EurEnDel - European Energy Delphi

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Abstract. EurEnDel is the first Europe-wide Delphi study on Energy, entrusted by the European Commission DG Research. EurEnDel assesses long-term developments in energy technologies, their potentials and expected impacts. The perspective taken combines a technology push with a social pull approach, embracing a time horizon of 30 years. The liberalisation of the energy sector, the increasing amount of trans-national research as well as rapid technology developments challenge today's innovation systems and demand a greater integration and cohesion into EU-wide innovation strategies. EurEnDel employs a Union-wide Delphi survey to cover the need for reliable information on long-term trends and developments, which will then be presented in form of scenarios as guiding lines for future research priorities. Thus this paper provides the rationale and design of the foresight study as well as some preliminary results. Project results will continuously be published on the project website: www.eurendel.net.

Introduction

The core of EurEnDel is a Europe-wide Delphi survey with two rounds of expert consultations. The Delphi method is an appropriate approach for combining consensual-based technology foresight and technological, social and economic aspects of sustainable development. According to these two main foci, EurEnDel examines how social requirements and technological developments simultaneously exert influence on the speed, thrust and centre of innovation. The knowledge gathered gives insight into the possible future constellations of Europe’s energy sector and on the actions necessary to secure long-term competitiveness and enhance quality of life.

What is technology foresight?

Foresight can be defined as the application of a systematic, participatory, future-intelligence gathering and medium-to-long term vision building to impact present day decisions and mobilize joint actions (Keenan and Miles 2002). Foresight techniques offer a means for strengthening the relations and interactions across institutional boundaries, so that knowledge can flow more freely among constituent actors, thus improving the efficiency of the knowledge system as a whole. The combination of analysis and communication processes in foresight exercises fulfils several functions:

- It is a collective and consultative process, with the process itself being equally important as the outcome (Kuhlman et al 1997).
- It identifies important emerging technologies, which are needed for achieving wealth creation and quality of life (Halal et al 1997).
- It supplies decision support for setting priorities in research and development to match the supply of technologies to future needs in an era of tight budgets (Martin and Johnston 1999).

In short, it assures the five Cs: Concentration on the longer run, improved co-ordination between visions, intentions and actions of stakeholders, Consensus on areas that seem promising, Communication about societal needs and S&T opportunities, and Commitment to the implementation of the policies that may be appropriate in the light of the exercise. This is a condition for a closer alignment in the articulation, execution and exploitation of research efforts (Martin 1995).

The rationale and the design of the EurEnDel study aim at combining different foresight techniques, thus contributing to a more comprehensive assessment of future energy technologies.

The Delphi method

The Delphi method was developed in the early 1960s by the RAND Corporation (Linstone and Turoff 1974). It has since then been applied in many national foresight activities, as well as in numerous industrial/commercial studies (Loveridge et al 1995, Cuhls et al 2002). The core of the Delphi method is a multi-round survey. With each questionnaire the participating experts receive the results from the previous rounds. This procedure helps to obtain clearer judgements on highly uncertain issues. At the same time, the anonymity of the process ensures that the opinions of influential individuals do not dominate the findings (Gordon 1994).

In contrast to simple surveys, which are limited to gathering information, Delphis integrate elements of expert discussions, which bring about additional value by generating consensus among participants and by building up a shared view on future visions (Miles and Keenan 2002).

Rationale of EurEnDel

One major critique on the Delphi method is that only linear extrapolations of current developments are gained, while overlooking innovations related to more than one field of science. Furthermore, the scientific background of the experts – mostly technology-oriented – may lead to wishful thinking in the sense of overrating the technological feasibility instead of focusing on future needs (Kreibich 1998). The aim of EurEnDel is to compensate those weaknesses by following an innovative approach to employ the Delphi method in combination with other well established foresight tools.

The EurEnDel project follows a strict sequential order of analysis, which can be broadly divided into the following phases:

- Establishing the research framework and defining the input to the Delphi Questionnaire, using different Foresight techniques,
A second necessary step was that of creating a common framework for different strings of analysis, which may decisively influence energy demand in Europe (EU15 and accession states) by the year 2030. Supply options have also been considered, but primarily as a mean of satisfying a future demand, which may be different from todays in terms of scope and characteristics. A second necessary step was that of creating a common framework for different strings of analysis, which had three main objectives:

1. Identifying the key factors for the future development of the European energy system, taking into account different features of demand and supply options.
2. Guaranteeing a state-of-the-art analysis of the mostly technology-oriented national Delphi surveys, which had been carried out in recent years.
3. Creating an understanding for the relative importance of technology trends within a major framework defined by social and political influences.

