Project no. 022825

Project acronym: ERMInE

Project title: **Electricity Research Road Map in Europe**

Instrument:	Coordination Action
Thematic Priority:	SSP 3.2: The development of tools, indicators and operational parameters for assessing sustainable transport and energy systems performance (economic, environmental and social)

ERMInE PUBLISHABLE FINAL ACTIVITY REPORT

Date of preparation	February 29th, 2008		
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Project coordinator name	Michele de Nigris		
Project coordinator organisation name	CESI RICERCA		

Revision 0

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1. INTRODUCTION

The electricity sector in Europe is experiencing a strong evolution, characterised by many factors, such as the electricity market liberalisation, the strong dependence of EU energy consumption on import of combustibles, the growing focus on environment, the wide diffusion of information and communication systems and the progressive creation of the digital society and the enlargement of Europe.
In this context, Research and Technology Development (RTD) programmes are facing a general trend of fund reduction and the electricity operators are focusing their research efforts on short term objectives aimed at increasing their competitiveness, rather then on long term objectives able to significantly innovate the electricity sector. This calls for appropriate strategies and policies in the planning, selection and prioritization of the research needs and funding.
Several projects and initiatives are active at National, European and International level aimed at setting up Road Maps for the development of the energy systems in different parts of the world and some of them are specifically devoted to point out the RTD needs in the near or mid-term future.
The ERMInE project intends to contribute to the definition of the European RTD strategies, by providing a view of the recent and present scenario of the electricity RTD efforts and specific needs of the European electricity sector in the next 20-25 years.

2. PROJECT OBJECTIVE

The objective of the ERMInE project is twofold:
- to trace the recent and present RTD expenditures and strategies in the EU electricity sector;
- to outline the specific RTD needs and priorities in the forthcoming 20-25 years.

Accordingly, the project outcomes consist of two major products, for which two specific publicly available reports have been issued.
1. The ***Map*** of the time evolution, since 1985, of the RTD efforts invested in the EU electricity sector by the most relevant actors, (*i.e.* the European Commission, the National Governments, the Electricity Supply Industries and the Manufacturers) in the different thematic areas.
2. The ***Road Map*** of the possible evolution of the RTD priorities, specifically tailored to the European context for the next 20-25 years. For the general thematic areas (generation, transmission & distribution, end use) the priorities are specified in terms of relative contribution of each promising technology to the achievement of the general objectives set in the European Commission Green Paper *i.e.* sustainability, competitiveness, security of supply.

3. PROJECT BOUNDARIES

The boundaries of the project are:
- generation;
- transmission and distribution;
- end-use: industry, residential/tertiary.

The boundaries include also the RTD&D activities related to the actions to be undertaken to limit the environmental burden and the activities linked with the setting up of the electricity markets and the connected regulations. The project includes also demonstration (RTD&D).

4. THE CONSORTIUM

Table 1 The ERMInE CONSORTIUM

PARTNER	***INTERNET SITE***	***CONTACT***
CESI RICERCA - Italy	www.cesiricerca.it	michele.denigris@cesiricerca.it
ENEL PRODUZIONE S.P.A. - Italy	www.enel.it	barbucci.pietro@enel.it
EURELECTRIC - Belgium	www.eurelectric.org	mpaun@eurelectric.org
KEMA - The Netherlands	www.kema.com	cees.gast@kema.com
EBL Kompetanse AS - Norway	www.ebl.no	aft@ebl-kompetanse.no
IPE - Poland	www.ien.gda.pl	k.madajewski@ien.gda.pl

5. PROJECT TOOLS

➔ ***Questionnaires***
They were a data collection tool addressed to national public institutions, public regulators, power producers, T&D network operators, manufacturers, public and private research centres.

➔ ***Discussion documents***
They were the basis to organise Area Workshops and to prepare Area Reports.

➔ ***Vision paper***
In this paper, to be used as discussion document for the workshops, the partners expressed their views on the electrical system developments in the next 20-25 years.

➔ ***Workshops and meetings***

- *Four Area Workshops*
  - West area (BE, DE, IE, LU, NL, UK): Brussels 11 - 12 Oct. 2006
  - North area (DK, FI, NO, SE): Oslo 1 November 2006
  - East area (BG, CZ, HU, EE, LT, LV, PL, RO, SK): Warsaw 31 Nov. - 1 Dec. 2006
  - South area (AT, CH, CY, ES, FR, GR, IT, MT, PT, SI, Balkans): Rome 1 - 2 Feb. 2007

  The objective was to provide discussions on the current state of electricity RTD efforts in four areas of Europe, plus indications for the specific RTD needs in the next 20 - 25 years.
- *Iberian meeting, Madrid, 24 May 2007*
  It was specifically dedicated to the validation of the collected data for Spain and Portugal.
- *First Focused meeting, Milan, 2 October 2007*
  The main objective was the discussion and validation of the ERMInE Road Map draft.
- *Second Focused Meeting, Brussels, 21 November 2007*
  A focused meeting was held with the members of the Eurelectric R&D Working Group.
- *Final Conference, Brussels, 20 February 2008*
  The main results of the project, (the Map and the Road Map) have been presented.

➔ ***Digital databank***
It has been developed to collect, organise and to allow elaborations of two main data sets:

- the parameters related to each EU country and its electrical system ("background data");
- the RTD expenditures, by funder category and by thematic area for each country.

➔ ***Project web site***
A web site (http://www.ermine.cesiricerca.it) has been implemented.

6. THE MAP OF THE RTD EFFORTS IN THE EU ELECTRICITY SECTOR

The Map of the RTD efforts is intended to provide an understanding of the recent and present research efforts and expenditures of the main actors in the European electricity sector.
In particular, the Map aims at presenting the historical evolution (since 1985) of:

- the structure of the electrical system in the EU countries ("background data");
- the RTD expenditures in each country, categorised by funder category and by thematic area.

6.1 The methodology

6.1.1 Boundaries and definitions

- In the STRUCTURE OF THE EU ELECTRICAL SYSTEM ("background data"), several important parameters of the electrical system (*e.g.* generation capacity, annual production...) are defined.
- The RTD expenditures are considered for three main RESEARCH AREAS: generation, transmission and distribution, end use. In addition, transverse items are to some extent taken into account: environmental concern, electricity market and regulatory issues.
- The RTD FUNDERS are classified in main categories: EU Commission, National Governments, Electricity Supply Industries (both public and private) and Manufacturers.
- The TIME EVOLUTION is examined considering the years 1985, 1990, 1995, 2000 and 2004.

6.1.2 Data collection: Electricity structure fact sheets

For the Electricity structure fact sheets ("background data"), 240 (inter-) national data sources were explored for 34 countries (EU-27, and ascending States, Norway, Switzerland), covering the period 1985 - 2020. These fact sheets are related to country specific data, electrical system structure, T&D systems, legislative constraints, environmental issues and national stakeholders.

6.1.3 Data collection: RTD expenses

The collection of the RTD funding data, was continually redefined during the project evolution, according to the real feasibility of the collection of all the foreseen data.

THE COLLECTION PROGRESSED ACCORDING TO THE FOLLOWING STEPS:
- analysis of literature data and publicly available databases;
- direct data collection by means of a detailed questionnaire;
- direct data collection by means of a simplified questionnaire;
- organization of four Area Workshops and of an Iberian meeting;
- elaboration of a "minimal data set", integrating the previous data with interviews, estimates, etc.

Several PUBLIC DATABASES and LITERATURE DATA have been considered.
- International Energy Agency (IEA) database
- EUROSTAT database
- EU Commission: a publication on the EU fundings in energy RTD in the FP2-FP6 programmes[1] and the Project Synopses of the Joule I - III programmes.
- EC Projects
  Several Projects supported by the EU Commission resulted of interest for ERMInE: REDS (A survey of R&D spending for renewable energies in EU Countries), SENSER (Synergies between European and National Strategies for Energy RTD), PSI (Priority Setting Initiative), EurEnDel (European Energy Delphy - Technology and social vision for EU energy future).
- EURELECTRIC Reports on R&D in Eurelectric countries for years 1994, 1995, 1998, 2002:
- World Energy Council report: "Energy Technologies for the 21st Century - Energy Research, Development and Demonstration expenditure 1985-2000: an international comparison".

The DETAILED QUESTIONNAIRE was structured according to the following rationale.
- Both funders and performers of RTD activities could fill it in.
- As for the RTD subjects, the questionnaire was organized in a hierarchical structure:
  Main group: seven main groups were available: generation, transmission, distribution, end-use, environment, standards for the electricity sector and electricity market.
  Group: for each main group, several sub-topics related to the main group were proposed.
  Area: similarly, for each group, several areas were available.
- The data were requested for several years, some compulsory (1985, 1990 1995, 2000, 2004) some other optional. Out of 296 distributed questionnaires, only 73 were sent back.

A SIMPLIFIED QUESTIONNAIRE was distributed to selected recipients that had difficulties in completing the detailed questionnaire. Funding data were requested only for years 1990, 2004, 2010 and for a limited number of RTD topics.

The four AREA WORKSHOPS and an IBERIAN MEETING have been held.

Since in the data collected by means of the questionnaires several data for relevant funders in many countries were lacking or incomplete, it was decided to derive a MINIMAL DATA SET, aimed at providing as complete as possible data, at least for some years and RTD topics.
This minimal data set was implemented according to the following steps:
- extraction of data from the previously collected data set, for specific years and topics;
- integration from other sources such as public data and workshop outcomes;
- estimate / guess (if possible) of missing data;
- estimate of the degree of data reliability and availability, for the most relevant main groups (generation, transmission & distribution, end use).

[1] D. ROSSETTI DI VALDALBERO, B. SCHMITZ, W. RALDOW, M. POIREAU; *European Union energy research*, Revue de l'énergie, n° 576, Paris, March-April 2007.

To have a general view of the quality of the collected data, Figure 1 shows the relative distribution of the reliability and completeness levels of the data records, considering the main groups generation, T&D and end use for the funders Electricity supply industry, Government, Industry.

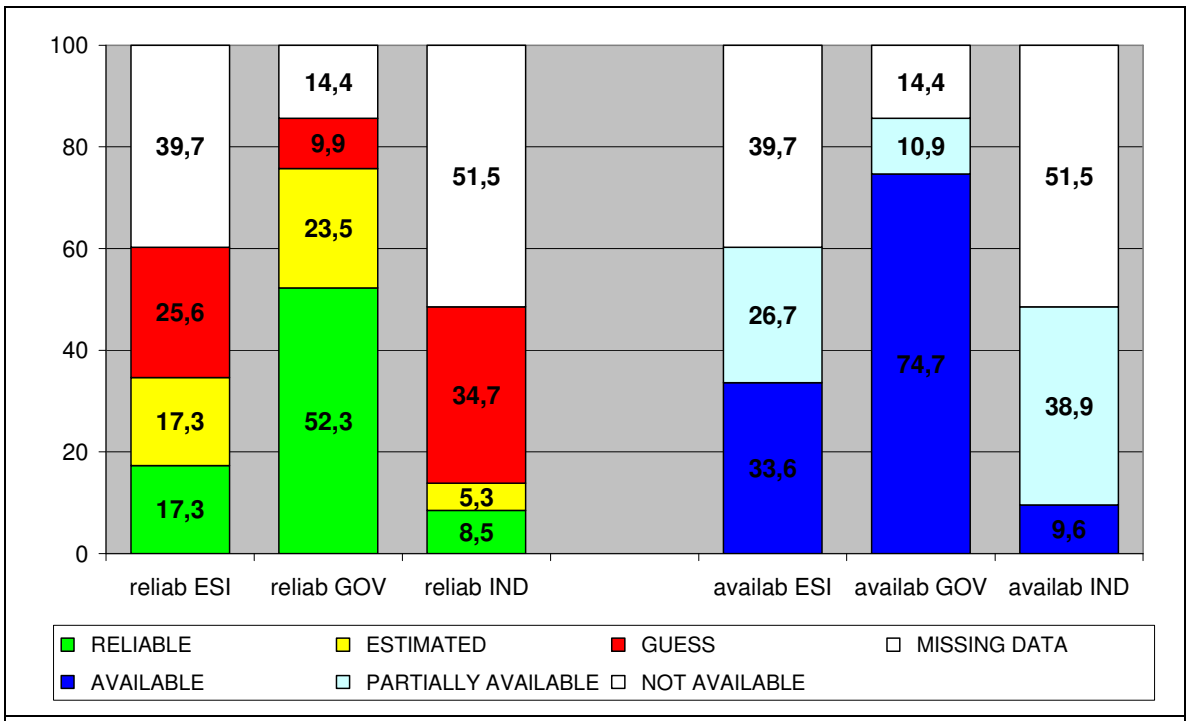

Figure 1 Percentage distribution of the data reliability and completeness levels

6.2 The public digital database

A publicly available database (Figure 2) has been delivered, structured in two main data sets: Member State key data ("background data") and RTD&D Funding Data.

