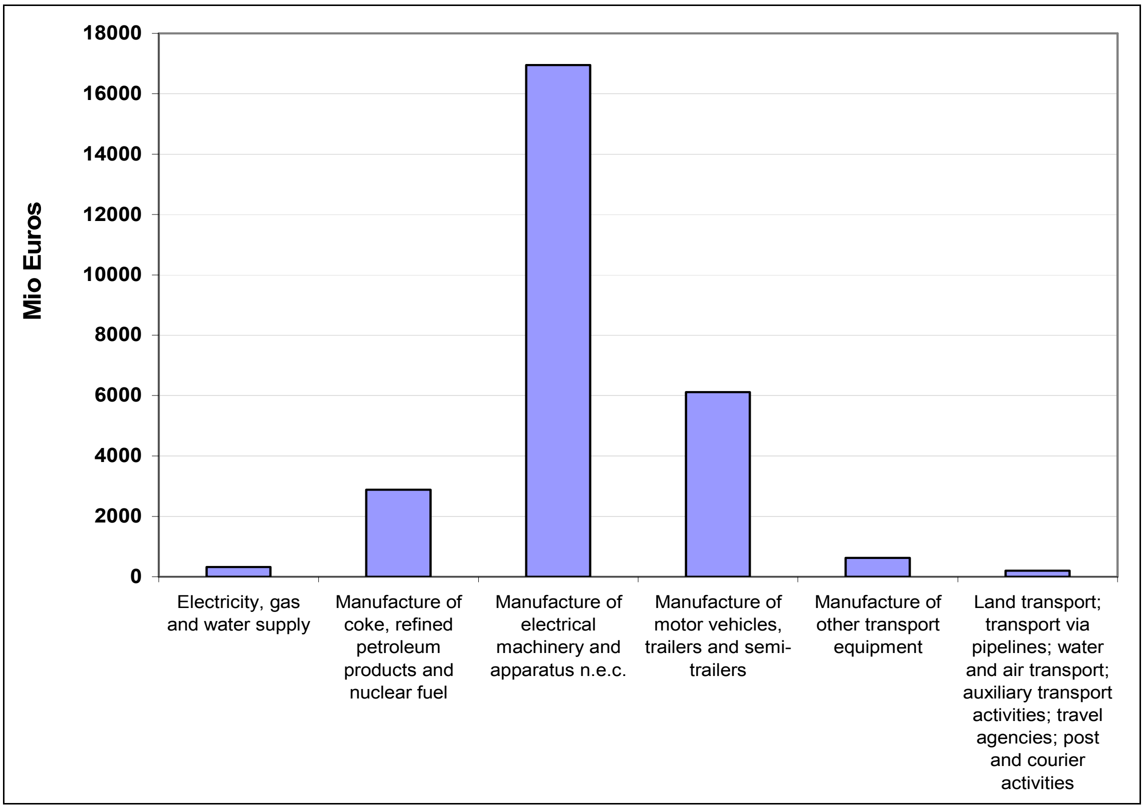


Note: For some Member States, data for the year 2004 were used as more recent data were not available. This is the case in particular for the sector 'land transport, transport via pipelines; water transport; air transport; supporting and auxiliary transport activities; activities of travel agencies; post and courier activities.

Source: Eurostat, BERD database

Also in absolute terms the by far largest R&D expenditures of the private sector occur in the manufacturing sectors, in particular the manufacture of motor vehicles. On the contrary, private sector R&D expenditures in electricity supply and coke production remains rather limited. This is shown for the EU aggregate in Figure 16.

Figure 16: Business R&D expenditure in energy- and transport related sectors (average of 2003 and 2004)



Source: Eurostat, BERD database

A detailed analysis of private sector's expenditures on R&D in the relevant sectors by individual EU Member States (see Figure 23 and Figure 24 in annexes) reveals that France invested five times more in research in the electricity, gas and water supply sector than the second ranking Member State, Germany, followed by Italy, Spain, Austria and Finland. The large spending in France is mainly due to the importance of nuclear R&D. This conclusion is supported by IEA figures, according to which around 62% of energy research goes to nuclear research in France, compared to some 40% at EU level. For the same reason, investment in R&D in the manufacture of coke, refined petroleum products and nuclear fuels is led by France, followed by Belgium and Spain. Germany experiences a clearly decreasing trend, which may reflect the government's commitment to phase out nuclear power and the decreasing importance of domestic coal mining. Germany and France also share the largest private spending on research in the manufacture of electrical machinery. However, there is a converging trend with Spain experiencing a large increase since 2000.

In most Member States, the majority of business' R&D funds come from the business sector's own resources, while less than 5% of the sources are covered through government funds. In Poland, Hungary and Cyprus, however, the government's contribution is larger.

Business corporate research expenditure in the transport-related sectors are much above those in the energy-elated sectors. Not surprisingly, Member States in which car manufacturing plays an important role clearly dominate the private research expenditure in this area. As a result, businesses in Germany and France invest by far the largest amounts in R&D in these areas, followed by Sweden, Italy, Austria and Spain.

5.2.2. The EU Industrial R&D Investment Scoreboard

While the BERD database provides data on a national level, data on R&D investment on a company level can be extracted from the EU Industrial R&D Investment Scoreboard (see Section 2.1). In the following, information on the top R&D investing, EU-based companies that operate in energy- and transport-related sectors is presented. However, it must be noted that this does not necessarily imply an R&D investment in energy technologies. Furthermore, the underlying data source (i.e. companies' financial reports) does neither contain information on the location of R&D performance but only on the location of the registered headquarter offices, nor does it allow a breakdown along individual technologies.

Energy-related sectors

The economic activities of the scoreboard classification that are directly related with energy are oil and gas producers; oil equipment, services and distribution; electricity, gas, water and multi-utilities. Moreover, the companies registered in the category "Electrical components & equipment" should also be considered as firms that may invest in energy-related R&D. Although the composition of this group is heterogeneous with respect to their industrial activities and investment, they should be included in order to offer a more complete picture on R&D funds at the industrial level.

If aggregated, the scoreboard data show that R&D investment in absolute terms is by far the highest in the electrical components and equipment sector, followed by the oil & gas sector. The energy R&D intensity, defined as a ratio of energy R&D expenditure and net sales, is also the highest in electrical components and equipments, reaching above 5%. It is followed by the oil equipment and services and electricity sector with the energy R&D intensity being close to 1%. Also R&D investment per employee is most relevant in the electrical components & equipments sector.

Table 8: R&D investment by selected companies in energy-related sectors, aggregate of EU-based companies (and non-EU for comparison) in 2005

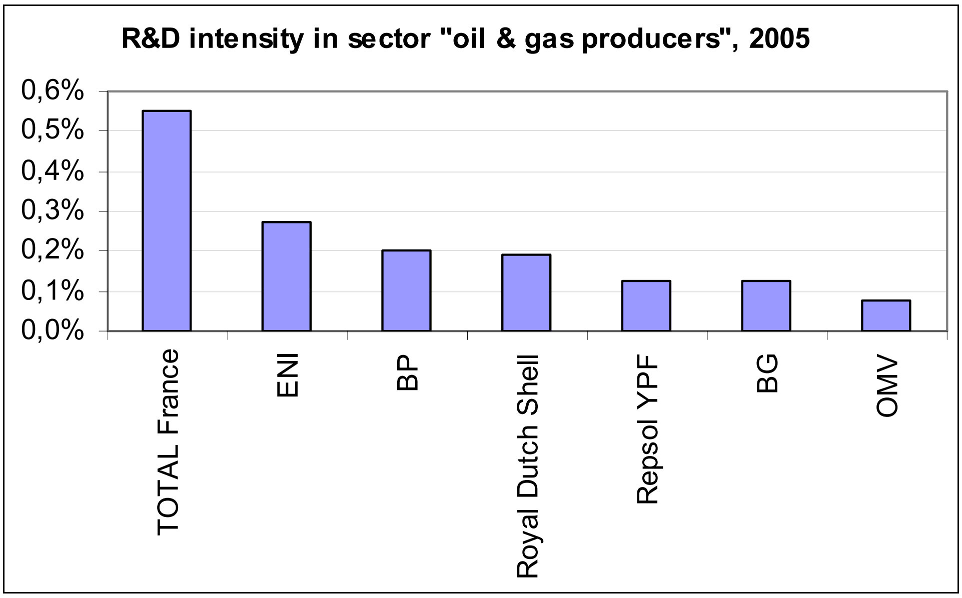
	Oil & gas producers	Oil equipment, services & distribution	Electricity	Gas, water & Multi-utilities	Electrical Components & equipments
R&D investement (million Euro)	1887,42	126,74	1141,11	405,60	6724,05
Net sales (million Euro)	740995	14342	147819	205602	124761
Employees (persons)	492115	57035	422946	682335	755980
Market capitalisation (million Euro)	665104	30964	201400	212500	110573
R&D intensity	0,25%	0,88%	0,77%	0,20%	5,39%

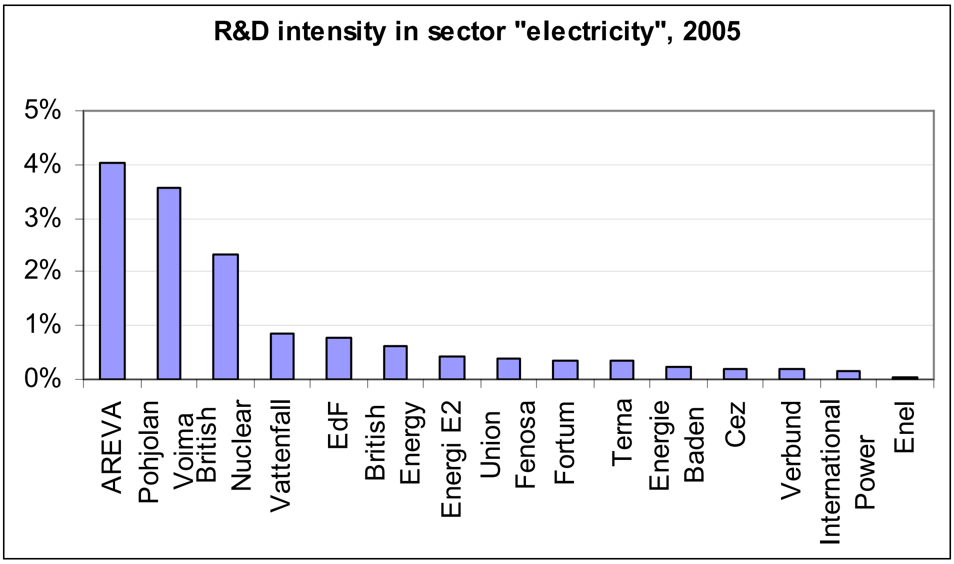
R&D intensity (Non-EU)	0,30%	2,10%	0,90%	0,60%	3,10%
R&D per employee (thousand Euro)	3,84	2,22	2,70	0,59	8,89
R&D per market value	0,28%	0,41%	0,57%	0,19%	6,08%
R&D per market value (Non-EU)	0,22%	0,67%	0,98%	1,01%	2,53%
Source: Scoreboard data, 2006					