This common framework could be established by grouping the large list of possible factors cited by the participating research institutes in 15 “problem fields”, related both to demand and supply options, but also to political and social trends, which are likely to have an important influence on the future constellation of the energy system.

Table 1 Problem fields as defined in EurEnDel

<table>
<thead>
<tr>
<th>Problem fields as defined in EurEnDel</th>
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<tr>
<td>1. Future Energy Demand – increase vs. efficiency gains</td>
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<td>2. Transport and mobility</td>
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<td>3. Spatial movements</td>
</tr>
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<td>4. Grid development</td>
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<td>5. Renewables' fate</td>
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<td>6. Carrier fuels and storage technologies</td>
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<td>7. Hydrocarbon Bottleneck</td>
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<td>8. Nuclear power</td>
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<td>9. Power play in the energy market</td>
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<td>10. Energy price and taxes</td>
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<td>11. Future social relations</td>
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<td>12. The future of work</td>
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<tr>
<td>13. Demographic trends</td>
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<tr>
<td>14. Technological progress</td>
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<td>15. Environmental Restraints and Objectives</td>
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Figure 1 Workflow scheme: development of Delphi statements for the EurEnDel questionnaire

Social influence in the energy field is more easily understood and analysed when parting from energy demand, instead of supply. So, the initial inquiry to all institutes, designed to stir an internal “brainstorming” process, has centred on factors, which may decisively influence energy demand in Europe (EU15 and accesion states) by the year 2030. Supply options have also been considered, but primarily as a mean of satisfying a future demand, which may be different from todays in terms of scope and characteristics.

A second necessary step was that of creating a common framework for different strings of analysis, which had three main objectives:

1. Identifying the key factors for the future development of the European energy system, taking into account different features of demand and supply options.
2. For each part, different methods have been used to identify and frame the questions posed. These are further described below.
external experts and discussed at the Structural Analysis workshop. Structural analysis or “cross-impact”- analysis is a method developed by different researchers to aid in the organization and assessment of large sets of variables in the construction of scenarios. By studying the relationship between a given set of seemingly unrelated events and trends, consistency can be added to the questions, which may be put forward to experts in a Delphi Questionnaire (Gordon 1994a, Whitely et al 1990).

The present analysis has been carried out with the help of a special version of this methodology, denominated MICMAC (Matrice d'Impacts Croisés Multiplication Appliquée à un Classement or Cross-Impact Matrix Multiplication Applied to Classification), a computer-based tool which depends upon a Boolean algebra concept. As other cross-impact methods, it helps to determine relationships between a given set of variables in a “system” in order to identify those, which have the strongest impact on the system as a whole (key factors). The strength of the MicMac application lies in identifying variables of indirect importance and particularly those, which are likely to elude the analyst (Coates 2000). The tool is often used as a starting point for a logical sequence of work in Futures Studies to define a coherent framework for expert inquiries and for the final scenario building process. Once the experts have discussed and defined the impact between each of the variables in the system, the matrix generated by the program helps to group the different variables by influence and dependence, as shown in the graphic below.

Figure 2 Grouping of variables by the MicMac Program

“Determining factors” or variables are those, which have a very strong impact on the system and may therefore act as motors or as restraints, but which are difficult to control. The knowledge of these forces is very relevant when designing Strategic Vigilance Systems, which are specific tools for observing long-term tendencies in futures studies.

“Strategic” or “key factors” are those which combine a strong influence with a high level of dependence, indicating which actions should be given priority in the elaboration of Strategic Plans.

“Targets” and “results”: the evolution of these factors will depend on how the other elements of the system develop. Some of them may be used as control variables in Delphi Questionnaires.

“Regulating Variables” and “Secondary Instruments” are factors located close to the centre of the matrix and may be helpful for achieving strategic objectives, although their influence on the system is not decisive.

“Autonomous variables” are those, which have shown the lowest impact on the development of the system as a whole.