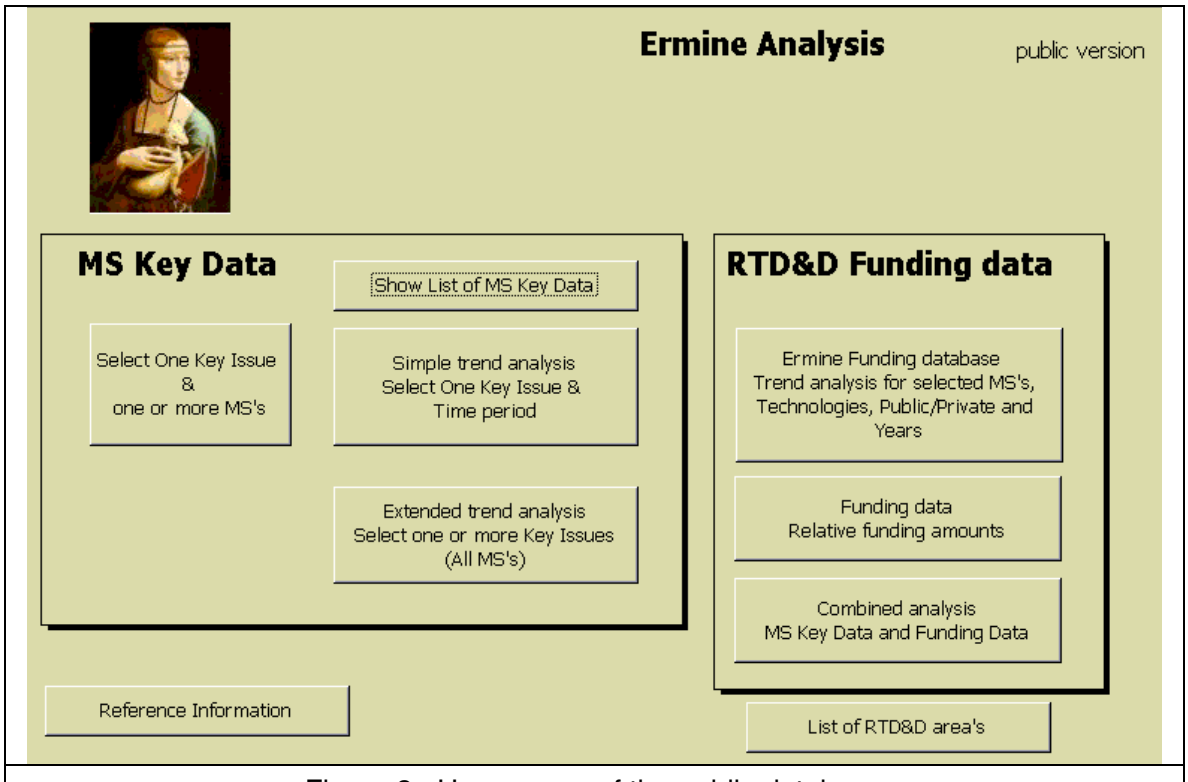

Figure 2 Home page of the public database

For the MEMBER STATE KEY DATA, several options of data elaboration are available:

- *List of Member State key data:* i.e. of all available background data.
- *Select one key issue and one or more Member States*: one specific background parameter can be extracted and analysed for one or more countries.
- *Simple trend analysis - Select one key issue and time period*: the time trend of a specific background parameter for all countries can be extracted and analysed.
- *Extended trend analysis - Select one or more key issue (all Member States)*: a detailed time trend can be extracted for more parameters and countries.
- *Reference information*: the literature sources of the background data.

As for the RTD FUNDING DATA (Minimal Data Set), three main options are available.

- *ERMInE funding data - Trend analysis for selected MS, Technologies, Public/Private and Years*
  It is possible to extract and analyse all data, as available in the Minimal Data Set, as well as data elaborated starting form the IEA database. In the case of the IEA-derived data it must be taken into account that the available data are not exactly the same as reported in the IEA database, since the structure of the IEA data organization, is different from the Minimal Data Set. IEA data present some more details and, on the other hand, some topics are missing.
- *Funding data - Relative funding amounts*
  It is possible to analyse data, normalised to a specific background parameter.
- *Combined analysis - MS key data and funding data*
  It is possible to analyse RTD funding data in combination with a background parameter.

6.3 The evolution of the RTD fundings in the EU electricity sector

6.3.1 An overall view

An overview of the electricity RTD expenditures by ESI, Government, Manufacturers and EU in the period 1985-2004 (in MEUR – 2004) is shown in Figure 3.

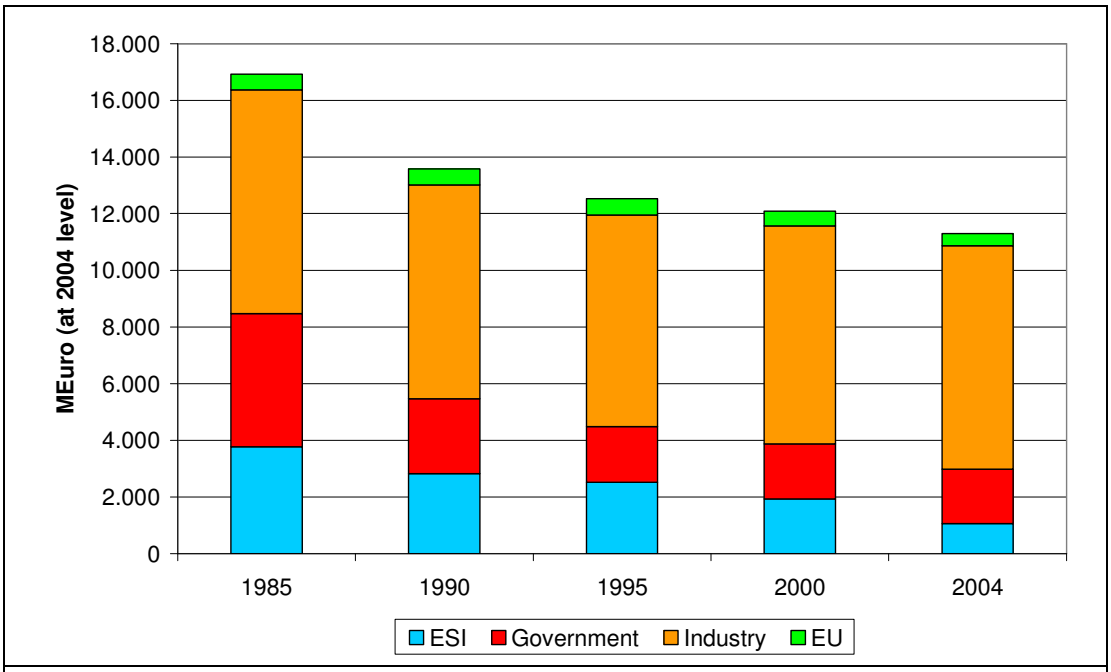

Figure 3 Time trend of the RTD expenses all over Europe, by funder category
EU data are estimated on the FP funds around the considered year

A shown in the Figure 4, comparing 1985 and 2004, an evolution of the RTD expenditures by the different actors is evident.

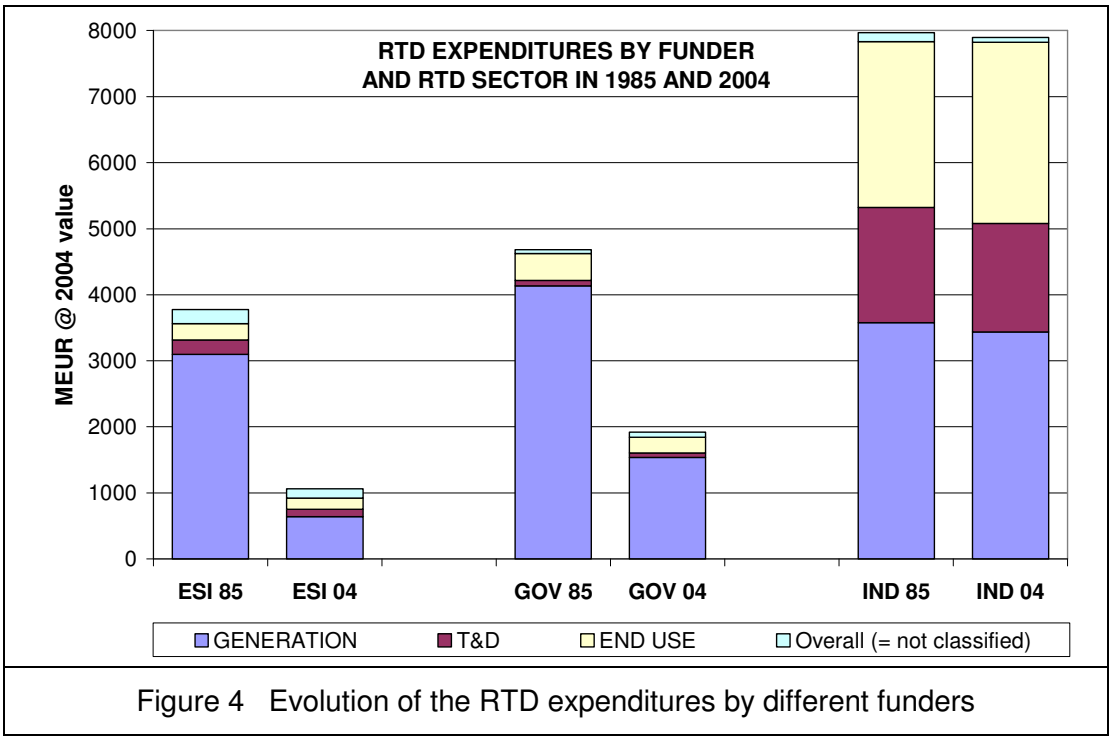

Figure 4 Evolution of the RTD expenditures by different funders

In 2004 the total research spending of the **Electricity Supply Industry** (ESI) amounted to more than 1,1 billion EUR. In 1985 the ESI research spending was 3,5 times higher with 3,8 billion EUR. The total research spending by ESI in 2004 was as follows:

- Power generation 0,64 billion EUR (1985: 3,10 billion EUR)
- Transmission & Distribution 0,11 billion EUR (1985: 0,22 billion EUR)
- End Use 0,17 billion EUR (1985: 0,24 billion EUR).

Power generation RTD investments decreased in absolute terms from 3,1 billion EUR to 0,6 billion EUR in the period 1985-2004, while the sharpest reduction rate occurred in the period 2000-2004. The focus was and is on power generation research, whereas in 2004 T&D and End use research took up greater parts of the total research spending compared with 1985.

Government (GOV) research spending decreased by 60% from almost 4,7 billion EUR in 1985 to 1,9 billion EUR in 2004, while the sharpest reduction rate occurred in the period 1985-1990 and stable RTD investments are seen in the 1995-2004 decade.
The total research spending by Government in 2004 was as follows:

- Power generation 1,53 billion EUR (1985: 4,14 billion EUR)
- Transmission & Distribution 0,07 billion EUR (1985: 0,08 billion EUR)
- End Use 0,41 billion EUR (1985: 0,24 billion EUR).

Over the entire period from 1985-2004, the Governments kept a strong focus on power generation RTD with a relative part of 75-90% of the total annual RTD budget. End Use RTD increased from 9% to 12% and T&D related RTD from 1,8% to 3,5% over the same period. The dominant focus of the National Governments within generation RTD was at nuclear RTD, although decreasing over the period 1984-2004, while RES related RTD increased slowly in that period.

European **Manufacturers** (IND) in electricity related products and equipment spend a multiple of the ESI budget in research and development. Big spenders with a research budget of >0,5 billion EUR are Siemens (5 billion EUR), ABB, Alstom, AREVA. “End use research” manufacturers, like LeGrand, Schneider and Philips, have important contributions in the research expenditures as well. In 1985 the total research spending of European manufacturers in electricity related products and equipment amounted to over 7,9 billion EUR, whilst in 2004 it equals 7,8 billion EUR; research spending of the manufacturers has been hardly changed in time.

The **EU** funded over the period 1987-2006 in total 13.297 MEUR (2004 currency values) through its Framework Programmes for energy related RTD. With main focus on nuclear (fusion and fission). In 1985 62% of the energy RTD budget was devoted to nuclear and in 2004 55%. The fission part decreased in this period from 30 to 20%.
Within the non-nuclear budget, the EU-funding for RES RTD is dominant, while FC/H_2/Storage are on the second place. Carbon Sequestration shows the highest growth rate. Nomalised per inhabitant, a decreasing trend in EU-funding can be seen. The EU-population increased in the period concerned from 342 million people to 429 million.

6.3.2 Overall trends

The European **ESI** (Figure 5) decreased between 2000 and 2004 drastically their RTD efforts in Generation, while T&D and End Use RTD investments remain low and constant.

The National **Governments** (Figure 6) decreased between 1985 and 1990 drastically their RTD efforts in Generation, while T&D and End Use RTD investments remain low and constant.

The **Manufacturers** (Figure 7) kept over the entire period from 1985-2004 a focus on power generation RTD with a relative part of 45% of the total annual RTD budget, while End Use RTD occupied 31-35% of the total annual RTD budget and T&D related RTD 20-22%.

The non-nuclear energy **EU** funding (Figure 8) is relatively small and has its focus on Generation (RES and CCS).