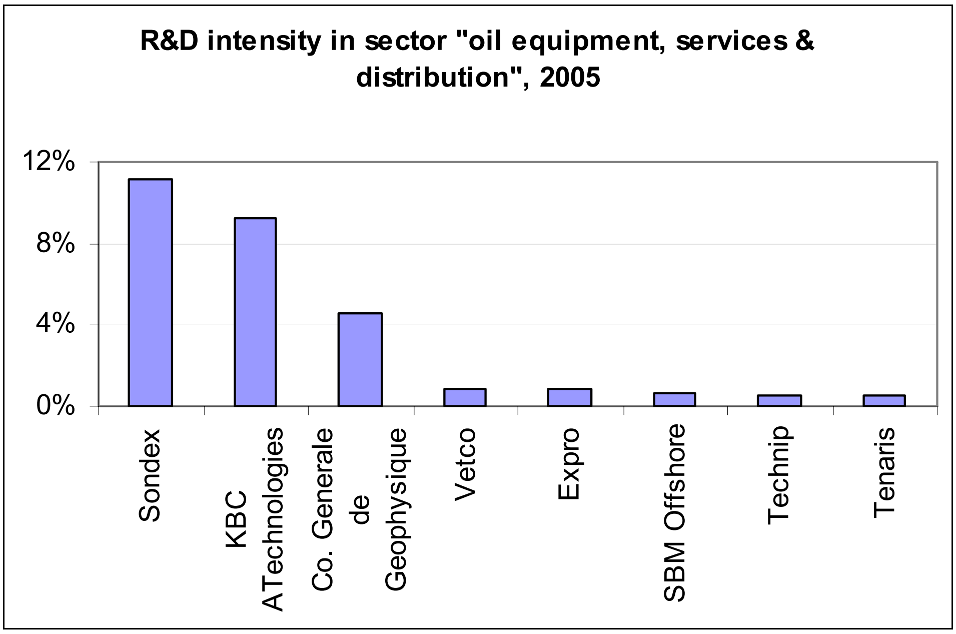
A breakdown on a Member State level indicates that companies with highest R&D investment are concentrated in the UK, France and Germany. Companies with headquarters based in Germany cover 78% of the EU investments in the electrical components and equipment sector, which is the dominant sector in terms of R&D investment.

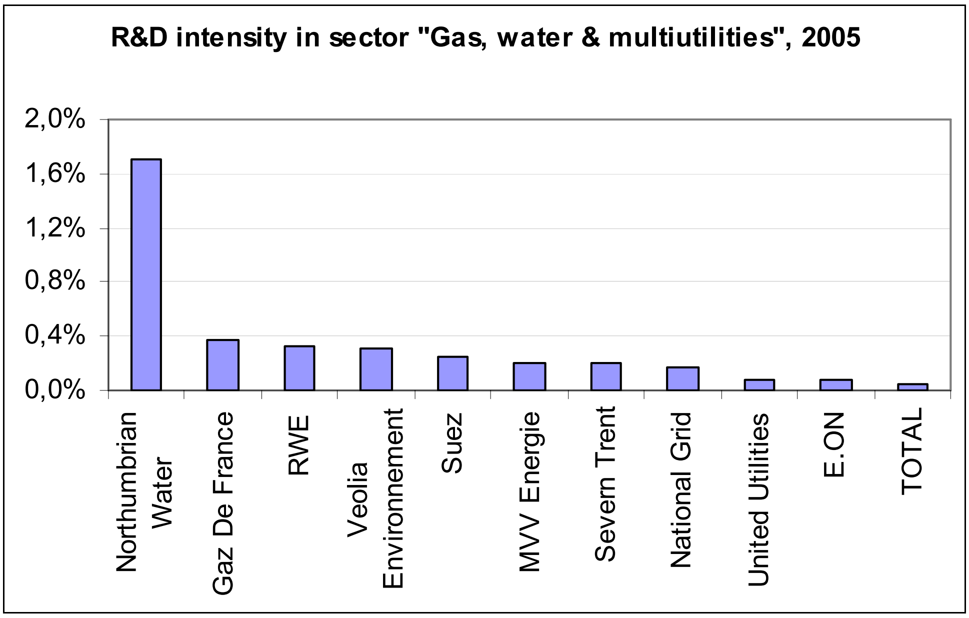
The scoreboard data also indicate that the top investing EU-based companies have a similar R&D intensity to that of non-EU-based companies except in the oil equipment field, where EU-based companies lag behind. In this area, however, EU-based companies strongly increased R&D investments between 2004 and 2005, thus being on a converging path. In other fields, their increase often remained below that of non-EU-based companies. In Figure 17, the R&D intensity of the different companies included in the scoreboard is presented for the different sectors.

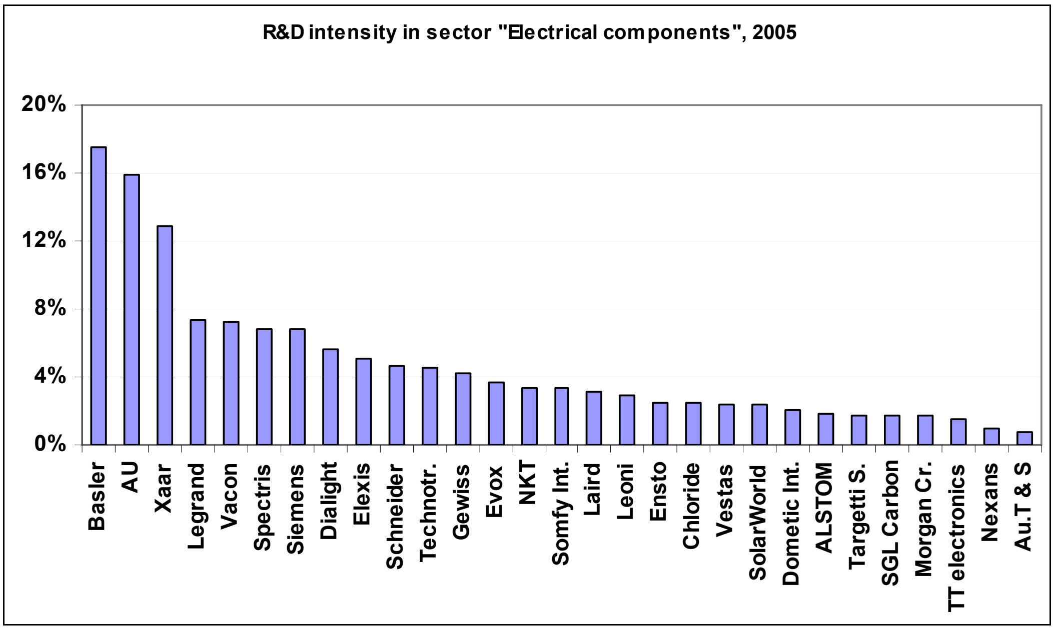
Figure 17: R&D intensity by companies in energy-related sectors




R&D intensity in sector "electricity", 2005
5%
4%
3%
2%
1%
0%
AREVA
Pohjolan Voima
British Nuclear
Vattenfall
EdF
British Energy
Energi E2
Union Fenosa
Fortum
Terna
Energie Baden
Cez
Verbund
International Power
Enel


R&D intensity in sector "oil equipment, services & distribution", 2005
12%
8%
4%
0%
Sondex
KBC ATechnologies
Co. Generale de Geophysique
Vetco
Expro
SBM Offshore
Technip
Tenaris


R&D intensity in sector "Gas, water & multiutilities", 2005
2,0%
1,6%
1,2%
0,8%
0,4%
0,0%
Northumbrian Water
Gaz De France
RWE
Veolia Environnement
Suez
MVV Energie
Severn Trent
National Grid
United Utilities
E.ON
TOTAL



Note: From this last chart the company "Intelligent Energy (UK)" was taken as its energy R&D intensity amounted to figure to 247%

Source: Scoreboard data

5.2.2.1. Transport-related sectors

Transport-related sectors in the scoreboard comprise the sectors 'Industrial transportation', 'Automobile and parts' and 'Commercial vehicles' with a total of 70 companies included in the EU. A complete list of companies can be found in Table 7. The sector 'Industrial machinery' certainly also included some companies that supply material to the transport-related sectors, but is too diverse to be included here.

The aggregated investment in European transport-related companies amount to €28 bn per year, clearly dominated by the sector 'automobile and parts'. Not surprisingly, this is led by Member States with an important car industry. Investments from German-based car manufacturers dominate the overall investments with around €17.8 bn, followed by French (5.9 bn) and Italian (1.6 bn) manufacturers.

