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TOPIC REPORT II.: TECHNOLOGY CHARACTERISATION AND FORESIGHT

EXECUTIVE SUMMARY

Technology characterisation and forecasting are energy policy development tools, which can be used in the process of energy RTD strategy development. The data needed and the methods used depend on the purpose and scope of the various applications. This topic area focuses on experiences in the EU countries with technology characterisation and forecasting (TC&F) related to modelling, scenario/foresight studies and databases, as used in energy RTD strategy development and priority-setting processes.

This topic report describes the TC&F activities in the EU Member States with regard to the methodologies that are used for technology characterisation (e.g. the collection and validation of data) and foresight as well as their role in national energy RTD policy-making processes. Common approaches and leading ideas with regard to TC&F activities in the different EU Members are reviewed, and strengths and weaknesses for application at national and the EU level are discussed.

An overview of the findings in this topic report is given below.

1. **Overview of activities**

The national technology characterisation and foresight (TC&F) activities that were reported, can be categorised in four groups:

1 Total national energy demand and supply
2 One or more individual sectors
3 One or more individual energy services, energy sources and technologies
4 Specific aspects of certain energy technologies and systems

Table S.1 gives an overview of the number of activities implemented. As indicated, most were modelling activities of total energy demand and supply.

Table S.1 An overview of the number of activities at each level, as indicated in the country reports. (x: few activities; xx: some activities; xxx: many activities).

Level	
1. total national energy demand and supply	xxx
2. one or more individual sectors	xxx
3. one or more individual energy services, energy sources and technologies	xx
4. specific aspects of certain technologies	x

2. **Scope and purpose**

The main findings with regard to the purpose and scope of national TC&F activities are:

- the time frame for most of the studies is up to the year 2030. Only a few activities go beyond this horizon;
- the purpose of most of the TC&F activities is to serve the development and evaluation of general energy and environmental policies and policy instruments and is generally not directly targeted at the process of energy R&D strategy development;
- the primary purpose of TC&F activities has changed over the years, from security of supply concerns to environmental aspects.

3. Technology classification and characterisation

Technology classification and characterisation is a process for which all countries have their own approach. There is no uniform classification for energy technologies to be found, and no formal procedure or methodology to collect data has been reported. The data used can be categorised into technology, scenario and statistical data. The focus with respect to the data used in national energy models is on economic and scenario data, as indicated in Table S.2.

Table S.2 Division of the data as collected in TC&F activities at the level of total national energy demand and supply. (x: little detail, xx: some detail and xxx: great detail)

technology data	**level of detail**
technology description (e.g. energy function, type of fuel input)	x
energy parameters (e.g. energy efficiencies, fuels used)	xx
environmental parameters (e.g. gaseous emissions, solid wastes)	x
other parameters (e.g. use of materials, status of technology)	x
socio-economic parameters (e.g. market barriers and drivers)	xx
economic parameters (e.g. investment and O&M costs)	xx to xxx
status figures (e.g. time of first availability, R&D risks)	xx
RTD economy data (e.g. estimated RTD costs, industrial interest and profits)	x
scenario data [a] (e.g. energy prices, demographic figures)	xx to xxx
statistical data [a] (e.g. energy use in a specific sector)	xx

a. A further split is not possible

4. Methodologies used for technology characterisation and foresight activities

No formal methodology to collect data has been reported. The type of data collected and the level of detail depend strongly on the type and scope of the study implemented. Table S.3 gives an overview of this level of detail.

Table S.3 Indication of the level of detail and the data collection methods in the activities at the different levels (x: little detail; xx: some detail; xxx: great detail; 0: not gathered)

Level	method of data collection	technical-technology	non-technical technology	scenario	statistical
national (1)	literature studies [a] expert inputs	x-xx	xx-xxx	xx-xxx	xx
sector (2)	technology analysis system analysis literature studies	xx	0-x	0	x
energy services, sources and technologies (3)	technology analysis engineering studies literature studies	xxx	0-x	0	0
specific aspects of certain energy technologies and systems (4)	no general methodology	The focus is often on technology data but varies greatly depending on the specific type of study			

a. These literature studies are mainly studies derived from activities at the sectoral level (2) and the level of energy services, sources and technologies (3)

For foresight studies in particular there are a number of energy models in use. Most of the models are economic optimisation models such as EFOM, MARKAL and MIDAS. A specific approach has been developed to calculate external costs. This European study (ExternE) has been used in several countries.