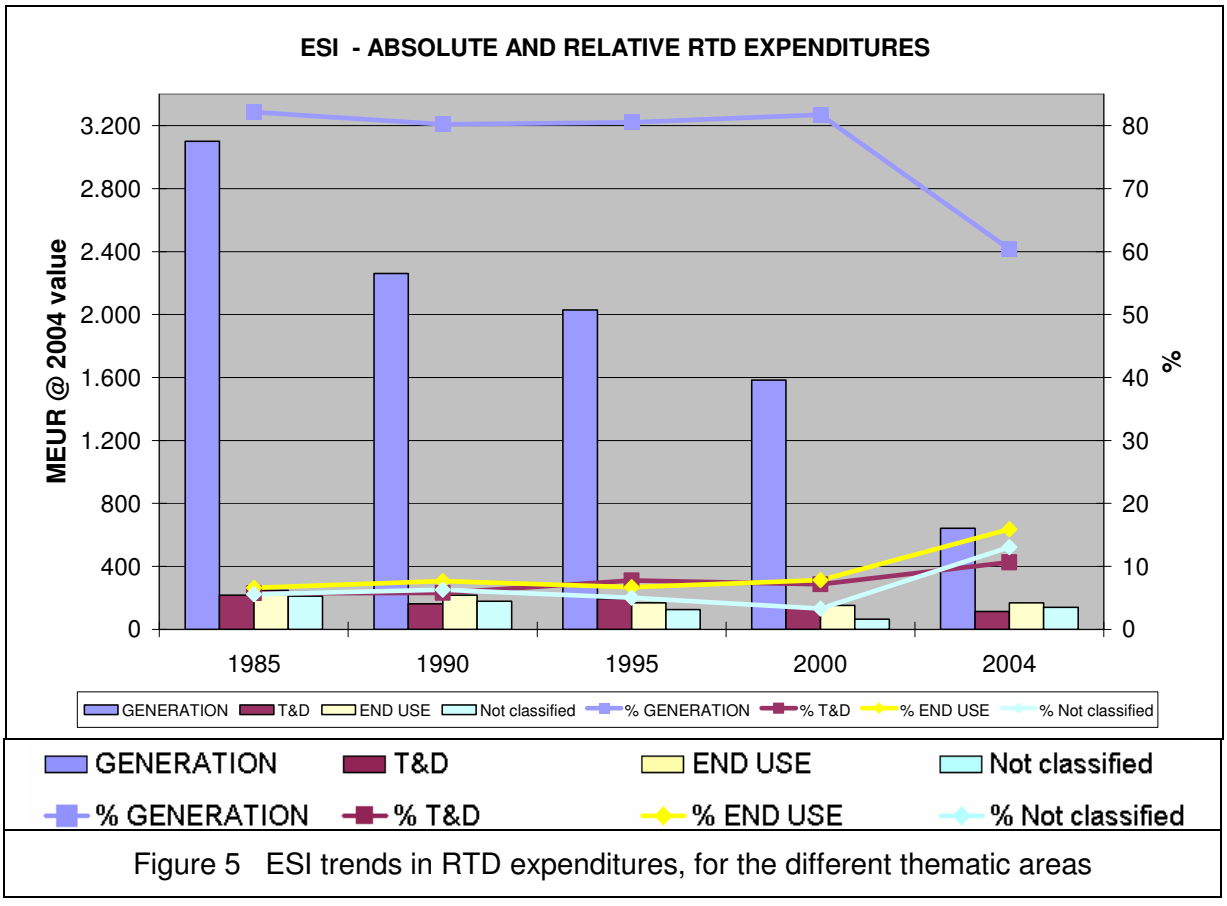

Figure 5 ESI trends in RTD expenditures, for the different thematic areas

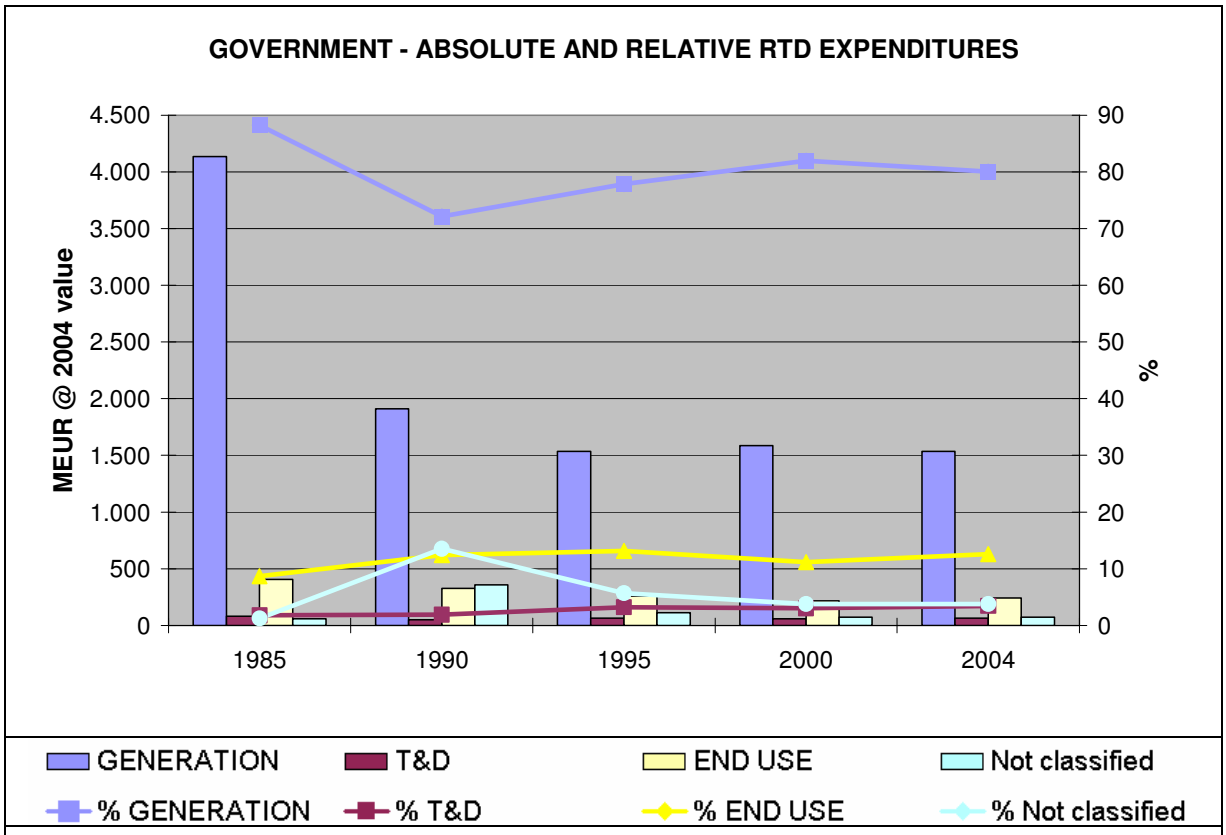

Figure 6 GOVERNMENT trends in RTD expenditures, for the different thematic areas

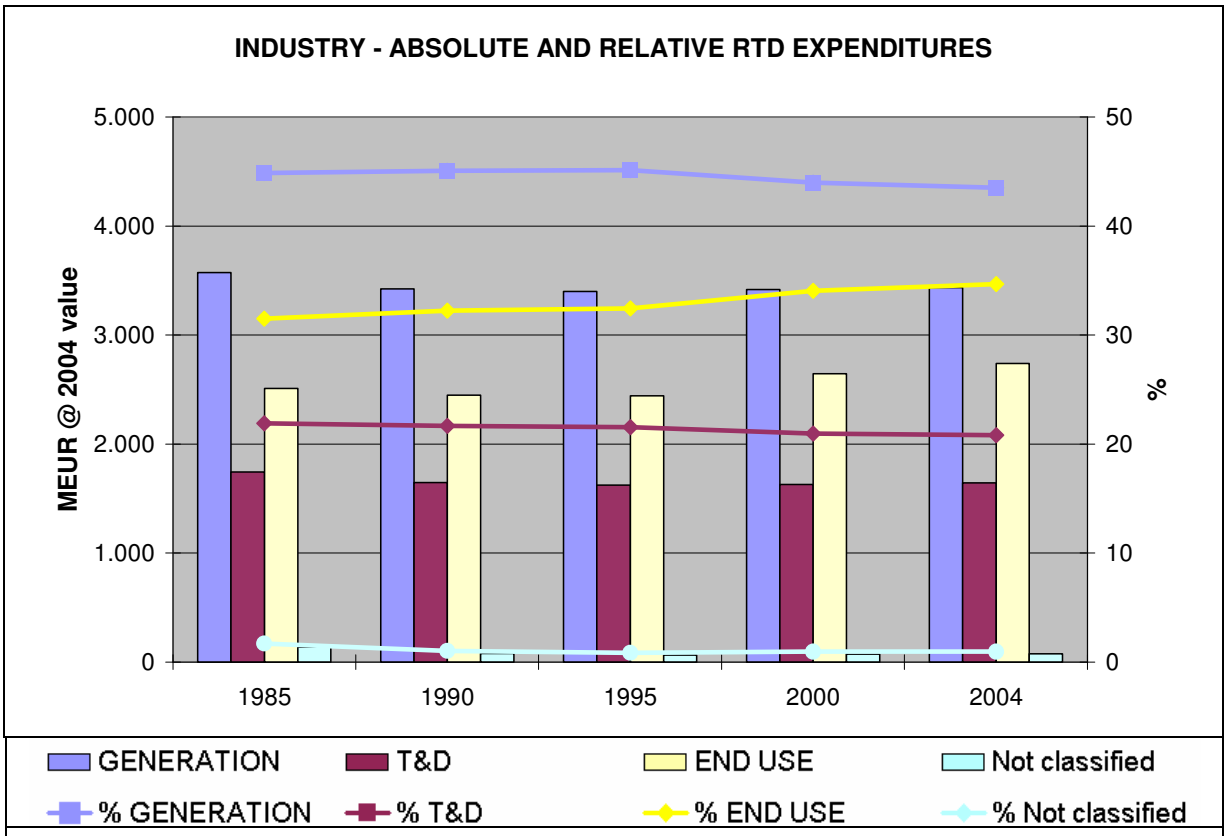

Figure 7 INDUSTRY trends in RTD expenditures, for the different thematic areas

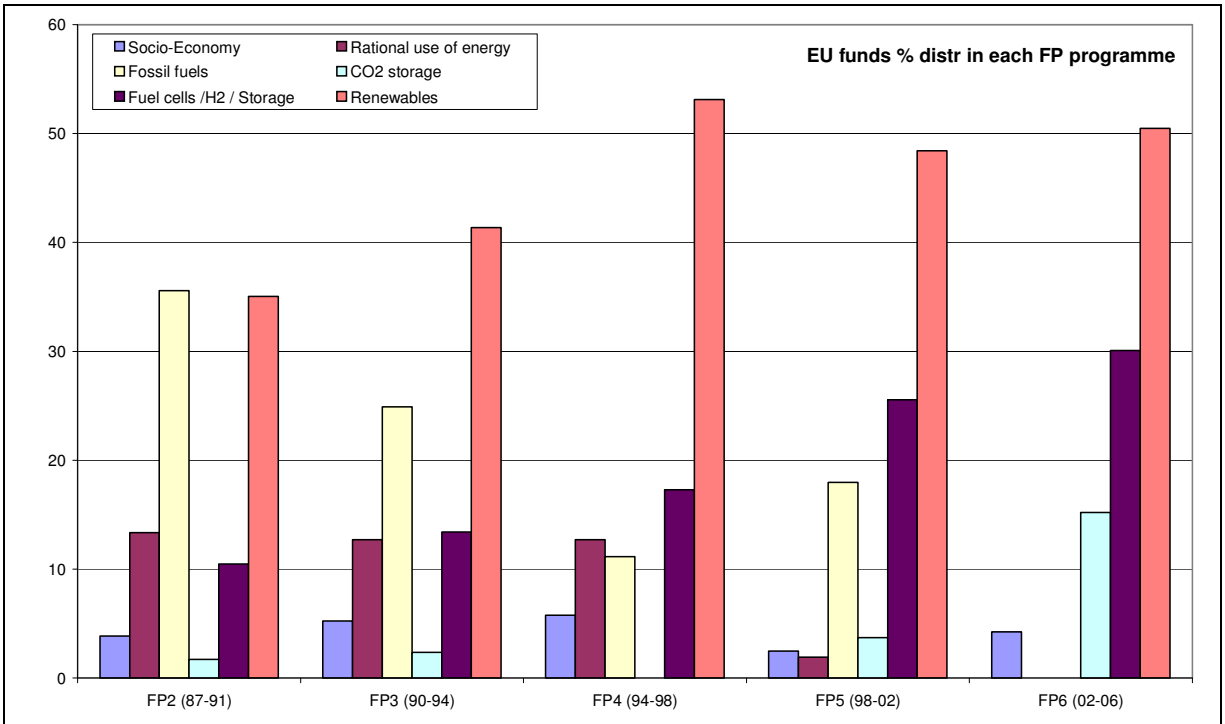

Figure 8 EU relative distribution of funds in FP programmes for different thematic areas

6.3.3 RTD Expenditures in EU Countries

Relating the Governments **RTD** spending to the **Gross Domestic Product** (GDP) of each country (as % RTD/GDP – Figure 9) it can be seen that in most countries the Governments decreased their electricity RTD investment drastically (40-70%) between 1985 and 1990 as % of their GDP.

Relating the **RTD** investments to the **kWh consumed**, it is found that in Germany, Italy, Portugal, Netherlands and UK, ESI (Figure 10) decreased their RTD investments per kWh by more than a factor five over 1985-2004 and in 8 other countries substantially. Governments (Figure 11) in Italy, Portugal and the UK decreased their RTD investments per kWh by more than a factor five over 1985-2004 and in 12 other countries substantially.

In the **Generation** area, nuclear and fossil fuel related research expenditure has been strongly decreased over the last 15 years and this trend is expected to continue, whilst for RES related research the relative small expenditure is expected to increase.

The **Transmission & Distribution** related research spending by ESI and Government - expressed as EUR/km line – has been decreased over the last 15 years, but several Member States expect funding increase in the years to come.
The Customer Minutes Lost (CML) varies widely in Europe ranging from 30 minutes to more than 7 hours per year per customer. In countries with long transmission lines a large portion of the CML are caused by the vulnerability of these long lines. Looking at CML in countries with long transmission lines (>10.000 km), a relation with T&D research spending can be seen.

Research funding for **End Use** application by ESI and Government has been decreased over the period 1985-2004: by ESI from 248 to 169 MEUR and by Government from 407 to 242 MEUR. On the other hand the research spending for End Use applications by the Manufacturers has stayed at a high level estimated at about 2.500 MEUR/a. Probably most ESI's consider - in the open electricity market - development of end use applications less and less as their core business.