For the specific purpose of the EurEnDel project, i.e. that of formulating input for future research strategies and technology options, the proposals for the Delphi statements have concentrated on the most influential “regulating variables” (i.e. tools), while the two predominant key factors, both related to political decision-making processes, will be explored further in the scenario building process, along with “motors and restraints” i.e. the determining factors, which are largely beyond the control of the EU.

**Literature and analysis of former Delphi studies**

The literature survey has been based on an evaluation of results of 17 existing foresight and Delphi surveys, leading to the extraction of 599 potential Delphi statements related to 8 of the 15 selected problem fields. The thematic areas, which are hardly addressed in the national exercises, are:

3. **Spatial movements**
4. **Grid development**
9. **Power play in the energy market**
10. **Energy price and taxes**
11. **Future social relations**
12. **The future of work**
13. **Demographic trends**

Where sufficient comparable information has been available, technology road maps have been drawn up to obtain a clear overview of anticipated technology trends. One road map is presented in Figure 3 below.

![Figure 3 Example of a technology road map.](image-url)

All in all, 11 of these maps have been elaborated for the project. The thematic field best covered by the national Delphi studies is that of renewable energies. The maps can be downloaded from the project Web page.
Societal visions
Cross-impact analysis and evaluation of former Delphi studies constitute the basis for the selection of the classical technical statements to be included in the first part of the final questionnaire. Symmetrically, societal visions represent the main input to the definition of the social vision section of the Delphi. The technology-push aspects of the first section are thus being counter-balanced by adding a social-pull perspective. Societal visions are defined in terms of desirable futures. They mark extreme cornerstones for situations that might arise if the values upon which they are based become predominant. The design process of the visions follows a bottom up approach. Parting from general social needs (for example physical needs or clean air) it narrows them down to socially driven visions of Europe’s Energy Future in 2030. The analysis could be singled out in the following sequential stages:

1) Literature evaluation
2) Visions workshop
3) Development of Societal Visions

The process starts out from gathering input on societal visions, demands and ideals, paying particular attention to trends, which are likely to exercise a strong impact on the future energy system, and to the analysis of EU policy goals (i.e. sustainable development, social cohesion, regional policies, poverty reduction and education).

The backbone of the societal visions has then been developed further in a Visions Workshop, a dynamic exercise carried out with the support of external energy and sociology experts. Starting from the analysis of the social impacts of energy innovations during the last century, societal needs in terms of desirable impacts have been identified in a mirroring process. Then, three energy futures for the year 2103 have been formulated, each corresponding to a cluster of related societal visions. Creative techniques have been employed to visualize ideas, hopes, wishes and concerns and to develop imaginary future scenarios. The adoption of this very long-term time horizon, was chosen to stimulate the experts’ creativity and free their minds from short term constraints and daily-business issues. Finally, for transferring the long-term conclusions to the time horizon of the EurEnDel survey, up to 2030, a backcasting methodology has been applied. In this step corresponding EU goals and the previously identified social tendencies have been incorporated into the three societal visions, which form the output of the whole process:

1) Individual Choice
2) Ecological Balance
3) Social Equity

They are understood to represent normative energy visions for Europe and to incorporate the major issues, which presently dominate the sustainable development debate: economic, ecological and social orientation. As each vision emphasizes upon different areas of societal demands, it becomes possible to highlight how different technologies can add to satisfying alternative social demands.

The final questionnaire
The final questionnaire thus comprises two main parts, an introductory note and background questions. The background questions on the respondents refer to age, sex, expertise, experience, and country of residence.

Part I contains 19 classical technology statements, which the respondents are asked to assess:
1) Expertise level - knowledge or expertise within the field concerned.
2) Time reference: When will the technological statement occur?
3) Impact on wealth creation (defined as the economic growth of the European economy measured in GNP/capita).
4) Impact on environment (defined as protection of the natural environment, biological diversity, air and water).
5) Impact on quality of life (defined as the major advancement in health and safety, education, employment, affordable housing, and cultural and recreational opportunities of most people)
6) Impact on security of supply (defined as robustness of security of supply to ensure that European citizens are not endangered with the shortages of energy supply and that Europe is independent from international policy and conflicts in this area)
7) Actions needed to enhance the likelihood of occurrence: Multiple response option, e.g. increase in R&D, financial measures, regulations, public acceptance.
8) Comments: The respondent is invited to comment further on the statement.