An overview of models used per country is given in Table S.4.

Table S.4 Models frequently used for foresight activities in the different countries.

Country	MARKAL	EFOM	MIDAS	ExternE
Austria				
Denmark				
Finland		X		X
Flanders (B)	X			
France			X	
Germany		X		
Greece			X	X
Ireland				
Italy	X			
Netherlands	X	X		X
Norway	X	X		
Spain			X	X
Portugal		X	X	
United Kingdom	X			X
Wallonia (B)			X	

5. **Energy RTD strategy development**

Energy RTD strategy development: programme development and priority setting, is a complex process, based on all kinds of criteria such as technological potential, costs, environmental impacts, employment prospects, public acceptance and institutional aspects. There is no standard methodology for energy R&D priority setting. However, two kinds of approaches can be found:

- largely structured and based on the use of model results;
- processes based on expert views and opinions of stakeholders.

In practice, countries base their strategy development on combinations of these approaches. An example of an attempt to integrate the approaches can be found in the Appraisal of Energy RDD&D, as carried out in the UK. However, the emphasis here is on the use of formal modelling tools (see section 2.5.3).
An overview of methodologies used for the different type of studies, is given in figure S.1.

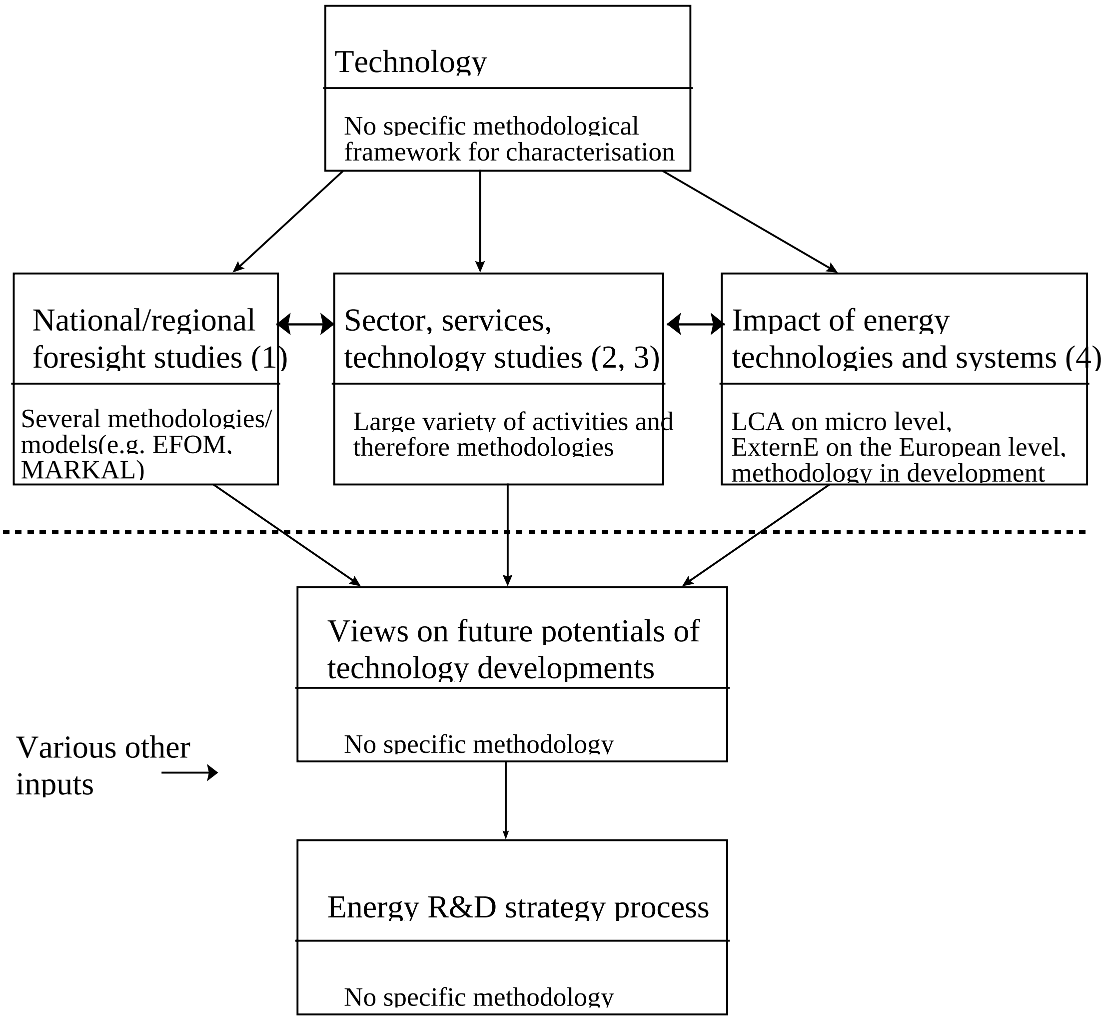


Figure S.1 Overview of the type of studies implemented within Technology Characterisation and Foresight activities and the methodologies used.