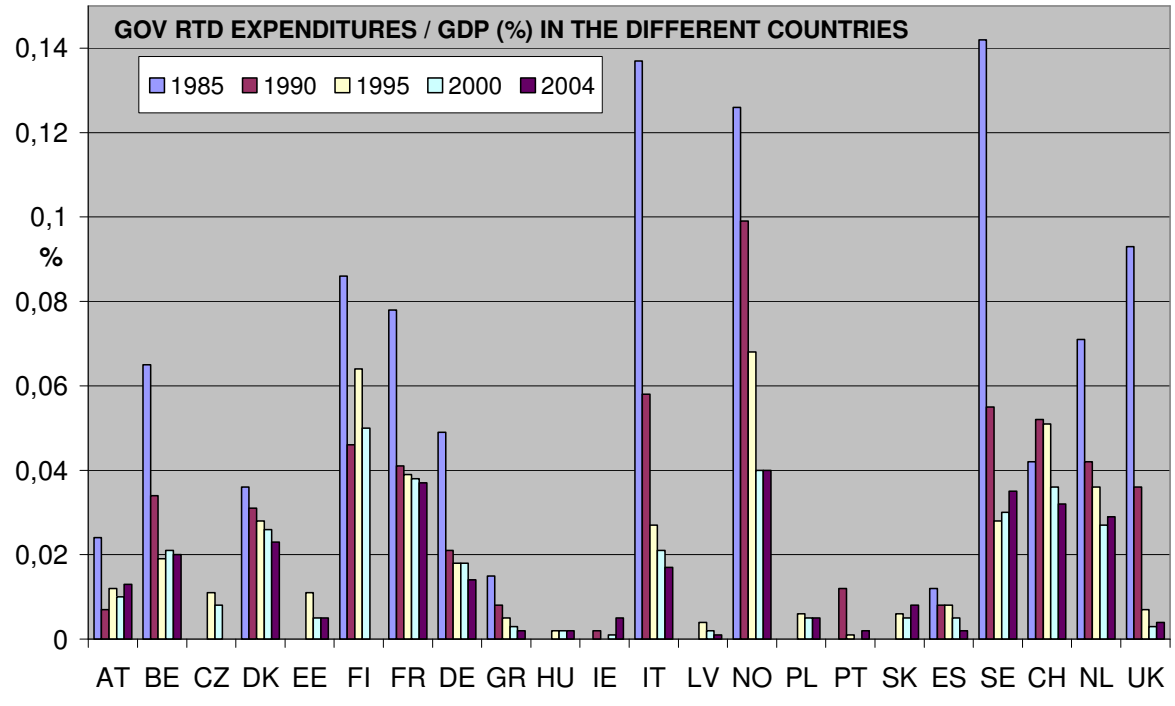

Figure 9 Government RTD expenditures normalised to GDP

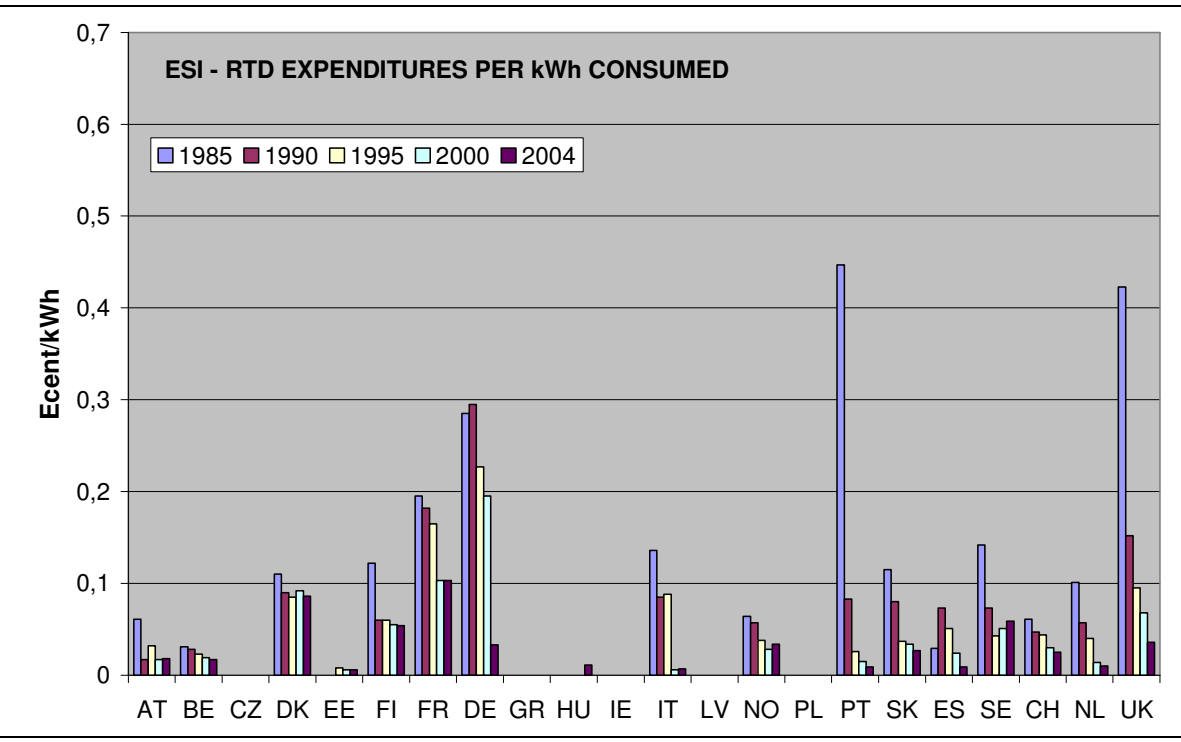

Figure 10 ESI RTD expenditures normalised to the consumed kWh

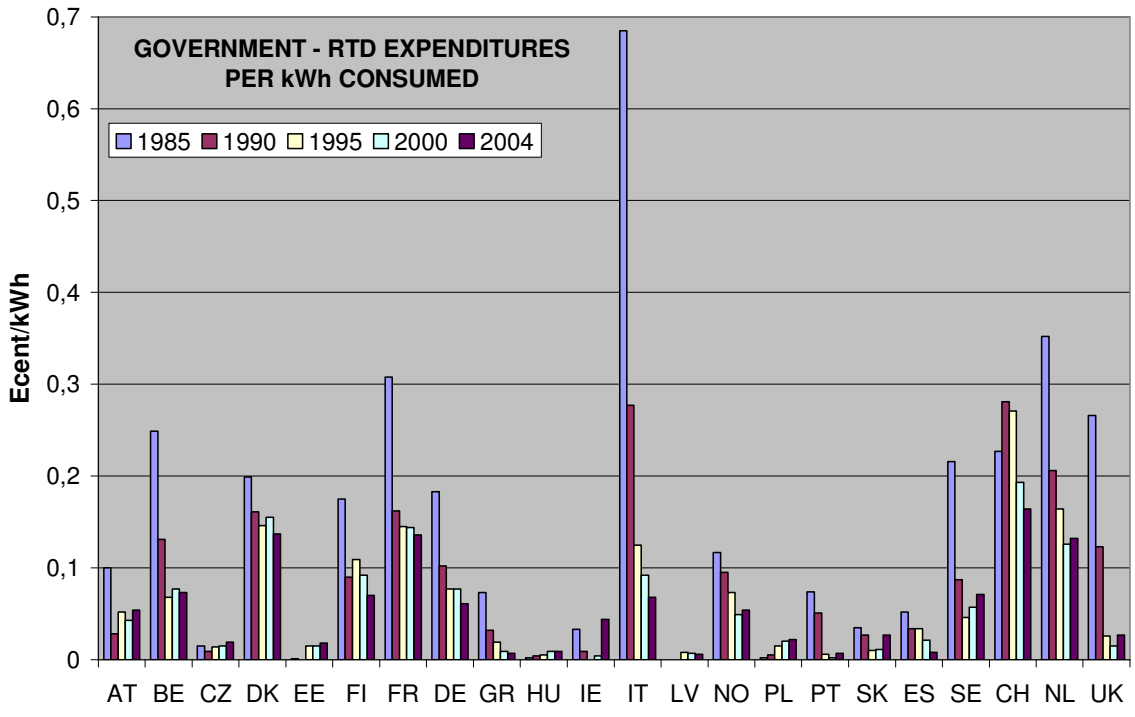

Figure 11 Government RTD expenditures normalised to the consumed kWh

7. THE ROAD MAP OF THE ELECTRICITY RESEARCH IN EUROPE

The Road Map deals with the research needs of the enlarged Europe (EU 25) for the electricity sector for the next 25 years.
It is a technological Road Map, *i.e.* the focus is on technologies (rather than on energy scenarios) in the thematic areas of generation, transmission & distribution and end use. Nevertheless, it has been developed assuming as reference outlook the strategic objectives identified by the European Commission in the Green Paper, *i.e.* sustainability, competitiveness and security of supply.

7.1 The methodology

The methodological approach was based on several steps and tools herein summarized.

Elaboration of a vision paper
This paper, where the ERMInE partners proposed their views, was a discussion document for the workshops and, revised according to the meeting outcomes, was the backbone of the Road Map.

Workshops and meetings
As already reported, several meetings were held: the *four Area workshops*, the *First focused meeting* and the *Second focused meeting*.

Analysis of other initiatives
Several initiatives are active (or were recently terminated) at National, European and International level, and are aimed at analyzing future development in the most relevant electricity technologies. Some initiatives are specifically devoted to set up the RTD needs in the near or mid-term future.
The consortium took in great consideration the efforts carried out and in progress and analysed and elaborated its documents on the base of the available material.

- *European Technological Platforms*: ZEFFPP, SmartGrids, EuMat, ICT, PV, Wind, NRM.
- *European Coordination Action* RELIANCE.

- *European Projects*: GRID, More Microgrids, EUSUSTEL, EurEnDel, REDS, “The State and Prospects of European Energy research”, “Comparative Study of Mechanisms, Results and Good Practices in Terms of Innovation and Transfer of results of Eneregy RTD in National and Community’s programmes".
- *National initiatives*: EPRI Electricity Technology Road Map (2003), DoE Road Map (Grid 203 by Energetics), Dutch technological Road Map (2001), French technology update: “Nouvelles Technologies de l’énergie”.

Definition of a multi criteria methodology

The ERMInE consortium has applied a particular methodology based on a multi-criteria approach, to be used to collect, manage and elaborate input data from stakeholders about the effectiveness of R&D actions in matching the Green Paper vision.
The methodology consists of the following main steps:

➔ DEFINITION OF CRITERIA, TARGETS AND TECHNOLOGIES
The starting point is the definition of the *Criteria* as stated in the Green Paper of the European Commission (competitiveness, sustainability, security of supply).
These Criteria can be specified into major political and technical objectives, which in turn are translated into *Targets* for each of the main fields of the Road Map (generation, transmission & distribution and end use).
The second step is the definition of the *Enabling Technologies*, *i.e.* the most promising technologies that could reach the Targets in the next 25 years, provided R&D actions are properly funded.
Figure 12 shows the mutual relationships among Criteria, Targets and Technologies.

➔ COMPARISON OF R&D ACTIONS IN DIFFERENT TECHNOLOGICAL FIELDS
A matrix has to be completed for each sector (Generation, Transmission & Distribution, End-use) on the base of the answers given by about 100 experts of different fields to a web-based questionnaire, where the R&D actions in each Enabling Technology are given a score to define their relative effectiveness to attain each of the selected Targets.

➔ DEFINITION OF RELATIVE PRIORITIES (WEIGHTS) OF TARGETS AND CRITERIA AND DATA ELABORATION
All input data obtained using an electronic questionnaire have been elaborated using a multi-criteria decision tool ("Expert Choice" by Cesi Ricerca).
However, in order to obtain a pair wise comparison of different R&D actions in view of their contribution to the targets of the European energy policy, it is necessary to weight both the Criteria and the individual Targets.
In particular:
- the Weight of a Criterion represents its importance (with respect to the remaining Criteria) in the frame of the European energy policy of the next decades;
- the Weight of a Target represents its relative priority (with respect to all other Targets of the same sector) to reach a particular Criterion.

➔ RESULTS OF THE ELABORATION
The following parameters are obtained from the elaboration.
- *INFLUENCING FACTORS*
  They indicate the relative contribution of each Enabling Technology to each Target.
- *GLOBAL RANKING COEFFICIENTS*
  They provide a quantitative estimate of the relative priority of the R&D actions for each Enabling Technology in attaining all the Criteria. Hence, R&D actions having the highest Ranking Coefficients should receive the highest priority.

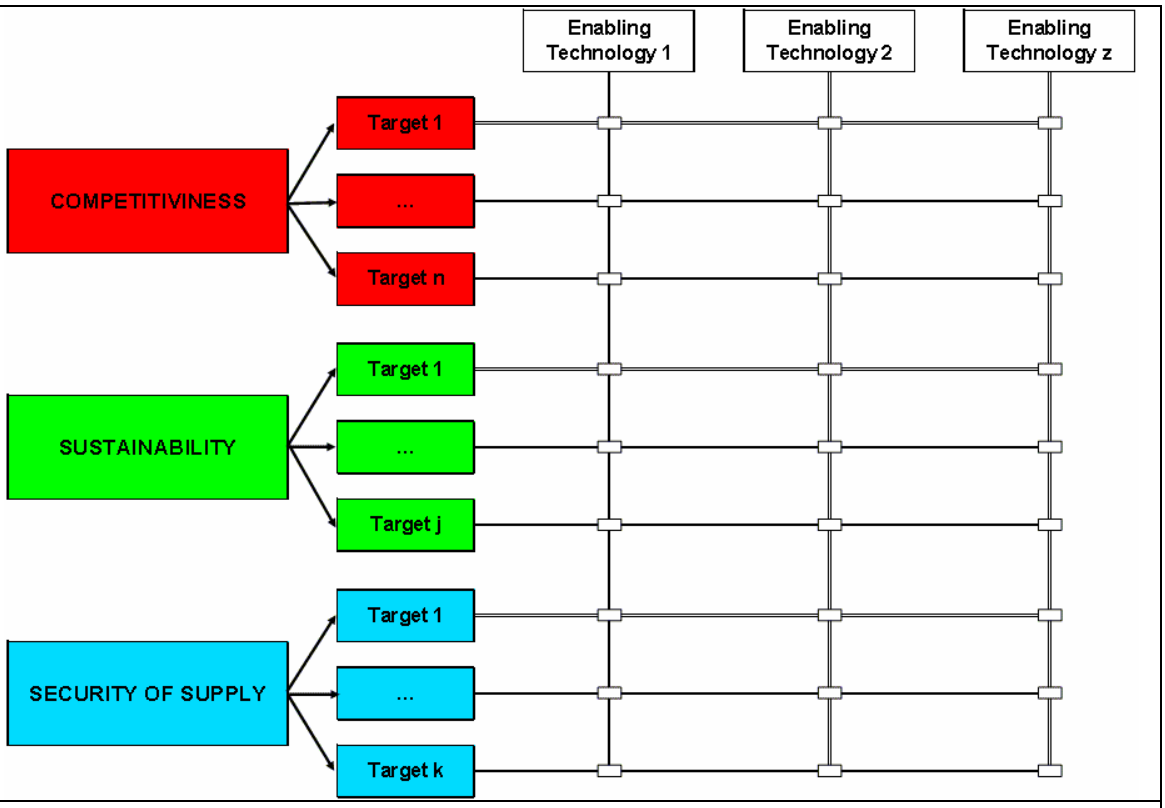

Figure 12 Relationships among Criteria, Targets and Enabling Technologies

Data collection

The scoring of Enabling Technologies and the weighing of Criteria and Targets was applied involving several experts of different background, by means of the following procedures.

➔ DIGITAL QUESTIONNAIRE FOR SCORING ENABLING TECHNOLOGIES
A digital questionnaire was made available on the ERMInE web site.

➔ TELE-VOTING AT THE FIRST FOCUSED MEETING
This approach was used at the first focused meeting, to interview people not only on the technologies but also on the weighting of Criteria and Targets.

➔ QUESTIONS AT THE SECOND FOCUSED MEETING
Questions concerning the effect of R&D actions on the Criteria were submitted to the members of the Eurelectric R&D WG during the second focused meeting.

Elaboration of technology fact sheets

For every promising technologies, a fact sheet has been elaborated, providing: the summary and analysis of the state of the art, the evolution, the research trends, the strategies and goals.

7.2 The resulting Road Map

In this section the most relevant results for each thematic area are briefly summarised. In particular, for each area the following results are presented.