Table 9: R&D investment by selected companies in transport-related sectors, aggregate of EU based companies and selected parameters for non-EU companies

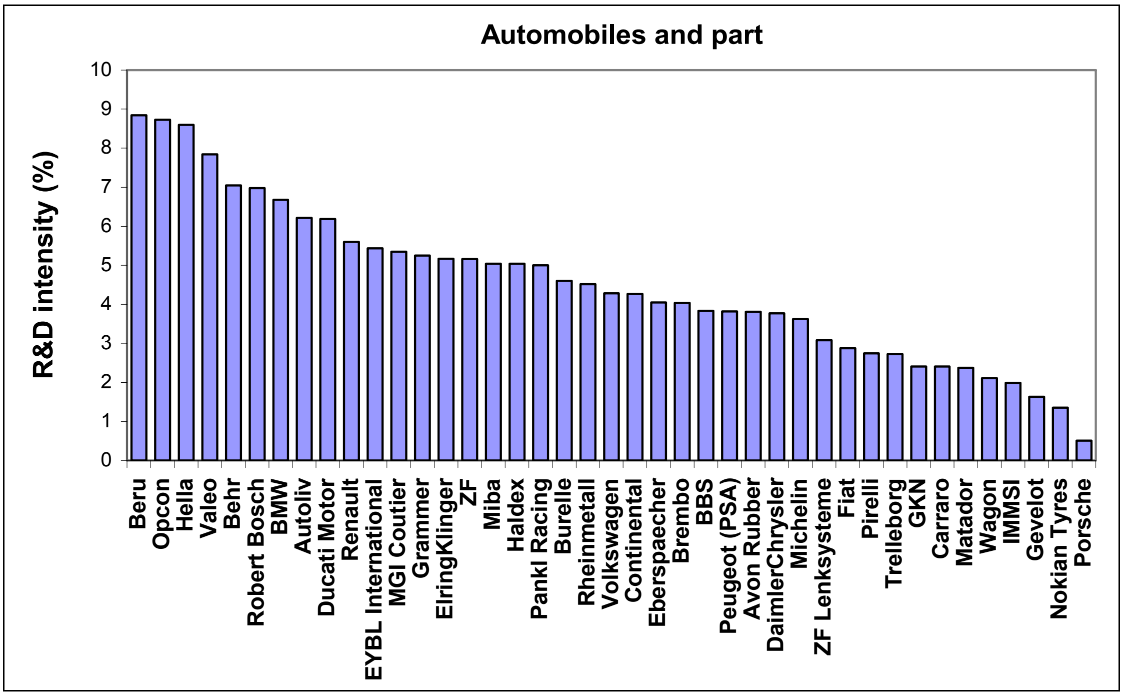
	Industrial transportation	Automobile & parts	Commercial vehicles & trucks
R&D investement (million Euro)	419	25984	1703
Net sales (million Euro)	107603	577655	44569
Employees (persons)	1036643	2180176	158701
Market capitalisation (million Euro)	54593	182744	32912

R&D intensity	0,39%	4,50%	3,82%
R&D intensity (Non-EU)	0,82%	4,04%	2,69%
R&D per employee (thousand Euro)	0,40	11,92	10,73
R&D per market value	0,77%	14,22%	5,17%
R&D per market value (Non-EU)	0,73%	8,17%	2,94%
Source: Scoreboard data, 2006			

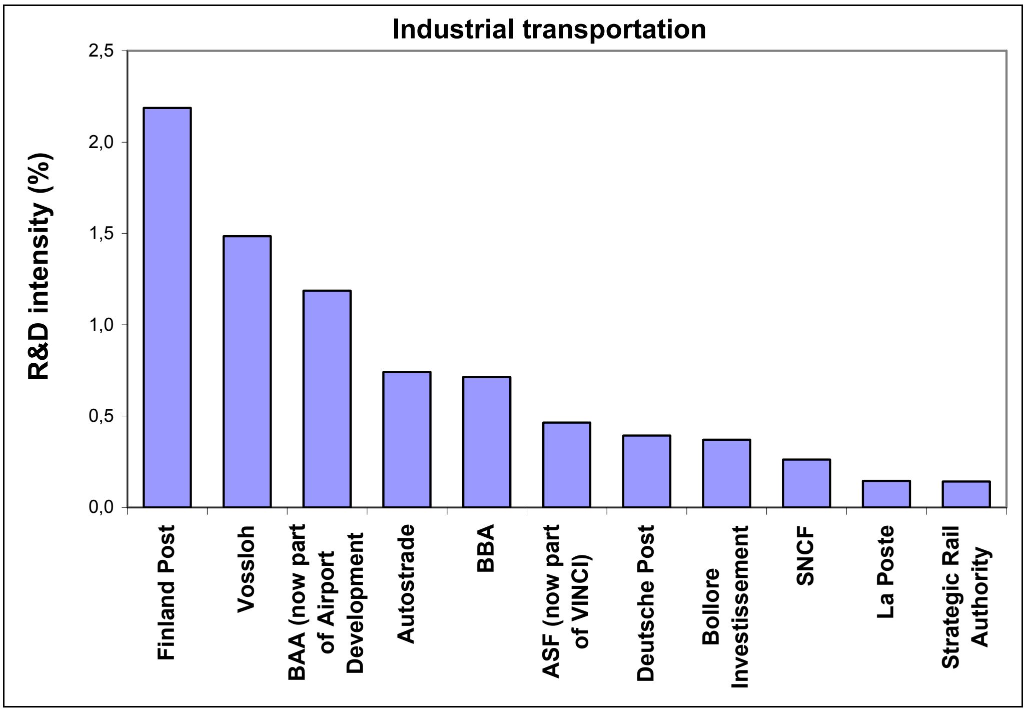
The automobile sector also shows important R&D intensity with investment levels being in the order of 4.5% of net sales. Together with 'electrical components' and 'commercial vehicles', this is the by far largest R&D intensity among all energy and transport-related sectors. The discrepancy in R&D investments among the manufacturing sectors and network/refining industries may (at least partially) be explained by the fact that they are exposed to a stronger international competition. On the other hand, it needs to be noted that the broadness of the considered sectors hides the important differences among the actors that operate in each of them. The R&D intensity of the different companies included in the scoreboard is presented in Figure 18.

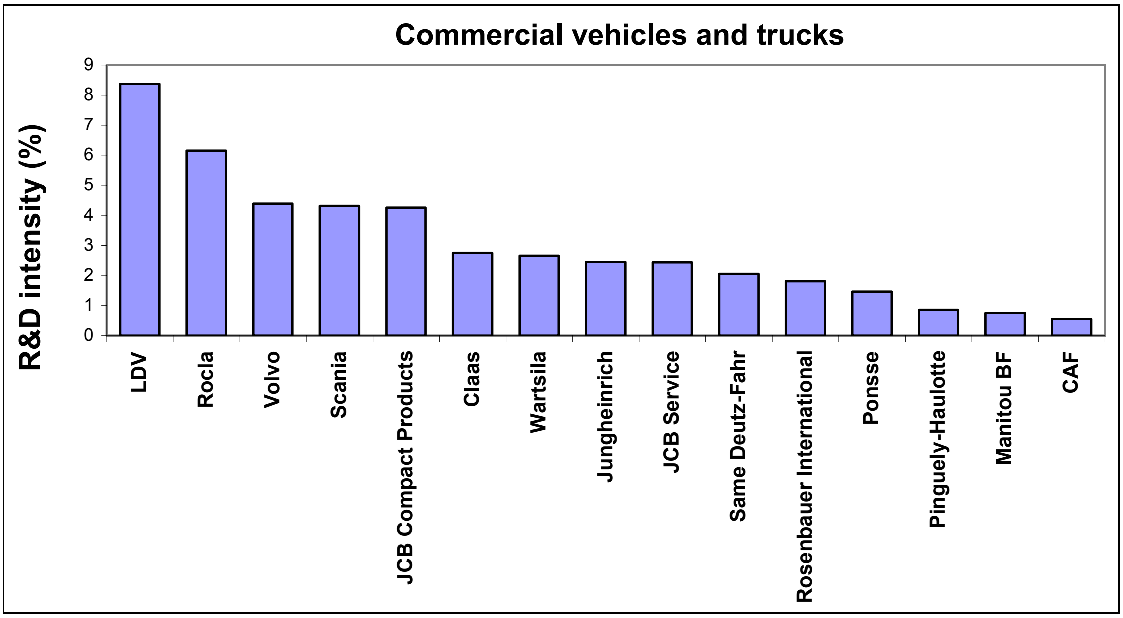
For comparison, the aggregate R&D investment intensity of non-EU companies was included in the above table. Overall, the same number of companies (70) was taken into account as for the EU. It becomes apparent that there are no major regional differences between R&D investment of companies, yet the EU-based companies in the automobile and commercial vehicles sectors show a (slightly) higher R&D intensity, despite the fact that non-EU companies registered a higher increase in R&D investment between 2004 and 2005.

Figure 18: R&D intensity by companies in transport-related sectors in 2005



Note: The companies Torotrak and Zytek are not shown as their R&D intensity amounts to 253 and 40, respectively





Source: Scoreboard data

5.3. Conclusions

Private actors involved in energy- and transport research comprise a broad range of business sub-sectors, strongly dependant on the technology cluster. Consequently, the type of business R&D varies considerably across EU Member States. In addition to R&D being carried out at company-level, there are a number of research centres that are jointly financed by industrial and public funds.

The comparison with private energy- and transport-related R&D investment in other parts of the world reveals that EU-based companies are not lacking behind. On the contrary, in some sectors their R&D intensity is even slightly above those of non-EU companies, indicating that EU companies operating in energy- and transport-related sectors perform relatively well with regard to R&D investments on an international level.

On an EU average the high importance of private R&D in the manufacture of car is remarkable. Large business investments are also dedicated to the manufacturing of electronic equipment. One of the underlying reasons may be the innovation pressure in car markets and electronic goods markets. Innovation is one of the strategies to distinguish from the competitors with e.g. technical innovation being a trademark. Furthermore, these companies are exposed to more competition than network-based companies such as electricity or gas and water utilities (which typically have a monopolistic or oligopolistic structure).

In general, companies in the energy sector generally show a relative low R&D intensity. This may be explained by the fact that utilities produce a homogenous good (electricity) with price competition being the main competition success criterion. Moreover, the recent liberalization of the power sector may have reduced the "monopolistic rents", and therefore the company's resources for investment in R&D. Finally, innovation in the energy sector often is not carried out at the level of the utility itself but at the level of component suppliers with a considerably higher investment in R&D. The energy sector might be classified as a 'supplier-dominated sector', following the classification of Pavitt [1984].

Having in mind that this energy sector is undergoing a continuous transformation process in order to limit its air pollution and greenhouse gas emissions and comply with EU directives such as IPPC, NEC or the renewable electricity directive, some studies conclude that "there is evidence that enterprises in the energy production sector do not spend enough on R&D and that this is perceived as a ‘negative driver’ of innovation." [Kaloudis and Pedersen, 2006].

It would be interesting to see whether there is a significant correlation between the private investment and the market pull mechanisms in a specific Member States, or whether the market structure and how liberalisation affects the R&D investment of companies.