Further, as a complementary feature that takes advantage of the two round methodology of the Delphi survey, the respondents are given the possibility of adding “Wild Cards” to the list technology statements. These “wild cards” are technological breakthroughs, which may have a relatively low chance of occurrence, but would have a severe impact on the energy system as a whole. From expert input given during the first round, two additional statements have been included in the second round questionnaire.

In Part II, an identical set of questions is has be evaluated in the light of the three societal visions, defining
- The importance of specific energy sources and technologies in each vision
• The impact of social, political, and economic instruments and innovations on each vision.

**Building the expert survey database**

The selection and identification of qualified respondents is crucial to the results of the survey (Gordon 1994). Following the general approach of EurEnDel, the selection of experts has to cover a broad background of expertise. Therefore, experts recruited from energy R&D related disciplines alone. Furthermore, it has to be kept in mind that the discussion on energy technology options is strongly influenced by political interests. The important criteria for selecting experts can be summarized as follows:

- **Diversity of expertise** comprising technology, market, regulation, and others.

- **Diversity of experience** ranging from social science to engineering researchers, from governmental administrations to non-governmental organizations, from energy users to producers etc. Categories are: R&D, public agency, industry, and other.

- **Diversity of geography** comprising experts from the EU Member States, accession countries and other countries.

The EurEnDel partners have identified experts in the following way:

- Selecting from existing expert databases of the research institutes or energy agencies

- Identified authors of energy publications

- Identified speakers on energy congresses

- Co-nomination of experts either by partners or on the project web-site (www.eurendel.net)

- Completing missing fields by directed research (internet, address databases, phone calls), e.g. for the energy journalists, public agencies and politicians, associations

A total of 3,461 experts have been selected, of whom 72% come from the 15 member stats of the EU, 15% from the 10 accession countries, and the remaining 12% from other parts of the world. Experts represent diverse expertise as well as work experience (Eurendel, forthcoming).

**The survey**

The EurEnDel survey has been conducted electronically using the programme Inquisite, an IT programme, which is widely used for different kinds of surveys (see www.inquisite.com/). In addition to the on-line version, a pdf download of the questionnaire has been made available for respondents wanting to send in their responses on paper.

The invitation procedure is the following: the gross population of respondents receives an e-mail invitation to participate in the survey. The e-mail contains the URL where the survey is hosted and a password to ensure that only the nominated experts can participate. The e-mail, sent out by Risoe National Laboratory, mentions the nominating institution as the remitter. Previous international surveys reveal the importance of national recognisable institutions when experts decide whether they are willing to employ the time necessary to fill out a questionnaire (Jörss et al. 2003).

The survey is conducted in two rounds, using the same password twice for the respondent. In the first round, 669 experts have participated in the survey, equivalent to a response rate of 19%. In the second round, 416 respondents have participated, equivalent to a response rate of 62%

The two rounds have been conducted from June to end of September 2003. Evaluation of the results is yet under way.

**Summary and next steps**

Parting from a thorough analysis of the state of the art of energy technology development in the EU Member and Accession States, the critical questions for Europe’s energy futures have been formulated in EuRenDel. Based on a cross impact analysis and a thorough review of national foresight studies, the most important “open questions” have then been translated into technology-oriented Delphi statements, recurring in each phase on input from external experts. The initial technology-push perspective has then been amplified by adding a social pull approach. Concerns and opportunities regarding social developments, gathered in a "Visions Workshop", have been synthesized in order to extract future social demands and to formulate visions for Europe’s energy future, as input to the second part of the Delphi questionnaire. The survey is conducted on-line and mailed to more than 3,400 European experts. The data gathered during the first round is analysed and subsequently returned to the participants for revaluation.

A thorough evaluation of the final results is yet to be conducted to assess the major Europe-wide technology trends, social requirements, challenges and possible solutions. These findings are to be incorporated into a set of coherent future scenarios, which consider technological and market trends in the light of environmental and social challenges. This scenario exercise will be checked against the findings of other energy scenarios based on quantitative models. Additionally, the findings of the technology-push analysis will be compared to the results of the second part of the questionnaire, which follow the demand-pull perspective. Both exercises will then lead to the final definition of policy implications for EU research policies.

In short, the EurEnDel project will provide a consensual and systematic assessment of future energy technology developments on EU level, including the expected range of, risks, chances and constraints.

**References**