➔ TARGET DEFINITION AND WEIGHING
Based on the analysis of political and technical issues related to the Criteria, the main Targets were defined, on which to evaluate the effectiveness of R&D actions (Enabling Technologies). On these Targets were then applied importance weights, according to the collected data.

➔ DEFINITION OF ENABLING TECHNOLOGIES
The list of the Enabling Technologies was defined through consultation with experts of the three fields: Generation, T&D and End-Use (industry and tertiary).

➔ LONG-TERM R&D PRIORITIES
These priorities for the Enabling Technologies, resulting from the elaboration of the collected data, are represented as polar diagrams.

Several further elaborations have been performed. They are available in the Road Map Report.

An overall aspect, underlying all sectors, is the weighing of the Criteria, as expressed by a group of experts (Figure 13). According to the experts, the Criteria have similar importance (Weight) to fulfil the Energy Policy of Europe, with some slight prevalence of Sustainability and relatively less relevance for Competitiveness.

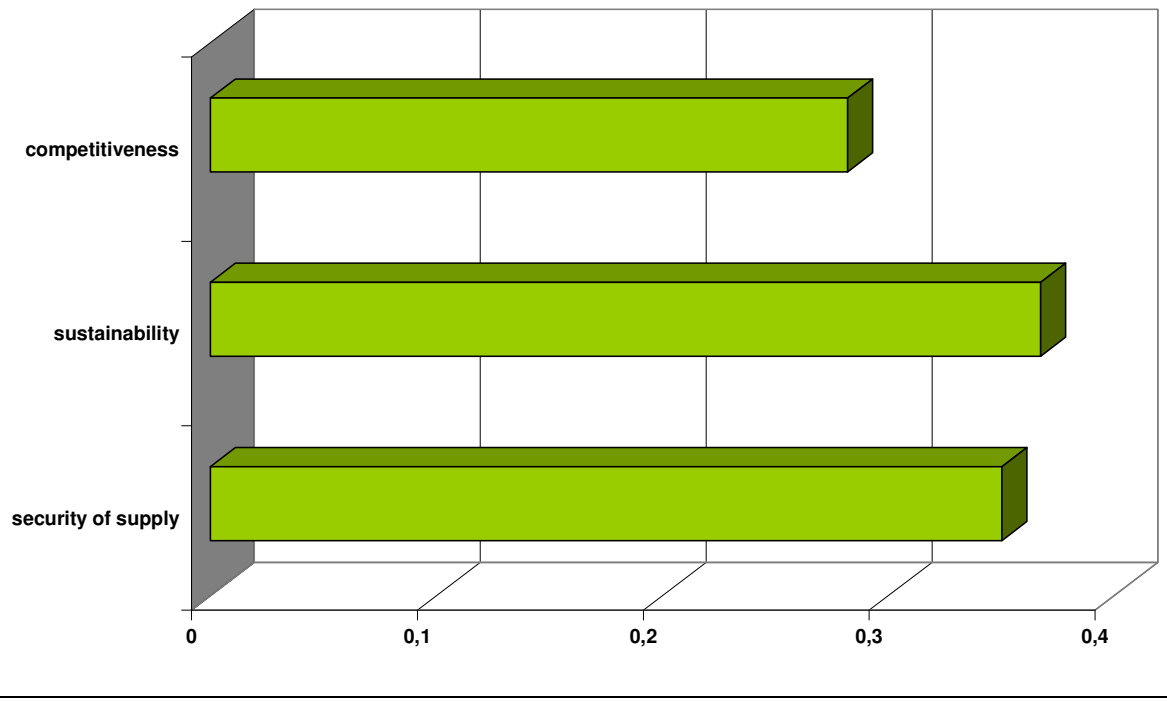

Figure 13 Weights of Criteria

7.2.1 Generation

7.2.1.1 Target definition and weighing

Table 2 Criteria and Targets for the sector GENERATION

CRITERIA	TARGETS
COMPETITIVENESS	Minimization of cost of electricity
	Increase of power plant load flexibility
	Increase of power plant availability
SUSTAINABILITY	Increase of power plant efficiency
	Reduction of power plant environmental impact
SECURITY OF SUPPLY	Diversification of energy sources
	Reduction of dependence on imported fuels

According to the data collected among experts, differences in priorities did not result very large for electricity Generation (Figure 14), with the exception of the criterion of Competitiveness, where the Target of Cost of Electricity was considered significantly more important than the Targets of Plant Flexibility and Plant Availability.

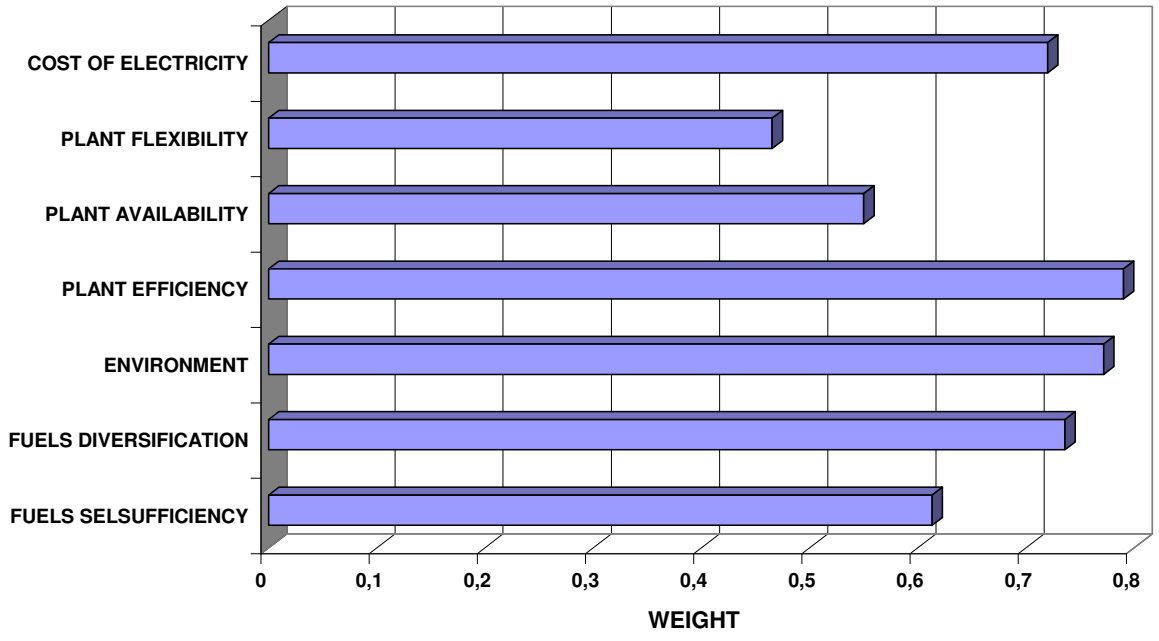

Figure 14 Weight of Targets for GENERATION

7.2.1.2 Definition of enabling technologies

The following Enabling Technologies have been defined.

- Fossil fuel technologies
  - Fluidised beds
  - Coal gasification
  - Coal USC
  - Advanced GT
  - CCS (Carbon Capture and Storage)
- Nuclear technologies
  - Nuclear fission
  - Nuclear fusion
- Renewable energy source technologies
  - Cogeneration
  - Biomass
  - Fuel cells
  - PV
  - Solar thermal
  - Wind
  - Sea waves/tides

7.2.1.3 Long-term priorities

According to the resulting radar diagram (Figure 15):

- among fossil fuel technologies, a clear preference has been given to coal gasification and CCS technologies;
- within Renewable Energy Technologies (RES), R&D actions should be directed to fuel cells, and solar technologies;
- nuclear fission should receive more R&D funding than nuclear fusion.

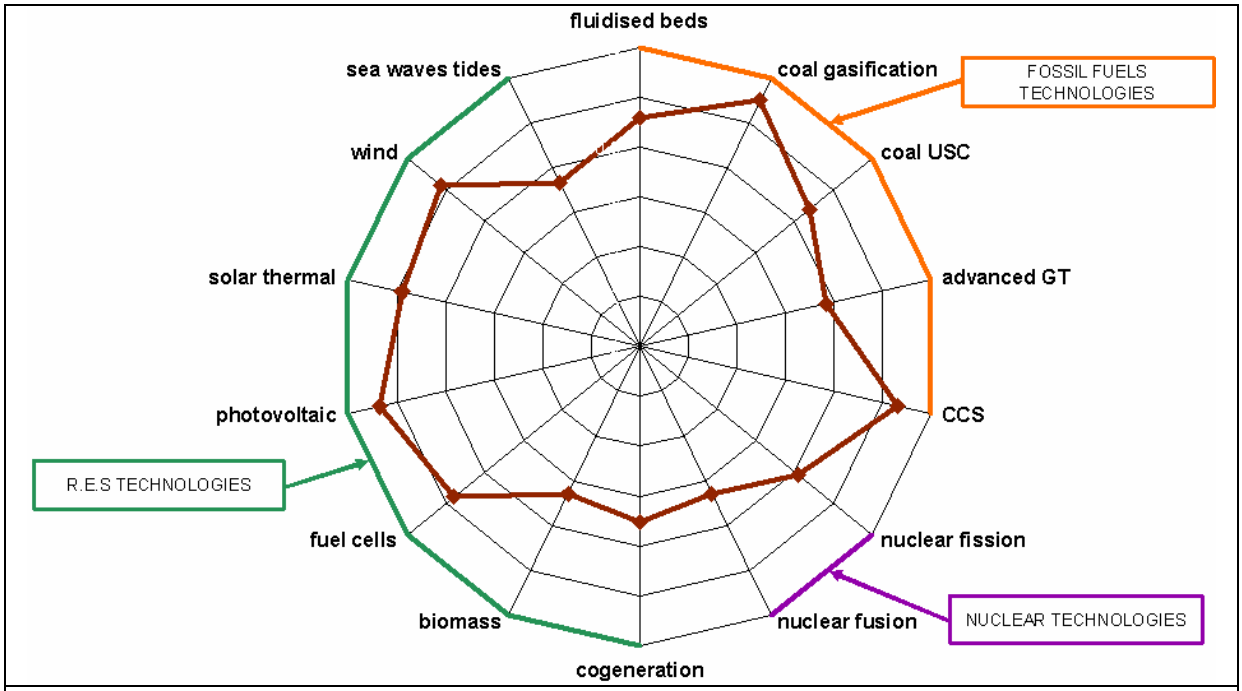

Figure 15 Long-term R&D priorities for GENERATION

7.2.1.4 Generation technology options in a time perspective

Figure 16 and Figure 17 show the expected development of the most promising technologies for electricity generation, based on the most recent technical analyses published by renowned industrial associations and/or interviews with experts.

Figure 16 covers technologies where it is possible to identify subsequent phases of increasing scale and closeness to industrial application. Figure 17 concerns technologies where the progress to industrial application does not necessarily follow a predefined series of phases, hence only the initial and final steps are clearly identified while the changes from red to deep green are only indicative. Dotted lines represent further evolution of the technology after the positive conclusion of the first demo tests, or (at the opposite) initial research activities in the early years of this century.

- In the case of *clean and efficient use of coal*, it was decided to treat carbon capture separately from CO_2 storage and thermal conversion in order to show the different technology options each with its own timescale. This approach is complex but it allows some interesting analyses.
  The first technology to reach industrial application will be related to CO_2 storage using deep saline aquifers, while CO_2 capture and high efficient generation from coal will reach maturity about ten years later, so representing the slowest steps in the way towards the first full commercial plant applying clean coal conversion.
  This plant will probably be based on an Ultra Super-Critical – USC boiler, as this technology will be probably available before the success of high efficiency Integrated Gasification Combined Cycles – Gen III IGCC while in the long term IGCC could prevail due to the

expected very high plant efficiencies of Gen IV IGCC. At the same time CO_2 capture will probably be based on technologies having a lower impact on plant efficiency than present ones using chemical absorbents.

- As for *nuclear energy* (fission-based), in the short term the most promising development concerns the so-called Generation III Reactors, while in the longer term one or more concepts of Generation IV Reactors could be successful.
  A major problem to be solved, independently of the generating technology, is fuel recycling.
- For *wind energy*, the most relevant sector is related to large-scale generators. While onshore technology is already commercial, major developments are expected for offshore systems.
  The most relevant improvements will be those related to the development of large diameter rotors and optimised foundations/floating supports. Should these problems be solved, offshore technology would be ready for commercialization in the mid term near 2020.
  In addition, a more general aspect is the need of reducing component and installation costs. This need could be satisfied only by a continuous effort of standardization and identification of standards that should be carried out until 2030 and beyond.
- *Hydropower* is the most mature renewable technology, however, in the mid-long term some improvements are needed, in particular the reduction of investment costs that are particularly high at the present moment and prevent the application of the technology at small scales.
  Most experts agree in foreseeing an increasing diffusion of intermittent renewable generation: in this case hydropower will play a key role in assuring the operational stability of the electricity net, thanks to the inherent characteristics of fast start-up/shutdown of the plants and the possibility to store energy for long periods. All these characteristics will certainly need to be improved by means of focused R&D funds and actions.
- Great hopes are at present directed towards *solar photovoltaics* power generation, even if accepted that the technology will significantly contribute to satisfy the electricity needs of the world only at the end of the century.
  The solar photovoltaic sector is growing fast, but great progress is needed both to strongly increase conversion efficiency and reduce the cost of cells and modules.
  While it is quite clear that the so-called 1st Generation technologies (silicon crystal-based PV, silicon thin films and concentrator technologies) are closest to application, more uncertain is the progress of the PV technologies which are presently in their initial state of development.
- Different *solar thermal technologies* are at present available, in particular Parabolic Through and Central Receiver Technologies, while others (Parabolic Dish Turbines) are expected to reach industrial deployment in the mid term. The major problem concerns general and strong cost reduction, which can be obtained by improving most components and modifying the construction procedures (the effect of economies of scale is expected in the long term, when the mentioned technologies will be extensively applied).
- As for *geothermal power*, the production of electricity is expected to strongly increase in the long term all over the world as a consequence of the success of Enhanced Geothermal Systems (EGS) and Binary Cycles. Both technologies have been already tested but EGS needs to be demonstrated at industrial scale in different geological situations, while Binary Cycles need significant efficiency improvements.