6. PUBLIC ENERGY R&D PRIORITIES

This chapter gives an overview of the current thematic priorities and R&D energy needs, based on the survey undertaken by the European Commission for the SET-Plan[19], the government spending on energy R&D listed in the IEA database, and additional literature (e.g. European Commission, 2005g). It needs to be noted that the following assessment contains a strong bias towards energy production and use, while transport-related priorities are only covered to the extent that they are explicitly energy-related (i.e. biofuels; hydrogen). This is due to the energy focus of both the IEA database and the SET-Plan survey.

Figure 19 and Figure 20 provide an overview of the research priorities by Member States based on the absolute and relative R&D public expenditures[20]. The reported numbers show the differences in Member State's public spending and thus, implicitly, reveal the different priorities in energy R&D. However, a number of shared priorities also become obvious, such as energy efficiency and renewable energies (yet with differences in the relative importance of the diverse renewable energy technologies). These priorities match well with the targets set by most individual Member States and the European Union to increase the share of renewables in the energy mix while simultaneously improving energy efficiency.

Table 10 shows that renewable energy spending has become increasingly important in many Member States over the past decade both in absolute and relative spending terms, often at the expense of nuclear and fossil fuel research. More surprisingly, the relative significance of research funds in the area of energy efficiency seem to have stagnated or even decreased in a large number of EU Member States while it has increased in the USA.

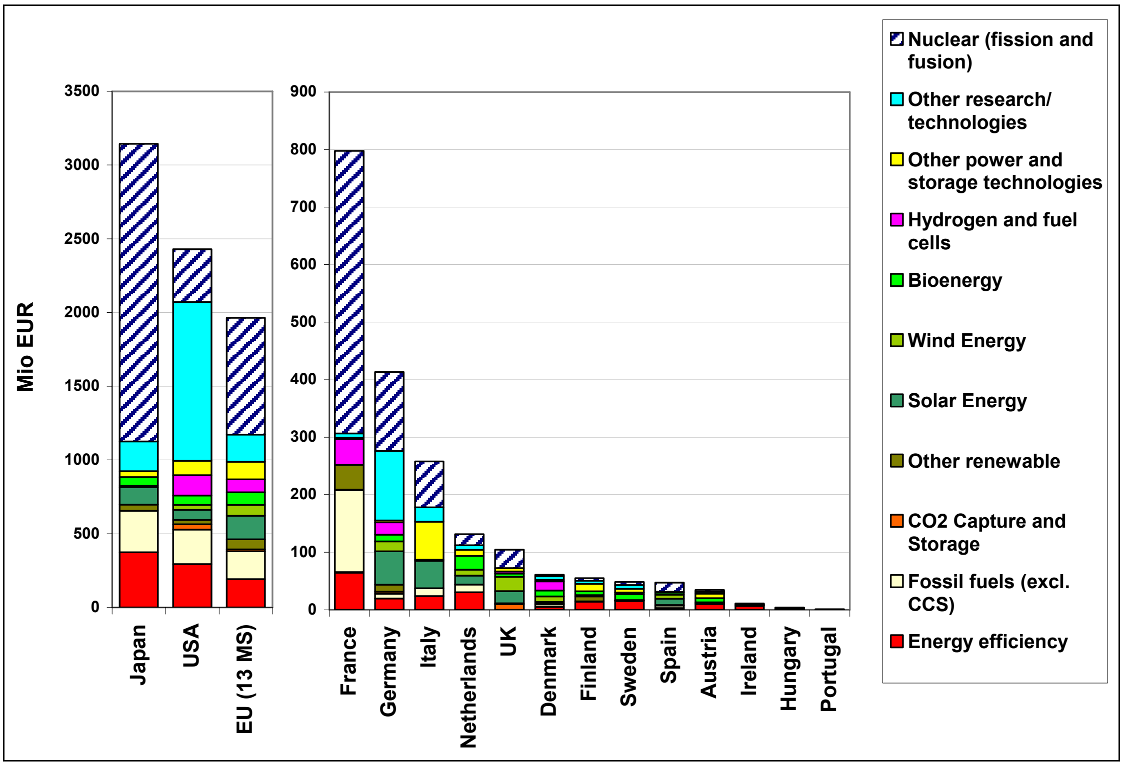
These trends are underlined by the list of strategic priorities for the national Energy R&D and innovation plans in the SET-Plan survey. The first conclusion that can be derived from the survey – and going beyond the scope of the IEA data – is that energy R&D priorities are highly focused along the electricity sub-sector and, to a lesser extent, to end-use-efficiency improvements (mainly in the residential sector).

Despite the relatively important weight that the transportation sectors play in terms of primary energy demand and GHG emissions, it is noticeable that transport issues were hardly mentioned. There are only three out of the 17 Member States that replied, which explicitly mention the development of new transport technologies or efficiency in transport as a priority in public R&D. This may be partly due to the a priori towards the energy sector by the survey.

[19] 17 Member States (out of 27) replied to the SET-P survey.

[20] The figures need to be interpreted with care. Not all EU Member States are members of the IEA, and for others, no data are available. This implies that the EU aggregated figures on energy R&D spending used below comprise only data from 13 Member States. Furthermore, the IEA database contains data gaps for a number of technologies and years for different Member States. As a result, in some cases, figures for the latest available years were used instead of the (missing) 2005 values.

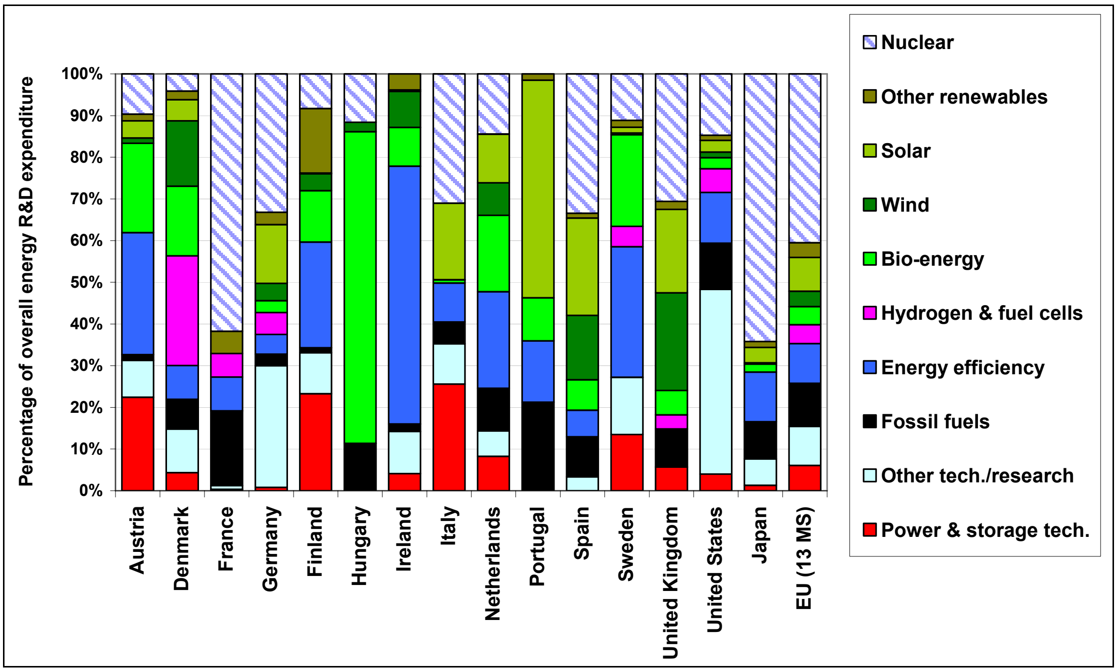
Figure 19: Public energy R&D expenditure in selected EU Member States, Japan and USA by thematic area in 2005



Note: For Finland and the Netherlands, 2003 data were used; for Austria, 2004 data. Belgium, Czech Republic, Luxembourg and Greece are not included due to data gaps for more recent years.

Source: IEA, 2007; complemented by data from the Member State survey.

Figure 20: Relative importance of different themes in overall energy-related R&D funding



Note: see note to Figure 19

Source: IEA, 2007; complemented by data from the Member State survey

6.1. Overview of thematic priorities

Nuclear R&D is still a significant activity for many Member States. About one out of three Member States list nuclear-related research among the first priorities in the national plan (not surprisingly for countries exhibiting a relatively nuclear-intensive power sector, headed by France, and followed by Lithuania, Bulgaria and the Czech Republic). This is reflected in the importance of public spending on nuclear research in overall energy R&D expenditure, which reaches above 60% in France, while accounting for between 0 and 30% in most other Member States.[21]

In the case of those countries looking at nuclear technology, priorities are the improvement of the affordability, safety and operability of existing and future nuclear power plants, including the development of new fission nuclear reactor designs. Pre-conceptual design research on a limited number or promising advanced designs is also being coordinated at the international level by the Generation-IV International Forum (GIF), whose members include USA, Japan, Korea, Canada, Euratom, France, Switzerland, China, Russia and South Africa. Particular emphasis is on research into systems with fast neutrons and a closed fuel cycle (with sodium or gas coolant), and the development, in close collaboration with industrial partners, of a very high temperature reactor (VHTR) for the cogeneration of electricity and process heat to meet the needs of the electricity and hydrogen markets in around 2025. In Europe, the new Sustainable Nuclear Energy Technology Platform will provide a forum for broad cooperation in both fast reactor and VHTR R&D.

Nuclear waste management is another key issue within nuclear R&D, including phased geological disposal and related demonstration of system integrity, and reducing the volume and radiotoxicity of the final waste for disposal through "partitioning and transmutation" (P&T). However, nearly all the R&D in the field of geological disposal will be funded through the "polluter pays" principle, whereby the end users pay, through the pricing of nuclear-generated electricity, for the necessary safe management of the resulting waste and related R&D. This is often via a levy-based system of ring-fenced funds managed by a national agency, though may well be incorrectly included as public R&D funding. There are a number of key R&D projects at the European level focusing on all the above aspects of waste management, from the various aspects of geological disposal to P&T systems and techniques. The former are increasingly focussed on implementation-oriented research and the deployment of the first operation geological repositories towards the end of the next decade. The latter are closely linked with R&D on advanced nuclear systems and fuel cycles.

The largest actor in nuclear research within the EU is undoubtedly the French CEA. With almost 15000 staff, CEA conducts a broad number of R&D programmes, from military applications to basic research, and though many of them are linked with the nuclear sector, a significant fraction of the CEA's budget is devoted to non-nuclear research.