In summary, an extensive portfolio of new, efficient and clean technologies presently exists for Electricity Generation. However none of them seems to be clearly superior to others in terms of capability of fully satisfying future electricity and environmental needs, so that a technology mix is expected to characterize the next decade.
Consequently in the mid term R&D funds shall be directed to a number of technological options, in particular Clean Coal Generation and Solar Photovoltaics according to the indications obtained at the Final ERMInE Conference.
A clearer situation will characterize the decade 2020-2030, when a selection between technologies will be concluded and hopefully some technological breakthrough will have happened.

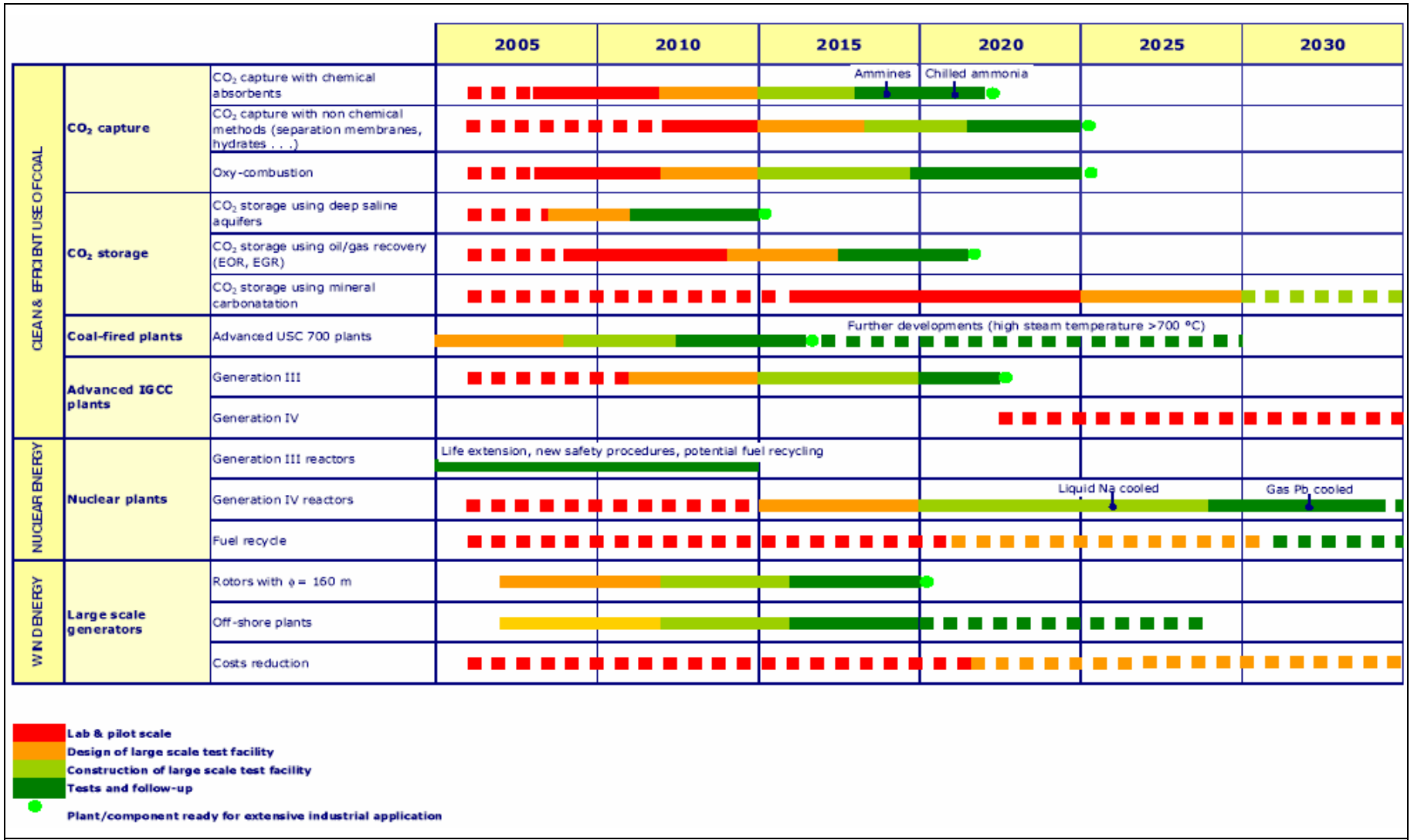

Figure 16 Expected evolution of some Generation technologies

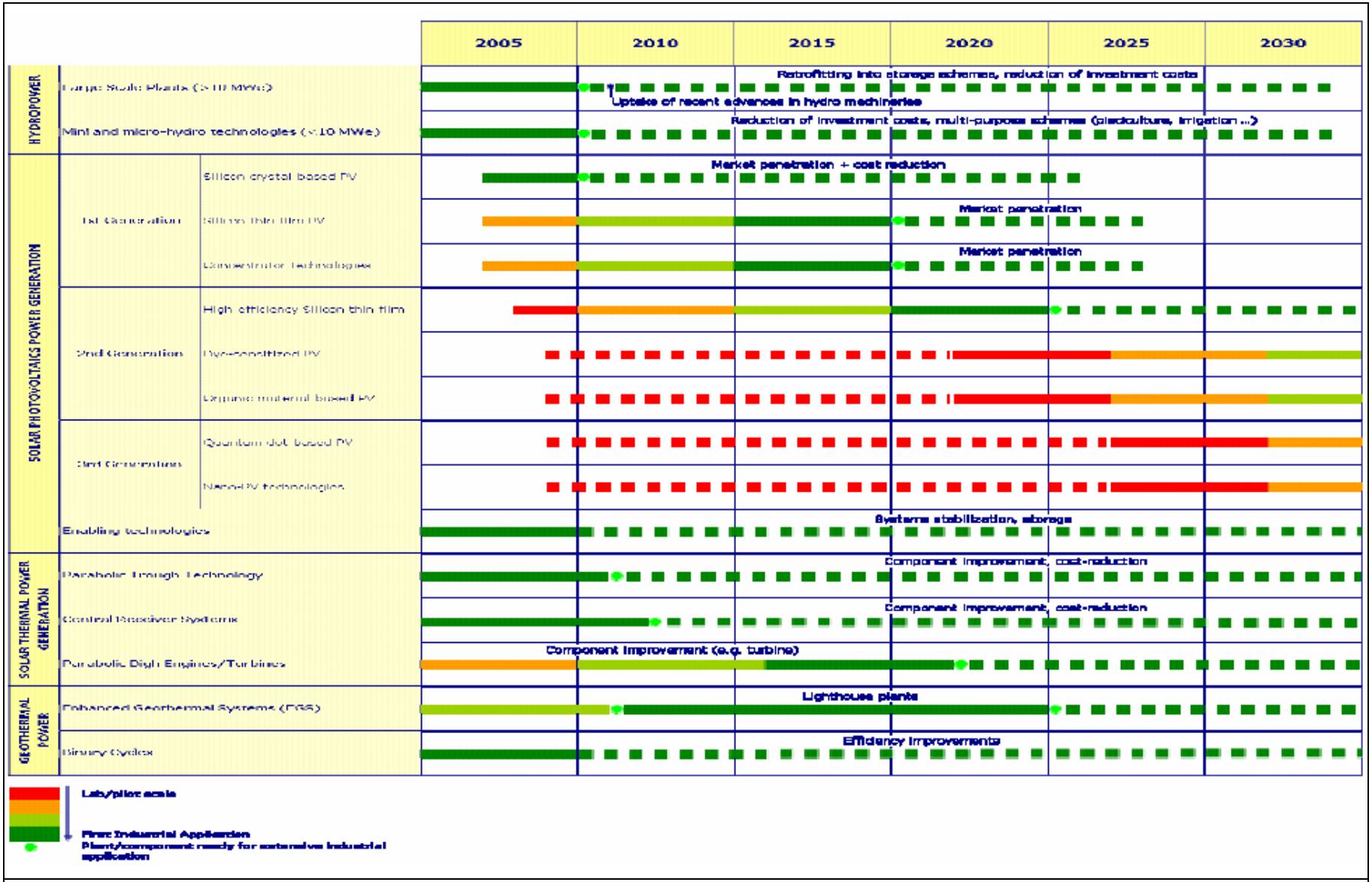

Figure 17 Expected evolution of some Generation technologies

7.2.2 Transmission and distribution

7.2.2.1 Target definition and weighing

Table 3 Criteria and Targets for the sector T&D	
CRITERIA	**TARGETS**
COMPETITIVENESS	Pan-European market
	Distributed Generation
	Customisation of products/services by means of SmartGrids
	Optimisation of present system
SUSTAINABILITY	DG and RES integration
	Reduction of power losses
	New components
SECURITY OF SUPPLY	System vulnerabilities
	Protect the system and mitigate the threats

The resulting weights of the targets in the T&D sector (Figure 18), show a wide spread (0.2 - 0.7).

- The main focus is on the security of the present system (network protection and network security and vulnerability).
- The second set of target priorities results to be the integration of renewable energy generators in the distribution and transmission network: i.e. the natural evolution of the electrical system, as well as the reduction of power losses and the reduction of the environmental burden.
- A certain attention was also given to the necessity to carry out RTD activities for maintaining the availability of the present ageing network.
- Experts judged that economical aspects, such as the development of pan European electricity markets or the customisation of the electricity product are of lower priority in terms of importance for the definition of the technology RTD needs.

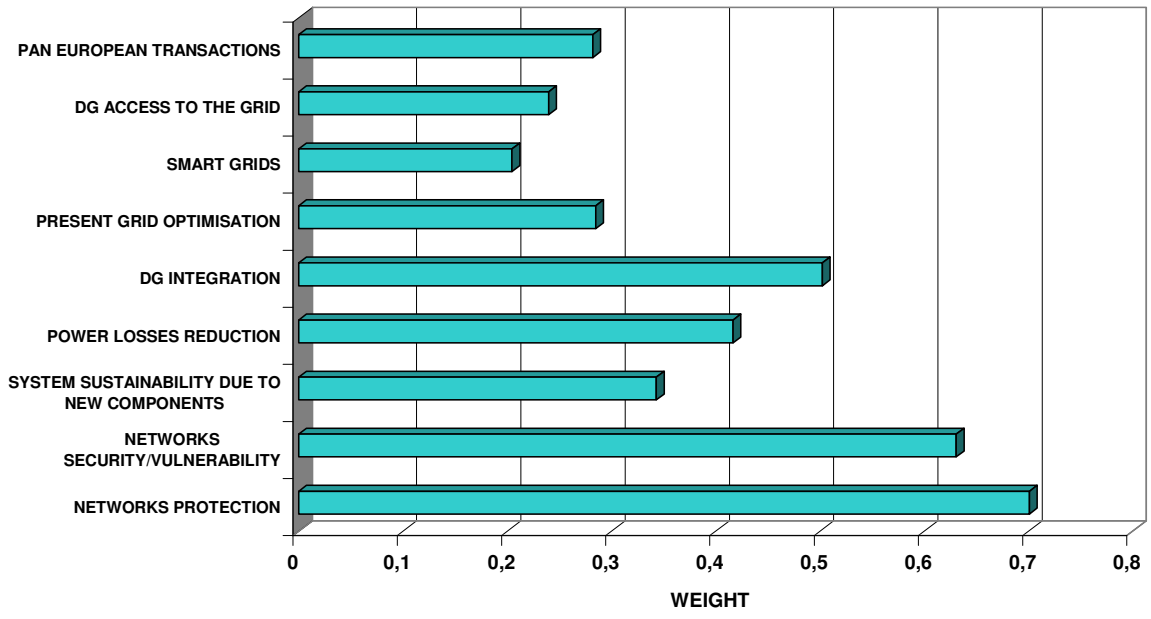

Figure 18 Weight of Targets for TRANSMISSION & DISTRIBUTION

7.2.2.2 Definition of enabling technologies

The following Enabling Technologies have been defined.

- Simulation tools
- Rules and standards
- New materials and components
- Power electronics
- DG technologies
- Electricity storage
- ICT (Information and Communication Technologies)
- Distributed intelligence
- Automation and control

7.2.2.3 Long-term priorities

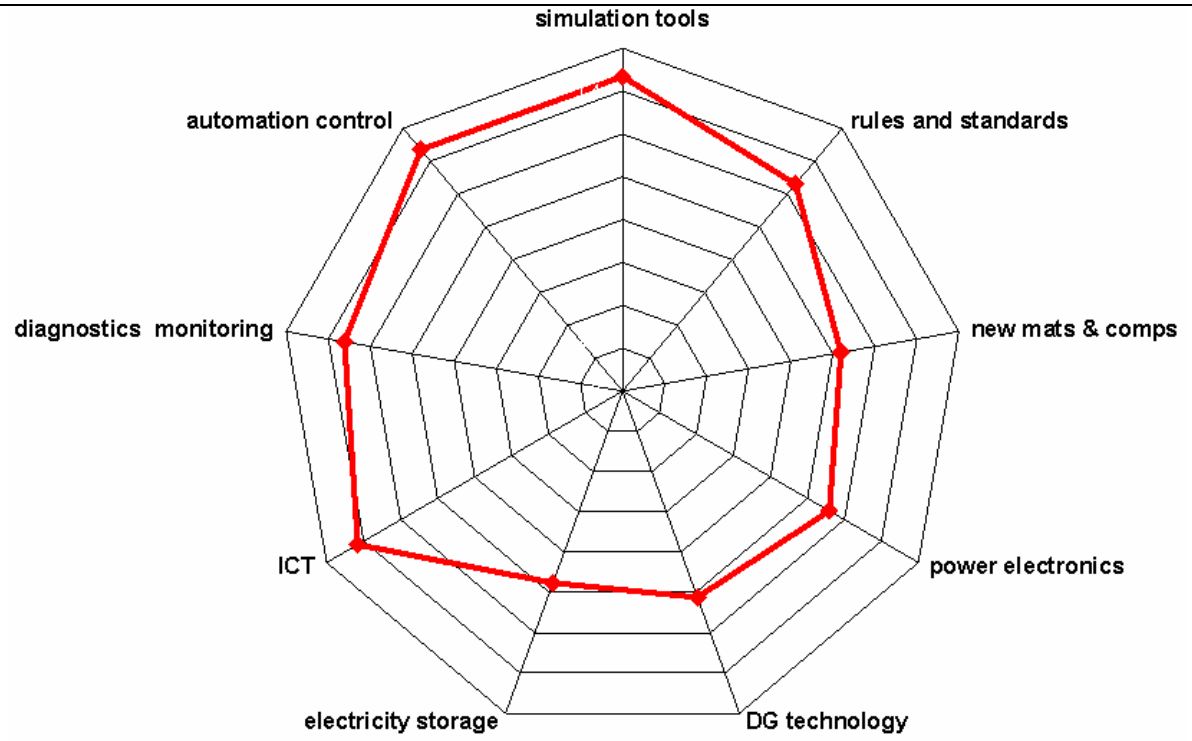

Figure 19 Long-term R&D priorities for TRANSMISSION & DISTRIBUTION

As shown in Figure 19, the consultation of large group of international experts provided the following ranking of priorities in a long term (25-30 years) perspective.

- First priority should be given to technologies having horizontal importance like Information and Communication Technologies (ICT), simulation tools and automation control. These are clearly aspects that cover several targets and whose influence is predominant.
- Diagnostic and monitoring tools are also outstanding, pointing out a concern for the ageing network and the consequent necessity to continuously follow up the evolution of the conditions of components and systems. Ageing models and life extension rules are also to be included in this item, as well as the monitoring of the working conditions of the network equipment.
- RTD activity for the development of rules and standards (installation and use guidelines, system development reference books, grid codes, system black-starting, components testing protocols and interoperability guidelines etc.) comes out as of great importance, also considering the progressive lack of specialised competences linked with the phasing out of the system specialists and observing the lack of new generations of power engineers.

- As for specific technologies, power electronics and DG technologies appear outstanding, immediately followed by new components and materials, representing the long term frontiers of the system development.
- Quite surprisingly, electricity storage has a lower score. This may be attributed to the fact that energy/electricity storage technologies, essential for the development and integration of renewable energy sources in the electrical system, are to be considered more in the generation fields (or in the end-use sector if we include in this sector the distributed generation) than in the T&D system. In this respect, the importance of storage technologies may have been underestimated in the present approach.

7.2.2.4 T&D technology options in a time perspective

The expected trend development for the main T&D technologies over the next 25 years are shown in Figure 20 (for simulation tools, rules and standards, new material and components and power electronics) and Figure 21 (for DG, storage, ICT and asset management).

- As for *simulation tools*, steady state simulation tools are nowadays available and the most advanced systems need to be deployed and set up to consider very large systems, while transient simulation tools, already set up experimentally at a very high level of engineering, need to be integrated, demonstrated and finally deployed: this last action shall take place for very large systems in the first years of the second decade of the century. Planning simulation of very large systems is still in the development phase: basic and applied research will be necessary for 10 more years before demonstration and deployment. A similar situation holds for the setting up of simulation tools and trainers dedicated to the assessment of the system vulnerability, while systems for the assessment of defence and restoration plans are already available and need demonstration on large scale. Market simulation, although already advanced, needs further applied research.
- *Rules and standards* related to the planning and control, in the immediate need applied research to define the exact requirements and needs, but need to wait the results of the development of simulation tools to be afterwards used for the development of the guidelines. Basic and applied research is needed for all aspects related to the development of active grids and for the standardisation of the integration of distributed energy sources in the grid.
- For *new materials and components* at least 10 to 15 years of basic and applied research will be necessary to develop new components, of course continuous development of existing equipment will be ongoing. The inclusion of on-board intelligence on network equipment is presently well on the way; we may imagine the availability of large-scale integrated solutions for demonstration within a period of less than 5 years. Advanced conductors for overhead lines with substantially higher current carrying capability are under final development or trial installation, while much higher ratings for underground cables are not here to be seen, because of the necessity to dissipate the losses generated in the conductor copper. High temperature superconductive equipment and devices are available at small or medium scale: the demonstration and large deployment are function of their economical convenience linked with the difficulty of maintaining temperatures in the range of - 200°C. New developments at significantly higher temperatures are still to come.
- Significant advancements were seen in the recent years in the field of *power electronics*. However, the reliability and the costs constraints motivate continuous development and new generations of semiconductors and devices.
- As for *asset management*, a continuous development is under way. However, especially in the transmission range, new generation of devices and diagnostic indicators are deemed necessary and their trial availability is not expected before 5 to 10 years.
- *All other sectors* are characterised by basic or applied research and development activities, whose results are expected in the next 10 years, in view of the demonstration and deployment.

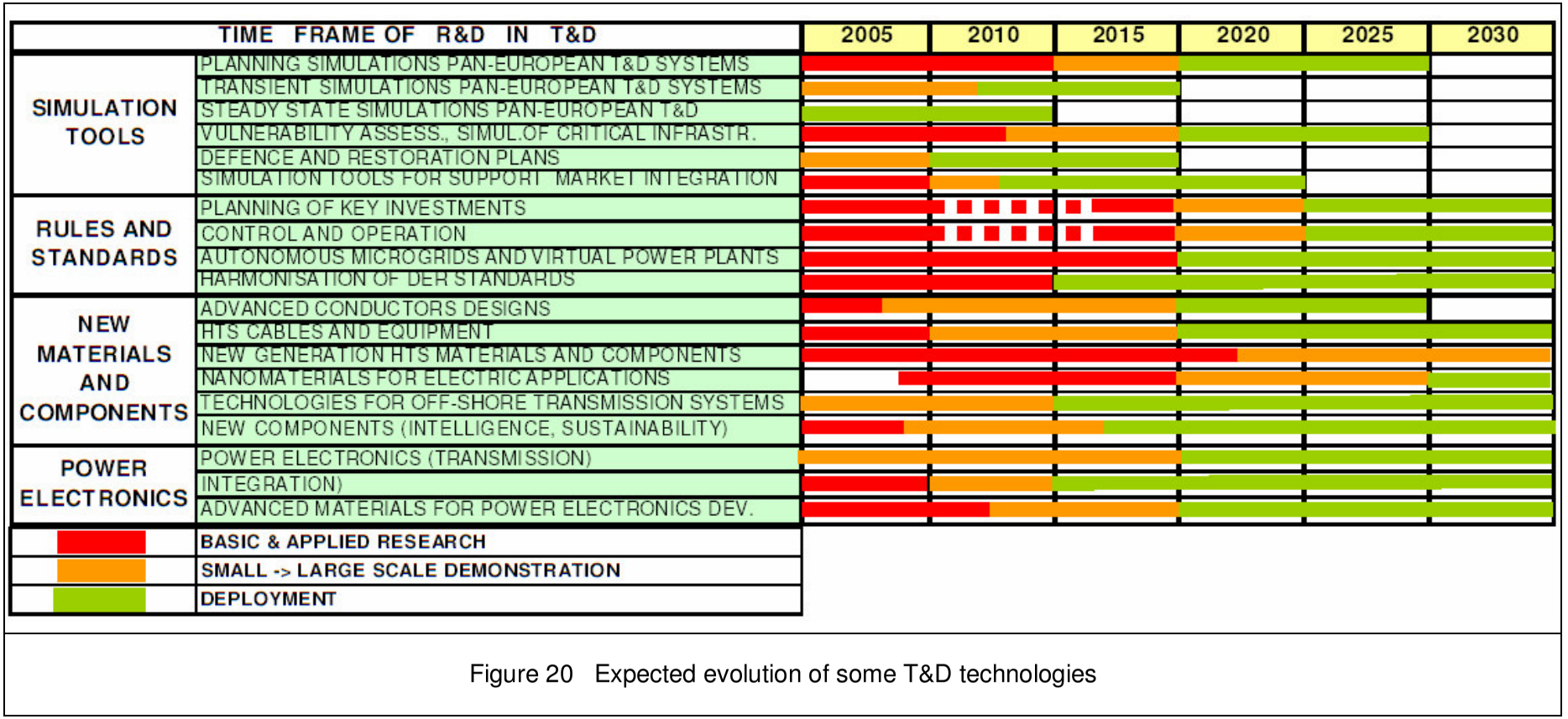

Figure 20 Expected evolution of some T&D technologies

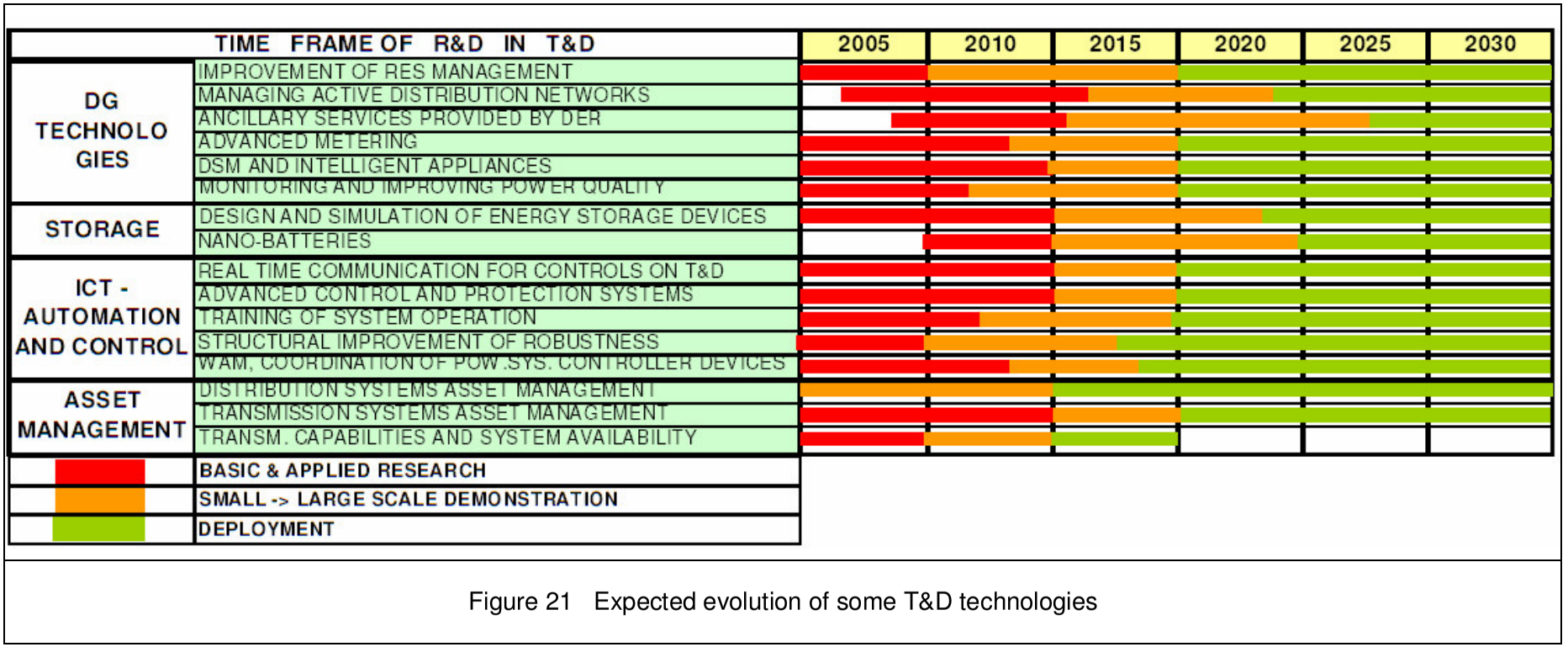

Figure 21 Expected evolution of some T&D technologies

7.2.3 End use (Industry and Residential/Tertiary)

7.2.3.1 Target definition and weighing

Table 4 Criteria and Targets for the sector END USE - Industry	
CRITERIA	**TARGETS**
COMPETITIVENESS	Market liberalisation
	Increased competitiveness of industrial products
	Increase of enterprise productivity
SUSTAINABILITY	Reduction of the global environmental impact
	Distributed Generation & RES Integration into the system
	Increase energy efficiency
SECURITY OF SUPPLY	Improve network security
	Encourage energy saving behaviour of end users
	Manage demand response

Table 5 Criteria and Targets for the sector END USE - Tertiary	
CRITERIA	**TARGETS**
COMPETITIVENESS	Market liberalisation
	Implementation of digital society
	Higher degree of wellness and comfort conditions
SUSTAINABILITY	Reduction of the global environmental impact
	Distributed Generation & RES Integration into the system
	Increase energy efficiency of appliances
SECURITY OF SUPPLY	Improve network security
	Encourage energy saving behaviour of end users
	Manage demand response