[21] These figures should be viewed with a certain degree of caution. Firstly, there is only very limited information on the breakdown between nuclear fission and nuclear fusion (Figure 7). Secondly, nuclear R&D in the fission area does not necessarily imply research on energy systems per se. This research effort will usually be predominantly on issues such as management of radioactive waste and nuclear safety rather than the development of future or advanced energy technology.

Fusion energy research in Europe is implemented in a single European programme, fully coordinated by EURATOM, incorporating all activities on magnetic confinement fusion. Europe's world leading fusion development programme constitutes a paradigm of a "European Research Area" (ERA) integrating national efforts and goals in a uniquely co-ordinated activity, funded by EURATOM and national budgets alike.

The long term goal of fusion R&D, as quoted in FP7, is "the creation of prototype reactors for power stations which are safe, environmentally responsible, and economically viable", while the specific goal is the creation of the necessary knowledge base, with the realisation of ITER and related "Broader Approach" activities being the major step towards it. ITER is one of the largest scientific endeavours ever attempted, and is being implemented in Europe in the frame of a world wide co-operation, involving China, the EU, India, Japan, the Republic of Korea, the Russian Federation and the USA. ITER is being implemented in the context of the so called "Broader Approach" to the rapid realisation of fusion energy, which includes a EURATOM participation in complementary activities undertaken in Japan. Furthermore, the EURATOM FP7 programme aims at developing also: R&D in preparation of ITER operation and possible improved techniques for the longer term; technology activities in preparation for DEMO and the longer term (in particular fusion materials); human resources, education and training.

The Community is contributing within FP7 a total of 1,947 Mio EUR over a five year period (2007-2011) excluding contributions from Associated States. In Europe the total annual expenditure on fusion R&D (including national funds in Member and Associated States) is in the order of 700 Mio EUR pear annum. As concerns the Broader Approach activities[1], EURATOM is committed to participate, at par with Japan, up to the value of 339 Mio EUR through, mainly, voluntary in-kind (around 90%) contributions offered by some Euratom Member and Associated states (five States currently, with an additional one having expressed the possibility to participate) and cash.

The EURATOM fusion programme is implemented, as concerns ITER and Broader Approach, through the "European Joint Undertaking for ITER and the Development of Fusion Energy", established in April 2007. The backbone of the programme remains the twenty-six Association Agreements between EURATOM and Member/Associated States (the principal mechanism of participation in the fusion EURATOM programme), and the "European Fusion Development Agreement" (EFDA) between EURATOM and all fusion Associates.

Concerning capacities, with regard to the major existing fusion facilities, and those under construction, Europe offers JET, the EU's flagship fusion experiment and the world's largest fusion device, complemented by twelve other medium to smaller fusion devices covering a wide range of configurations, including namely: tokamaks (toroidal, spherical) in seven States, stellarators (one in Spain one under construction in Germany) and reversed field pinch devices (in two States). In the broader context of using the fusion facilities, predominantly demonstrated through the common exploitation of JET, a strong emphasis has been maintained on collaborative and multilateral actions for common projects, which is another feature of the fusion ERA. The FP7 Euratom stipulates also that a review exercise in the EU

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22 The three areas of activities are as follows: (1) The engineering validation and design activities (EVEDA) for the proposed fusion materials testing facility – IFMIF, in Rokkasho; (2) A superconducting upgrade to the JT60 Tokamak (Satellite Tokamak Programme), in Naka; (3) Establishment of an International Fusion Energy Research Centre (IFERC), in Rokkasho, which includes: 3a) DEMO Design and R&D Coordination Centre; 3b) Computer Simulation Centre for Fusion Science; 3c) ITER Remote Experimentation Centre.

will be launched addressing "the facilities in the programme, the possibility of phasing out existing facilities and the need for new devices in parallel to ITER exploitation". This review manifests the maturity of the fusion programme in Europe and its commitment to establish a common optimised approach towards the rapid realisation of fusion as an energy source.

As far as human resources are concerned, the total number of staff involved in the EURATOM fusion programme is currently in the order of 2000 professionals. It is estimated that around 250 PhD students are currently performing their research at the Association laboratories, while the Commission has launched a Training Programme for up to 200 engineers and researchers over the next 5 years, as well as up to 10 individual fellowships per year to encourage career development and excellence in the programme and meet the challenges ahead for increased resources capable of driving the demanding goals of the programme.

Renewable energies are definitely identified as one of the most important priorities for the whole of the national R&D and innovation programmes. The importance of renewable energies in energy research is underlined by the public spending in this area, which amounts to almost 20 % of overall energy spending aggregated from the EU Member States listed in the IEA database, and provides 1/3 of the non-nuclear budget.

Member States' renewables R&D mainly focuses on primary renewable electricity from wind, solar, bioenergy etc. and, to a lesser extent, to biofuels. Renewable energy, however, is a broad subject and, even if generically considered as an absolute priority for almost all member states, this priority materializes differently in each case, assigning different weights to different technology clusters according to the strategic interests of each Member State. For example, geothermal and ocean energy are high R&D priorities only for two Member States.

Biomass-converting systems are high R&D priorities for several countries, especially in Finland, Austria and the Netherlands. The Nordic countries have a long tradition in the exploitation of these resources. From the optimisation of the use of biomass as a primary source for domestic an industrial heat, systems have been developed for power generation and production of different intermediate fuels. Biomass is considered to be "carbon-neutral", in that the amount of carbon it absorbs while growing is the same as the amount it produces when burned. Biomass projects can therefore be included in the CDM and JI of the Kyoto Protocol. Different conversion processes and technologies can be used to produce heat, electricity, combined heat and power, chemicals or liquid fuels for transport (ethanol, biodiesel, etc.). R&D activities regarding bio-ethanol production include processes for using lignocellulosic materials (e.g. wood) as feedstock. The EU is among the leaders in electricity generation using biomass, thanks to Sweden and Finland. Consequently, the scientific and technological capabilities for biomass are advanced in Europe. However, better coordination of the networks and an enhanced exchange of experience and best practices among different countries and between research institutes and industries are desirable. Europe also lacks a more integrated R&D approach with the sectors that could use energy from biomass or supply biomass. The market potential of biomass is high, but the competition between bio-electricity, bio-fuels, the pulp and paper industry, as well as food industry could be considerable. The legislation is relatively favourable with precise targets at European level. E.g. feed-in tariffs are in place as a key instrument in 18 Member States [European Commission, 2005g].

The priorities identified in several EU member state in this respect include the improvement of the exploitation of bio-residues and energy crops well fitted to energy production, development of supply chain logistics and development of separation and pre-treatment technology, and the optimisation of reliable and cost-effective technologies for both small- and large-scale plants (combustion, gasification, pyrolysis etc.).

Biomass receives the highest (Hungary) or second highest funding within the overall energy research portfolio in a number of Member States: Hungary, Austria, Denmark, Sweden, the Netherlands. In many Member States, research in biomass is clustered into three subcategories: power generation, combined heat and power, and products and fuels. For Poland, biomass is considered a strategic asset, since forestry products and vegetal waste are abundant and the country has a 1.5 million ha potential for energy crops, like some other large new Member States (Romania, Bulgaria, etc). Major research related to the use of biomass as a feedstock for heat and power generation include are pre-treatment of feedstock, combustion and co-generation, as well as gasification. In Sweden, the green certificate system– which requires a mandatory share of RES electricity in electricity used – or the CO_2 tax have strongly promoted the deployment of bioenergy in the power sector.

The elaboration of liquid biofuels for consumption in the transportation sector is a technological option that has received significant support due to the beneficial implication in terms of security and diversification of supply. The boost induced by the Biofuel Directive (2003) has materialised also in a number of initiatives from the private sector and the development of a good number of public-private partnerships. Back to the Biofuel Directive in 2003, a number of EU initiatives provide support to this technological filière and a considerable involvement of the private sector has been achieved, both for the development of standard biodiesel and bioalcohol techniques and for the development of promising second generation biofuel technologies. The R&D priority is the development of advanced conversion processes and bio-refineries, i.e. the integrated conversion plants for biofuels and bio products. Sweden reports as the top energy R&D priority in its national program the development of forest-based solid fuels and ethanol as a transportation fuel (above 80% of the total budget for renewables), and this is another top priority for Finland (ClimBus programme, funded with more than € 70 M) and the Netherlands. On the other hand, in Germany, bioenergy only received an 8.5% share of it. At global level, the US is the largest investor in R&D for this technology line, mainly motivated by security of supply concerns. The US objective is to facilitate technology development that can lay the groundwork for future commercialisation, not competing or duplicating work in the private sector. Detailed priorities include identifying sources of sustainable supply of biomass, developing pre-treatment, enzymes, process integration, fractionation fundamentals, and other advanced concepts, pursuing the thermochemical production routes and the promotion of efficient use of all residue streams (heat and power).

Photovoltaic technologies (PV) have experienced very high growth rates, with an average of more than 30% in the past 5 years. Higher levels of production have led to price reductions (roughly by a factor of 5 over the past 20 years), efficiency increases and higher systems reliability.

Si-crystalline-based cells are a mature technology (but competitive without subsidies only in Japan, see Section 4.3.) whereas technologies as thin-film silicon cells, dye-sensitised cells, and polymer solar cells need to improve much more before they can become competitive. In the EU both the academic research as the industrial research for PV are relatively well developed, and there exist close links between both. However, national R&D programmes are fragmented and there is no world-class R&D funding on a pan-European level. Moreover, there is a lack of harmonization of the Member States' policies and regulatory frameworks, but the preparation for European standards and codes is "in progress". In general, public control dominates the R&D policies, resulting in an undervaluation of manufacturing issues in R&D programmes [European Commission, 2005g].

The largest players in Europe are Germany, the Netherlands and, beyond the EU, Switzerland. The top priority in PV research for all countries is system cost reduction. Research activities range from very fundamental basic research at the cell level to applied research aiming at implementation at the industry level. From the two presently competing technologies for the long-term massive industrial applications, i.e. (multi) crystalline silicon and thin film technologies, there seems to be no specific commitment for any country in favour of one of them. Integration studies are perceived as very important and the European Commission also contributes significantly to its financing. PV absorbed a significant fraction (between 40 and 30%) of the total spending of the European Commission's Framework Programme on renewables, with a steadily declining share though. A crucial characteristic of the European PV sector is that most of the production is attributable to small and medium enterprises (SMEs), often lacking financial R&D muscle and therefore highly dependent on R&D subsidies to improve the product quality. On the contrary, the Japanese PV industry (world leader at present) is primarily organised around few large corporations. Large amounts of money are invested in PV R&D by these corporations, less dependent on public R&D money.

High Temperature Solar Thermal Technologies (HTST). The relative importance of this technology in R&D budgets in increasing. EU is catching up the leading position of the USA at global level. Within the EU, this technology is strongly and continuously supported by Germany and Spain, whose respective HTST programmes are highly integrated. Italy has recently assigned also an important budget to HTST, primarily focusing on parabolic trough and combined with molten salt accumulators. This program currently absorbs around 30% of the total non-nuclear energy R&D public investment in Italy. The ongoing demonstration projects launched in Spain have also benefited from the feed-in subsidization programme implemented by the government to foster renewable electricity and therefore having been very successful in attracting private investments.

Wind power is, within the “new” renewable energy technologies, the one experiencing the fastest and most successful development. By the end of 2006, the capacity of wind energy systems installed globally had reached almost 74 200 MW. Europe accounts for about 67% of this capacity, led by Germany, Spain and Denmark as most important deployment countries. Other regions, however, are catching up as substantial markets for the wind industry, including the USA and also some emerging economies, most notably India. Depending on the site characteristics, wind power has decreased the production costs significantly. Despite these achievements, wind energy R&D aims at achieving further cost reductions in order to remain competitive against other emerging renewable technologies. Given its intrinsically intermittent, non schedulable character, wind power has a serious bottleneck in its compatibility with demand changes along the load curve. Gaining higher specific power by developing larger machines will further reduce the costs and therefore make the technology more attractive despite its intermittency. Denmark, Germany and the Netherlands accounted for three quarters of overall wind energy R&D funding of the EU Member States listed in the IEA database in 2000-2005. Priority is put in innovative materials, and designs for future wind energy converters > 5 MW, as well as the development of more accurate prediction tools to anticipate the availability of resources. Since the industry is pretty mature, private R&D efforts often compete for new, IPR-protected developments and this circumstance is reflected in the structure of transnational R&D consortia.

R&D focusing on the exploitation of **ocean systems** for power generation is present in the R&D budget of five Member States – United Kingdom, Ireland, Denmark, Sweden and

Portugal. The overall financial effort being rather limited (none of these countries supported ocean systems with more than €2 Mio, implying a share of 0.5-2% of the overall energy research budget), but the trend seems to be increasing at least until 2004 (with a drop in 2005). Up to 2001, Japan had a level of funding comparable to Europe but Japan massively reduced and later phased out its public research efforts.

Energy depends for a large share on **fossil fuels** as coal, oil and gas, among which coal contains the largest carbon content and gas the lowest. 71% of worldwide electricity production is of fossil fuel origin (of which is 62% coal, 26% natural gas and 12% oil). Most likely, fossil-fuel-based power production is going to remain a large share of the energy mix for many decades. Therefore, continued technological progress in generation plants (e.g. gas turbines and coal gasification systems) is desirable in order to achieve improved efficiency and environmental performance at an acceptable cost.

In general the EU has good research capabilities (e.g. in clean combustion technologies for coal), but also here less fragmentation of R&D and more cooperation between industries and universities is needed. The EU cannot finance competitive R&D and lobby groups try to influence the priorities. Furthermore, R&D in fossil fuels is hampered by the uncertainty on future policies: E.g. the introduction of a carbon tax would mostly affect the cost of using fossil fuels. There is a CO_2 permits scheme in the EU since January 2005. As power generation involves large investments on a long time horizon it is important to determine the energy and climate policies very soon [European Commission, 2005g].

It is very interesting to notice that, amongst the large actors with high R&D budgets (FR, DE, UK, IT, NL etc.), a high priority is given to the development of advanced power stations (either coal, gas or biomass-fired) with higher energy conversion efficiency and with total or partial CO_2 separation and storage (CCS). This clearly conveys the idea that within R&D strategists, the traditional thermodynamic cycles (either the steam Rankine or the open gas turbine Brayton) are perceived as technologies still offering a high potential for improvement, especially if combined with carbon-removing techniques.

CO_2 capture and sequestration is an end-of-pipe solution for combustion. With the CO_2 permit scheme in force this technology is likely to become more important, in particular, for the large stationary combustion and chemical plants. For effective carbon capture the CO_2 in the exhaust gases must be separated and concentrated using innovative technologies as adsorption, absorption, membrane separation and cryogenics. In the EU R&D funding and government support has been rather limited and, again, there is a lack of cooperation between industry and government for large-scale demonstrations. There is a lack of industrial partners to take over laboratory research as well, and a complete new industry needs to be launched. However, the Saline Aquifer CO_2 Storage (SACS) project at Sleipner in an aquifer in Norway is world-class involving the European Commission, IEA, leading energy companies and the DoE. From the regulatory point of view, many issues remain unresolved about the transport and storage of CO_2 [European Commission, 2005g].

Clean fossil fuel combined with carbon capture and sequestration is also high in the R&D agenda of France and Italy. R&D bugets for these R&D activities ranges around € 10-20M per year in the key energy R&D European nations (Germany, UK, France). Emphasis is put on research to develop clean fossil fuel technologies (i.e. technologies to improve power plant efficiency and CO_2 capture and storage technologies). On the other hand, dedicated research on CCS seems to have become a more recent priority and often is not yet reflected in the figures on energy R&D spending, except for the UK where it accounts for 10% of total public energy R&D.

Although the level of government funding has been increasing over the last few years, funding at Member State level seems still not sufficient to engage in large demonstration projects. These projects should be taken care of by the European Commission, and this certainly is the trend the European Commission portfolio has been following in FP6, with involvement in such programmes. There is also CCS-related research in Norway aiming at utilising natural gas for power generation with CO_2 capture (Norwegian Climate Technology R&D Programme).

The clean use of fossil technologies combined with CO_2 capture and sequestration is also a top priority in the US R&D agenda. The US federal budget for R&D on carbon sequestration in the USA has been increasing steadily. The funding for the US DoE's sequestration programme sequestration in the US was around € 50 Mio in 2006, increasingly rapidly in a short time: it was less than € 8 Mio up to 2000, but increased to about € 33.6 Mio per year in 2003 and 2004.

Energy efficiency R&D is ranked also very high. It appears as a priority in about 70% of the analysed replies, often explicitly addressed to the building/residential sector (this is the case for Austria, Denmark, France, Germany, Netherlands, Sweden, and Spain). Together with fossil fuels, it is the second largest area of public non-nuclear energy spending according to IEA data.

It is important to remark that the systemic studies related to energy markets, looking to its structure and optimal regulatory mechanisms are also perceived as an important R&D field. This topic, for instance is the first priority in the Swedish case.

High-priority R&D fields directly related to the transportation sector are not often reported. Among transport and fuel research, biofuels (bio-ethanol, bio-diesel, Fischer-Tropsch-related technologies) appear most often as a priority, such as for Finland and Denmark. There are only three Member States explicitly mentioning energy efficiency in the transport sector and/or the development of new powertrains as a public R&D priority (Austria, France, Sweden). But as stated before, this may partly be due to the survey's bias towards the energy department, instead of the transport department.

Hydrogen, Fuel Cells (FC) and the application of hydrogen to transportation (either in internal combustion engines (ICEs) or with FC power trains) are mentioned as a priority area by more than half of the Member States. However, this field is never identified as a top priority, lying rather in the lower half of the priority list. This is clearly reflected by Member States' public spending: except for Denmark that invests more than a quarter of total energy R&D in hydrogen, the relative share of government funding in this area remains below 6% for other Member States. Fuel cell markets worldwide are in an early stage in both stationary (small- or large-scale) and transport application. No fuel cell system is cost-competitive yet (except in some very specific market niches). Most different types of fuel cells still suffer some technical problems as well. In general there are good basic research facilities in the fields of chemistry, material sciences and energy systems. However, the knowledge transfer between industry and universities should improve. The European research structure is not well adapted to changing R&D needs. There is a need for more coordination between European, national and regional programmes [European Commission, 2005g]. Compared to Europe, Japan and the US are more advanced in energy codes and standardization. Europe should design better instruments to bring innovative ideas onto the market. European fuel cell manufacturers are weak in the automotive market.

The entrance of fuel cells into the vehicle markets is a typical example of a two-sided market. The fuel cell manufacturers should not only convince the potential vehicle-owners, but also provide a widespread refuelling infrastructure with a guaranteed mass supply of hydrogen. In this respect, European Fuel Cell manufacturers' position is still weak in the automotive market.

In the EU the basic research capacity is generally good, but hydrogen still needs improvements of production technologies and fuel cells, reducing of production costs, building a hydrogen infrastructure, etc. Recently European countries focused on bottleneck technologies and non-technological barriers, and European energy companies built experience in large-scale hydrogen generation, distribution and handling including safety. Some, EU automotive companies are definitely betting for the industrial deployment of FC power trains (notably Daimler Chrysler), but important progress is still required, not only in the FC technology tself, but also in the ancillary developments, like the compressed hydrogen storage. There is a need for EU regulations, codes, standards and harmonized pull and push instruments.