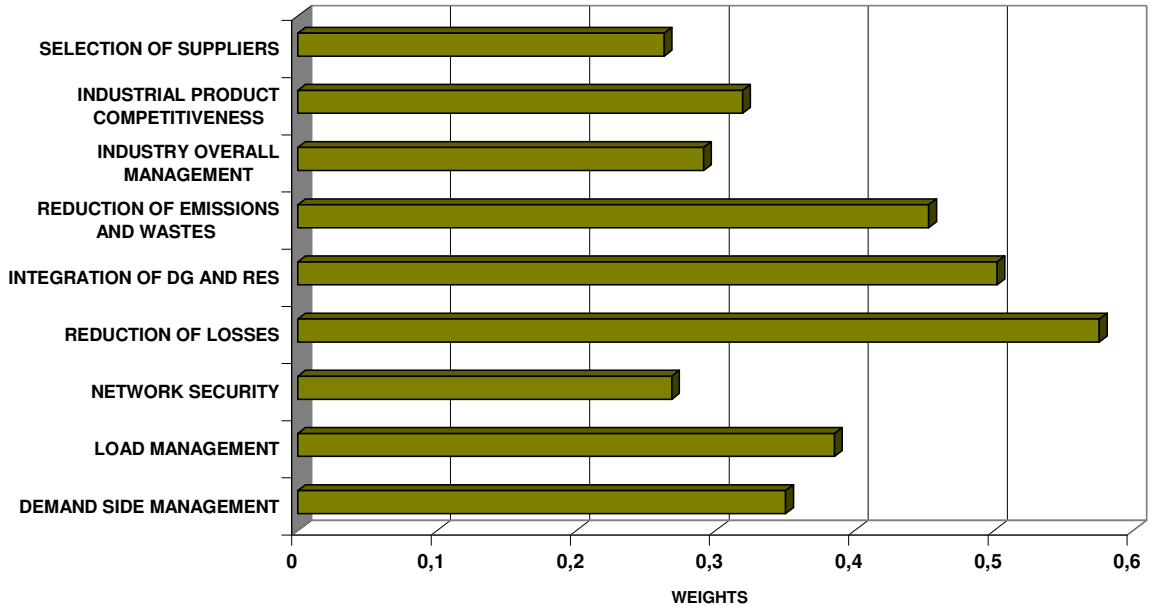

Figure 22 Weight of Targets for END USE - Industry

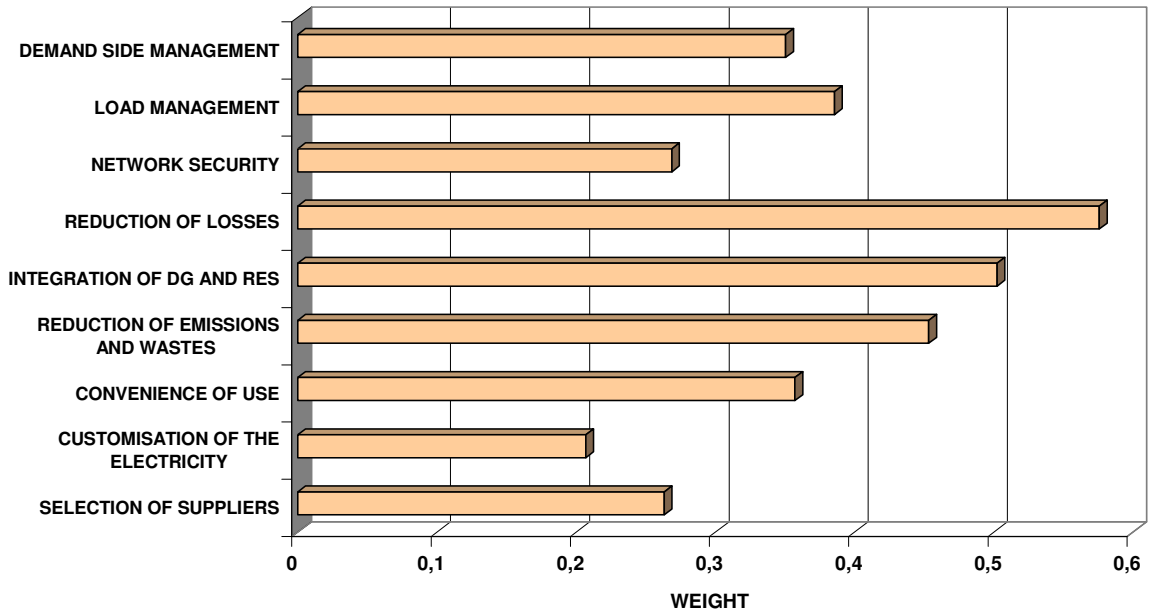

Figure 23 Weight of Targets for END USE - Tertiary

Weights obtained for End-use Targets are similar for the Industry (Figure 22) and Tertiary sectors (Figure 23), with clear prevalence given to sustainability aspects: Reduction of Losses and Integration of Distributed Generation (DG) with Renewable Energy Sources (RES), and in part to Reduction of Emissions and Wastes. As for the household sector, the convenience of use of appliances and interfaces is given high importance. As expected, the main issue here is the energy efficiency, in the industrial processes, the use of appliances, the lighting sector.

7.2.3.2 Definition of enabling technologies

For the Industry sub-sector, the following Enabling Technologies have been defined.

- Process optimisation
- PQ customisation
- Drives
- Lighting
- Heating / Cooling
- Distributed Intelligence
- Rules and standards
- Computer aided management
- Induction heating
- Wireless systems

For the Residential/tertiary sub-sector, the following Enabling Technologies have been defined.

- Lighting
- Heating / Cooling
- Motors
- PQ customisation
- Distributed intelligence
- Advanced IT
- Rules and standards

7.2.3.3 Long-term priorities

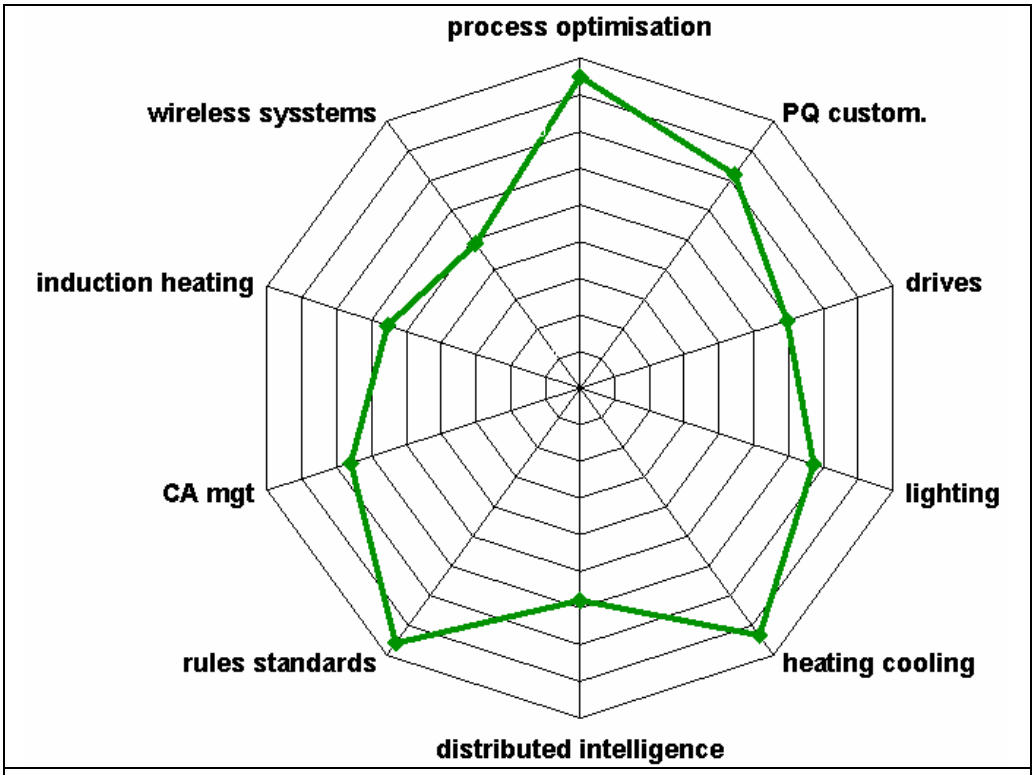

Figure 24 Long-term R&D priorities for END USE - Industry

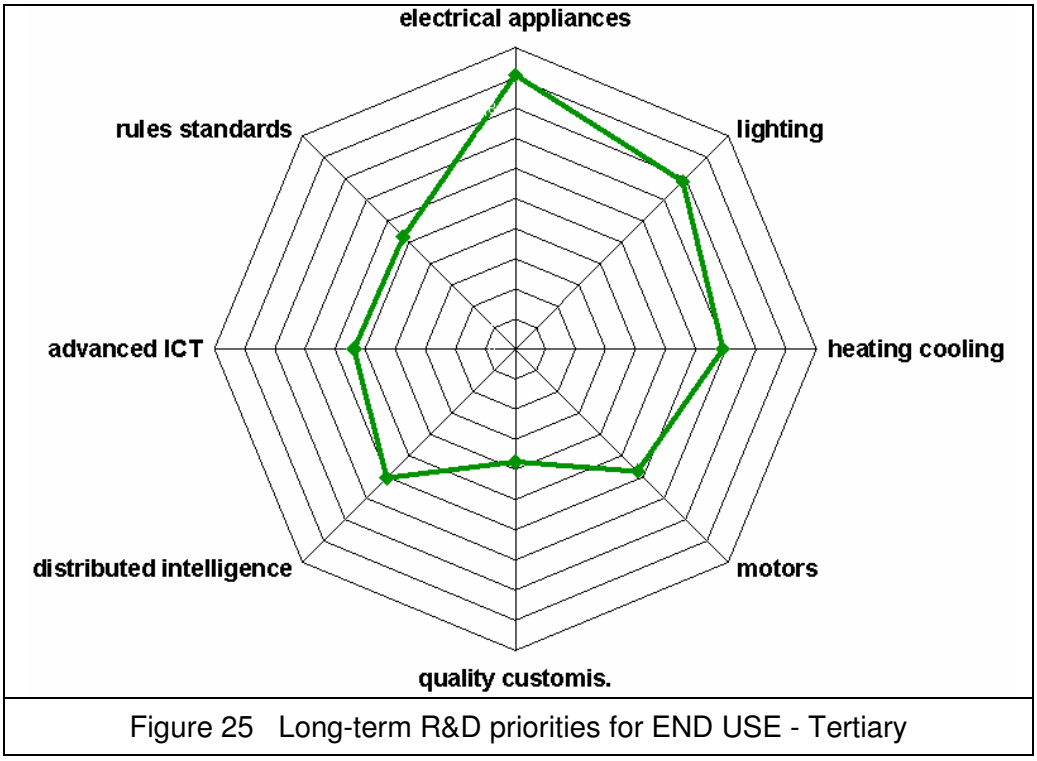

Figure 25 Long-term R&D priorities for END USE - Tertiary

Considering R&D activities starting now and producing full effects in the long term (25-30 years), the following indications can be given.

- II the End-use industrial sector (Figure 24) priority should be clearly given to process optimisation, rules & standards and heating/cooling technologies.

- In the End-use tertiary sector (Figure 25), priority should be given to energy efficiency aspects, implying that R&D should be directed to the development of modern electrical appliances, lighting, efficient heating and cooling systems.
  Distributed intelligence (domotics) can also play an important role in the future household-tertiary sectors.

7.2.4 Concluding remarks

Generation Sector

- A wide portfolio of technologies need to be developed and/or demonstrated in a relatively short timeframe in order to achieve the goals of the EU Energy Policy.
- Energy needs to become a priority in the European R&D agenda if the 20-20-20 goals are to be achieved.
- In the short term sustainable fossil fuels (*i.e.* efficient fossil fuels technologies and CCS) are the key technologies. They will need demonstration at large scale and that is going to cost a lot of money. The contribution of both the private and public sectors is required.
- RES technologies, in particular solar PV and solar thermal, should be also funded as they can contribute, together with Clean Coal, to the success of the European energy policy, based on the three main criteria of Competitiveness, Sustainability and Security of Supply.

Transmission and Distribution Sector

The R&D priorities in the T&D field appear to be twofold.

- Huge investments are necessary to optimise the electrical system of today: its structure, mainly developed in the ’60s and ‘70s in a regime of virtual monopolies, does not seem to be suitable for the necessities of a continent-wide free energy market. Equipment ageing requires continuous control, diagnostic and monitoring to extend the operational life well beyond the design life. A top priority of R&D activities in the present and near future is linked with all aspects of reliability and security: to ensure the continuity and the quality of supply huge efforts must be devoted to the development of tools to assist in the operation, optimisation and protection of the present system to improve its resilience and to accelerate its capabilities of quick response to disturbances and restoration in case of extended failures. Standards and procedures are also essential in this respect.
- As far as the longer term is concerned, attention shall be made in the transformation of the T&D system towards an open, accessible, integrated and sustainable pan-European energy system. Dispersed generation, predominantly based on renewable energy sources, will corroborate the bulk production from fossil and nuclear generators and power and energy flows will circulate at all voltage levels in downwards and upwards directions. This will imply the widest use of information technologies that will need to be specifically developed, demonstrated and applied. Energy storage will be a must to help compensate the fluctuations characteristics of non dispatchable renewables. New materials and components, with higher energy and environmental performances will be needed to reduce power losses and increase the level of loadability of the system minimising the number of new infrastructures limited by their lack of social acceptance.

End-use Sector

The emerging priorities are essentially devoted to the continuous increase of the energy efficiency in all aspects. This is in line with the present tendency and the deeper analysis carried out and reported into a dedicated very extensive annex of the Road Map Report showed that no striking breakthrough is expected in this sector. A continuous decrease of the specific consumption is observed for all household appliances. On the other hand, important improvements can be foreseen in the industrial sector, where the processes optimisation to achieve higher energy efficiencies can be optimised. R&D efforts shall be dedicated to this aspect. Another very important development sector is the management of the demand where ICT and DG can play a substantial

role: this would allow a partial revolution in the management of the energy system, in which at present the generation follows closely the variation of the load. Intelligent load management could bring towards the situation in which up to some extent the load could follow the availability of a much more sustainable generation.

8. DISSEMINATION

The dissemination was addressed to subjects that could potentially cooperate to the success of the ERMInE project, as well as can benefit from the project outcomes, according to their specific role:

- Political role: all bodies that define and support general objectives and strategies.
- Managerial role: public regulators and public administrators.
- Operational role: power producers, transmission and distributions network operators.
- Industrial role: manufacturers of electromechanical and electronic components.
- RTD role: public and private research institutes, technical universities, scientific associations.
- Coordination role: sector associations.
- Planning role: coordinators of European Technological Platforms and Projects of interest.

These subjects are dissemination active and passive addressees. In active terms, they cooperated to the project, *e.g.* by supplying information and contributions for the Map and the Road Map. In passive terms, they are beneficiaries of the project results, which can be profitably used for the planning of RTD strategies and initiatives at all levels (single institution, national, European).

The dissemination has been organised in several activities:

- AREA WORKSHOPS
  Four area workshops have been held during the project duration, in order to inform interested parties of the progress of the ERMInE initiative, to collect information and promote discussion.
- FOCUSED MEETINGS
  - The *Iberian meeting* (Barcelona, 24 May 2007) completely focused on Spain and Portugal.
  - The *Road Map focused meeting* (Milan, 2 October 2007) for the discussion and validation of a draft of the Rod Map.
  - The *Second focused meeting* (Brussels, 21 November 2007), held with the members of the Eurelectric R&D Working Group.
- DOCUMENTS
  - ERMInE Brochure published on the ERMInE web site
  - ERMInE Poster, presented at the Launching Event and First General Assembly of the European Smart Grids Technology Platform (5-6 April 2006)
  - ERMInE Vision Paper
  - Background Document for the Focused Meeting on Data Validation
- PROJECT WEB SITE http://www.ermine.cesiricerca.it
- "DAILY NEWS"
  Information on the project progress has been periodically sent by means of "Daily News", to Eurelectric members, including actors and policy makers in the electricity market interested in R&D developments of European power generation, transmission and distribution companies, manufacturers of electromechanical and electronic components, power grid administrators.
- INFORMATION TO EURELECTRIC STRUCTURE OF EXPERTISE
  Within Eurelectric Structure of Expertise all members of several Committees and Working Groups have been periodically informed on the progress of the project and related events.
- FINAL CONFERENCE
  The Final Conference was held in Brussels on 20 February 2008. The main results of the project, in particular the Map and the Road Map have been presented.
- PUBLICATION OF REPORTS
  The final reports, in particular the Map and Road Map Report have been published in the public area of the ERMInE web site.