Table 10: Trends in public spending on R&D for different energy technologies between 1995 and 2005 [in absolute spending and in the relative share in overall energy spending]

	Non-nuclear energy										Nuclear
Absolute spending	Energy efficiency	Hydrogen & fuel cells	Renewable energy sources	Bio-energy	Other tech./ research	Power & storage tech.	Solar	Fossil fuels	Wind	Geo-thermal	
Austria	S		+	+	+	+	-	-	S	+	+
Belgium	--		-	-	--	-	-	-	S	S*	++
Denmark	S		+	+	S	-	-	-	+	S*	+
Finland	--		++	+	--	-	-	--	++	S*	-
France**	++		++	N/A	+	+	++	-	++	+	S
Germany	+		+	++	++	++	+	S	-	++	-
Hungary	S*		+	+	S*	S*	-	+	+	S*	+
Ireland	++		+	+	+	S	S	S	++	-	S*
Italy	--		S	--	--	++	++	++	++	S*	--
Netherlands	--		++	++	-	-	+	S	+	-	-
Portugal	-		S	+	-	-	++	S	S*	S*	-
Spain	-		+	S	-	+	-	--	--	-	-
Sweden	-		S	+	-	+	-	--	--	-	-
United Kingdom	-		++	S	--	S	++	--	++	-	-
United States	++		-	+	++	-	--	S	-	-	-
Japan	-		++	++	++	-	++	S	+	--	S

S: stable **+: increase**
S*: stable and equal to zero **++: strong increase**
-: decrease
--: strong decrease

	Non-nuclear energy										
Relative importance	**Energy efficiency**	**Hydrogen & fuel cells**	**Renewable energy sources**	**Bio-energy**	**Other tech./ research**	**Power & storage tech.**	**Solar**	**Fossil fuels**	**Wind**	**Geo-thermal**	**Nuclear**
Austria	-		-	+	+	++	+	+	S	+	+
Belgium	--		-	-	-	--	-	-	S	S*	++
Denmark	-		-	S	-	-	-	--	S	S*	+
Finland	--		++	+	-	S	-	-	++	S*	-
France**	++		+	N/A	+	+	++	++	++	+	--
Germany	S		-	+	++	S	-	-	-	+	--
Hungary	S*		--	++	S*	S*	--	++	+	S*	++
Ireland	++		--	--	--	+	-	--	++	-	S*
Italy	--		+	-	--	++	++	+	-	S*	-
Netherlands	--		++	++	-	-	+	+	+	-	S
Portugal	--		++	++	-	-	++	++	-	-	-
Spain	-		++	+	--	-	++	+	++	S*	--
Sweden	-		+	+	-	+	-	-	-	S	+
United Kingdom	-		++	S	--	S	++	--	++	S	--
United States	++		-	S	++	-	-	S	S	S	-
Japan	-		+	+	+	-	S	+	S	-	-
S: stable **S*: stable and equal to zero**			**+: increase** **++: strong increase** **-: decrease** **--: strong decrease**								

Note: France recently changed the methodology – the French figures must thus be interpreted carefully. For the same reason, no EU aggregate is provided. For some Member States, years different from 1995 and 2005 had to be used due to lack of data in these years.

Source: based on IEA data

7. RECENT DEVELOPMENTS

In the last couple of years, energy R&D has gained new momentum globally and in the EU, reflecting the increasing awareness of supply security and climate change.

However, as the assessment is based on information up to 2005, most of these on-going activities could not be captured in this study. At the time of writing, no data beyond 2005 were available on energy R&D expenditures or budget appropriations. Similarly, the information used concerning the energy R&D infrastructure in EU Member States relied to a large extent on published reports with similar cut-off dates. Even though it has been tried to be as much up to date as possible, the overall picture presented does not fully capture the most recent developments in EU Member States.

The following shall provide a brief overview of the changing international energy context and its implication on EU energy research. Not withstanding the lack of quantitative data, it will be shown that there have been positive developments in energy R&D in some EU Member States within the last two years. Despite these improvements, the main conclusions of this study still remain valid.

In the last two years a number of important changes in the global and EU energy markets have occurred. Most prominently, the prices of primary energy carriers have escalated, particularly for oil and gas. After more than a decade of cheap oil around 20 US$/barrel, prices have steeply risen in the last couple of years, reaching peaks of around 80 US$/barrel. Such levels reflect the growing demand from fast-growing economies like China and India as well as supply shortages originating from geopolitical tensions and short-term market expectations. The reduction of oil production from OECD countries, as well as political instability in the Gulf region, Nigeria, and Venezuela and extreme weather events (e.g. Katrina) contributed to higher oil prices. Prices for natural gas followed the oil price trends in general, yet with fewer fluctuations [IEA, 2007c]. In late 2005/06 the EU was affected by shortages in the natural gas supply from Russia, which emerged from a dispute between Russia and Ukraine. This has raised major concerns about the gas supply security, also bearing in mind that more than half of the world's proven gas reserves are concentrated in a few countries, namely Iran, Qatar, and Russia.

At the same time, the global awareness for climate change has grown substantially. At their 2005 summit in Gleneagles, the leaders of the G8 acknowledged this challenge, and recognised the need for global reductions of greenhouse gas emissions at the 2007 Heiligendamm summit. In February 2005, the Kyoto Protocol eventually entered into force, forcing its signatories to put in place emission reduction policies. Furthermore, global negociations on further climate change action after the end of the commitment period of the Kyoto Protocol in 2012 are about to start. In this context, the EU proposes to cut greenhouse gases by at least 20% by 2020 compared to 1990; this target would be extended to 30% under an international agreement with broad global participation and if other developed countries commit themselves to comparable emission reductions.

The twin-challenge of ensuring a secure energy supply while reducing energy-related greenhouse gas emissions is met by actions at the EU level. The European GHG emission trading system (ETS) has put a price to carbon, and will possibly be the basis for a broader emission market, including more sectors and countries. As a consequence, the incentives for adopting energy (and carbon) saving technologies are progressively permeating the choice of many companies. Similarly, the EU policies promoting renewable energies are showing effect with a boom of wind energy and the production of biofuels gaining on momentum very recently. In early 2007, the Commission published a comprehensive 'energy package' [European Commission, 2007g], which was in large parts adopted by the European Council [Council, 2007].

Overall, the increasing awareness of long term supply risks and the urgent need for action in order to mitigate climate change as well as the EU commitments to reduce greenhouse gas emissions, increase renewables and reduce energy use underline the need for energy research.

Energy research is therefore now attaining more attention in a number of Member States, reversing the prior stagnation in energy R&D spending. This will be illustrated in the following by a few examples.

Germany is planning to publish a roadmap for its energy policy until 2020 in late 2007. Its preparation included three 'energy summits' between the government and major energy industries in 2006 and 2007, aiming at discussing the overall energy concept until 2020. The energy industry promised investments of 20 bn Euros in new power plants and infrastructure until 2012, and allocates another 40 bn Euros in renewable energies [IEA, 2006d]. The German government announced in return to increase funds for energy research. At the German 'energy summit' in 2007, the German research minister announced an investment of around 2 bn Euros in energy research between 2008 and 2011 (compared to almost 1.7 bn Euro under the current 5th energy research programme 2005-2008).

In a strategy paper published in August 2007, the German government also sketched cornerstones of an integrated energy and climate change policy [BMWI, 2007]. Amongst other, it proposes the construction of at least two or three carbon capture and storage pilot plants. It also stresses the importance of energy R&D in meeting the challenge of climate change and underlines the announced increase in the energy R&D budget. Besides, a proposal for a 'High Tech Strategy for Climate Change Mitigation' is to be proposed by October 2007.

The UK launched the review of its energy policy in late 2005, measuring progress against the 2003 White Paper on Energy. The resulting new Energy White Paper was published in May 2007. It recognises the need for increasing energy R&D expenditure and proposes the launch of the public-private Energy Technologies Institute with a minimum budget of around £600 million over ten years. Furthermore, the Environmental Transformation Fund will open in 2008, bringing together government's support for energy technologies with support for energy and environment-related international development [UK DTI, 2007].

In France, the law of the 13 July 2005 sets out the strategic orientation of energy policy in the context of the long-term emission reduction objectives and supply security. It recognises the need for innovative energy technologies and consequently asks for a national energy research strategy. The recently published report on the national energy research strategy identified a number of priority low-carbon technologies, including future nuclear reactors, an optimized use of biomass, solar and geothermal energy, carbon capture and storage and pointed out the importance of increasing energy efficiency [Gouvernement, 2007]. It also underlines that international collaboration will be an essential element in the national energy R&D strategy.

In its review of the national energy R&D strategy, the Irish Department of Communications, Marine and Natural Resources focused not only on projects, but also on the institutional capacity for energy R&D in Ireland [IEA, 2007d]. The following energy research review eventually led to the creation of the new Irish Energy Research Council with the aim of coordinating energy research efforts in Ireland. At the same time, Ireland substantially increased public funding for energy R&D.

Recent discussions in the above and other EU Member States as well as other international players also indicate that some technologies may have gained additional momentum in recent years, which may not yet be reflected by funding data for energy R&D until 2005. It is evident that energy efficiency and renewable energies continue to be considered as options of high importance.

Furthermore, a number of EU Member States intend to install additional coal power generation facilities. Research in carbon capture and storage technologies is becoming more pronounced in recent years, with the aim to support the further domestic use of coal in carbon-constrained economies and to realize important export opportunities.

The interest in nuclear energy seems to be renewed in recent years[23], pushed by concerns about supply security and climate change. Finland and France are in the process of building additional capacities. In the USA, the Global Nuclear Energy Partnership was announced in 2006 with the aim of developing and installing a new generation of nuclear power plants.

Moreover, many of the recent initiatives explicitly address the importance of energy system research and an improved combination between market push and pull instruments. Eventually, enhanced international cooperation in energy R&D is necessary to finance the important investments needed and handle the climate change challenge ahead. This paves the way for the enhanced synchronisation of energy R&D among EU Member States the Strategic Energy Technology Plan aims at.

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23 Currently, fifteen of the EU-27 Member States produce nuclear-based electricity, while many of the remaining Member States adopted phase-out policies.

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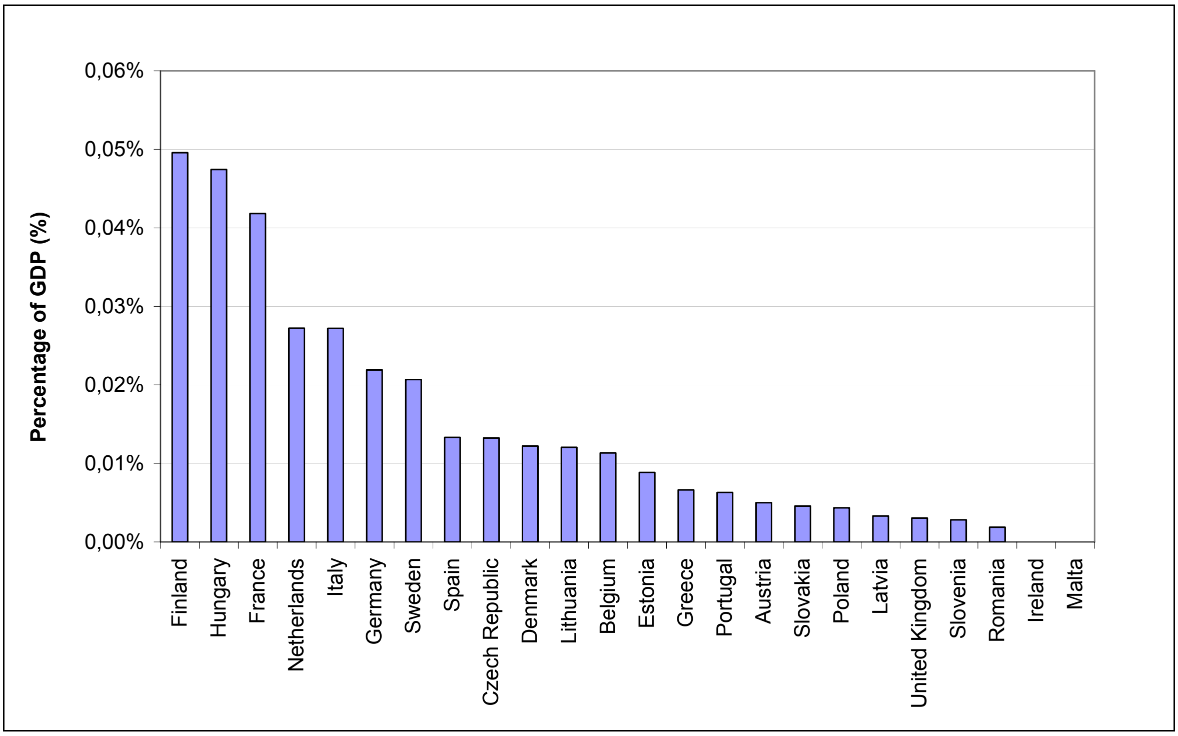
Annexes

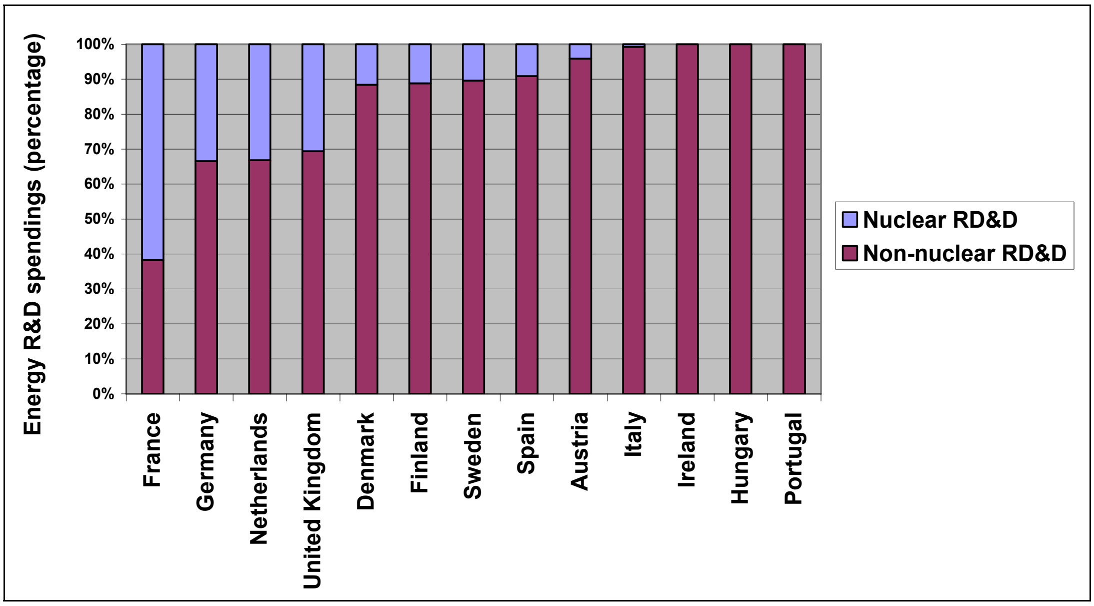
Figure 21: Government budget appropriations for production, distribution and rational utilisation of energy relative to GDP, 2005



Note: Funding from the EU through the research framework programmes and the Intelligent Energy Europe Programme are not included in the EU-figure; data for Poland relate to 2004; no data for Bulgaria, Cyprus and Luxembourg

Source: Eurostat GBAORD

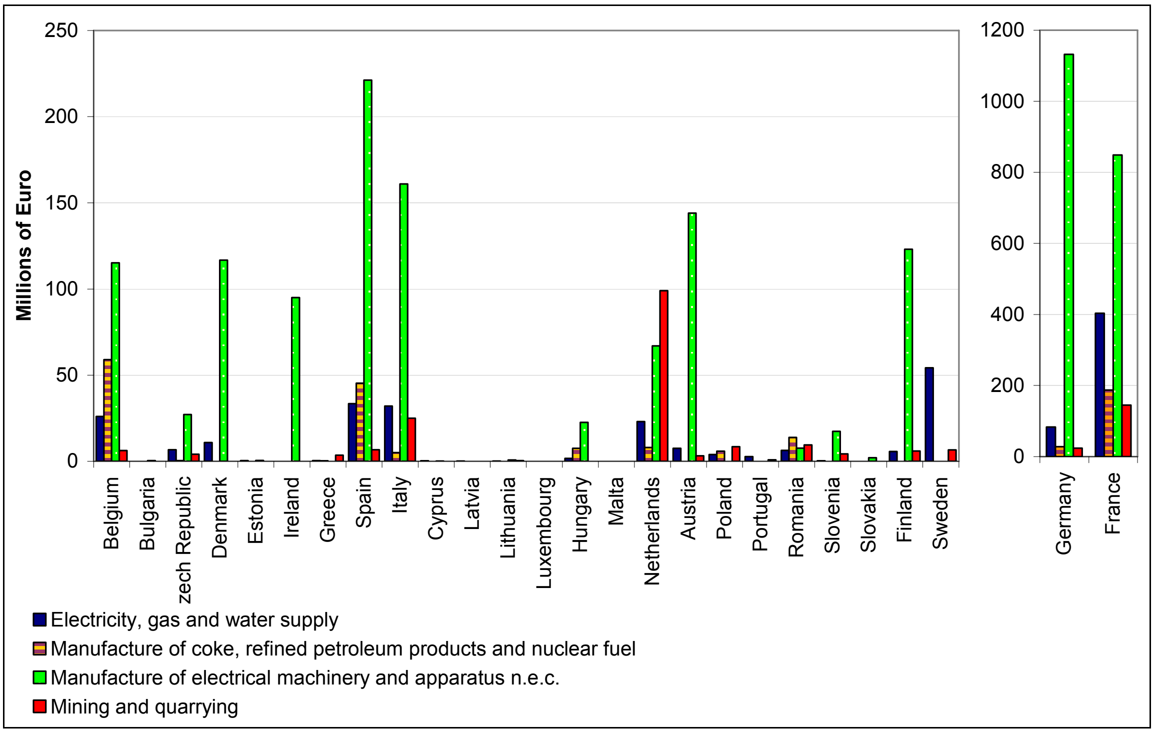
Figure 22: Distribution of nuclear- and non-nuclear priorities in public spending on energy R&D in 2005



Note: For most countries, 2005 figures were used. However, there are a number of countries for which another year had to be used due to data shortcomings in more recent years: for Austria, 2004 figures are applied. In the case of Finland and the Netherlands, figures for 2003 were used. Belgium, Czech Republic, Luxembourg and Greece are excluded due to data gaps for more recent years.

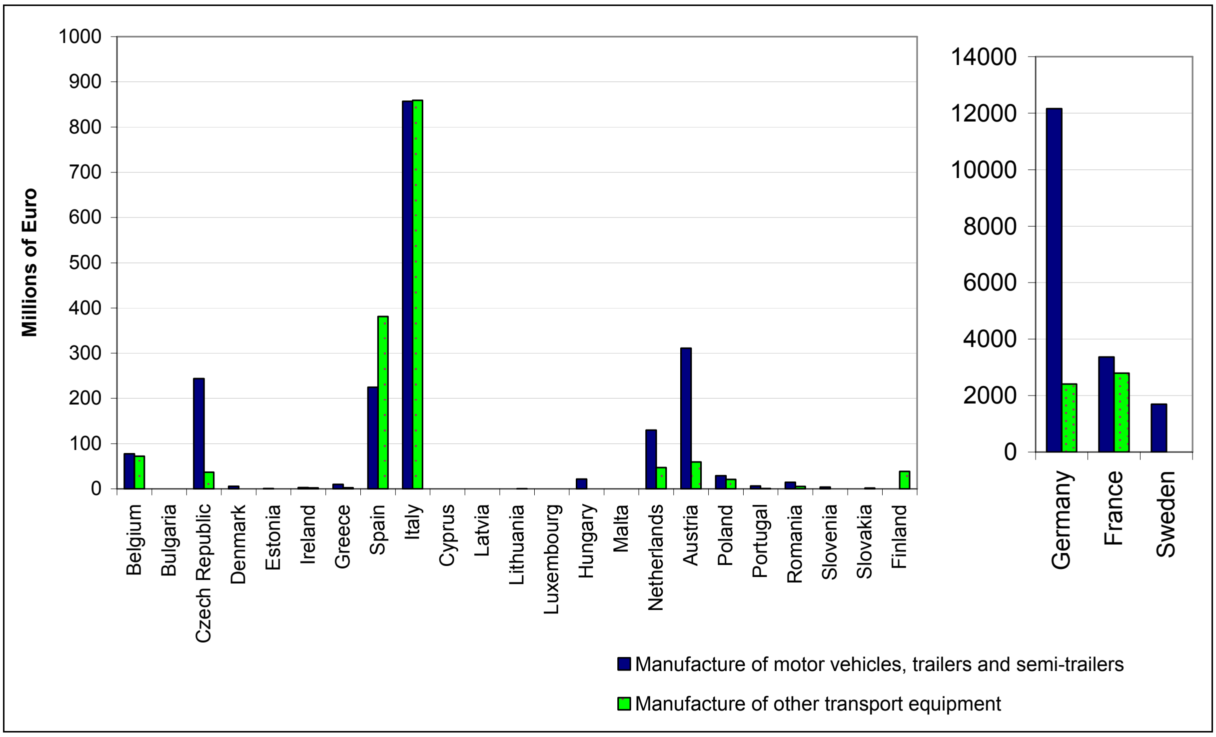
Source: IEA database; France: Ministry of Industry

Figure 23: Business R&D expenditure in energy-related sectors



Source: Eurostat, BERD database

Figure 24: Business R&D expenditure in transport-related sectors



Source: Eurostat, BERD database