6. Conclusions

The main conclusions of this report can be summarised as follows:

Technology Characterisation

- Several Member States put significant effort into technology characterisation. Reported problems are related to the lack of consistency and transparency of data collection methods.
- Little (international) exchange of technology characterisation data or co-operation in data gathering has been found.

The analysis of future impacts and consequences
Different methodologies have been reported and studies and analysis may focus on various levels and scopes. The main driving force behind these activities has been shifted from energy supply concerns to environmental and economical issues (employment).

Methodologies
A wide variety of methods has been reported, varying from large energy system modelling activities to specific market survey techniques and life cycle analysis tools.

Process of RTD strategy development

- Models and foresight studies are not prime movers for priority setting in energy RTD. Energy RTD strategy development is often seen as a political process, supported by TC&F methods.
- There is no "ideal" methodology for energy RTD priority setting. Good practices consist of various combinations of analytical and consulting methods.
- Much experience exists with regard to energy R&D priority setting in various Member States. These experiences can be used to improve the co-ordination between European and national energy RTD strategies.

7. Recommendations

On basis of the analysis and the conclusions drawn above, four major recommendations could be formulated to contribute to the improved use of TC&F activities in the process of energy RTD strategy and programme development at the European and national levels:

- support the exchange of data and co-operation in data collection between Member States and between the EU and national activities;
- develop a benchmark for energy foresight models;
- investigate coherence and interaction aspects between different models/methodologies;
- analyse national energy RTD strategy processes and opportunities for co-ordination and synergies.

1. GENERAL INTRODUCTION

1.1 PURPOSE AND STRUCTURE OF THE REPORT

Technology characterisation and forecasting are energy policy development tools which can be used for energy RTD priority setting. The data needed and the methods used depend on the scope and purpose of the specific activity. This topic area focuses on the existing experiences in the Member States with technology characterisation and forecasting (TC&F) related to modelling, scenario/foresight studies and databases.

With regard to the above, the participating countries were asked to:

- catalogue methods of technology characterisation and forecasting;
- make an inventory of existing experience and actual use of EC modelling;
- catalogue the purpose and scope for each activity;
- review strengths and weaknesses of these methods;
- comment on suitable methodologies for EU level.

This topic report is based on the information provided by the Member States in their country reports and other material that has been gathered throughout the project, such as studies, reports and additional information provided by the countries. Results from prior JOULE projects (PANEL) and experiences within the IEA framework were also examined.

Using this information, common approaches and leading ideas with regard to TC&F activities are reviewed in relation to their strengths and weaknesses and potential contribution to the improvement of co-ordination and synergies between European and national energy RTD strategies. This topic report therefore describes the TC&F activities in the EU Member States with regard to the methodologies used for technology characterisation (e.g. the collection and validation of data) and foresight, and their use in the process of national energy RTD policy development.

The structure of this topic report is as follows:
Chapter 2 gives an overview of the situation with regard to TC&F activities in the EU Member States. Section 2.2 gives an overview of the definitions used for TC&F activities. Section 2.3 gives an overview of the activities at different levels and the purpose and scope of these activities. Next, section 2.4 discusses technology classifications and technology characterisation (or in other words, data collection) and the relation between technology characterisation and the level of the activities. Finally, section 2.5 discusses the methodologies used for technology characterisation, foresight and priority setting.

Chapter 3 focuses in more depth on the differences and similarities among countries and the leading ideas that can be derived from the country reports. This chapter ends with an overview of the conclusions that can be drawn and the trends that are signalled, and which are of interest for energy RTD priority setting at EU level.

In Chapter 4, conclusions are formulated and recommendations are given on ways to improve the use of TC&F activities in the process of energy RTD strategy development and the improvement of co-ordination between the EU and the Member States.

Figure 1 structures the outline of this topic report.

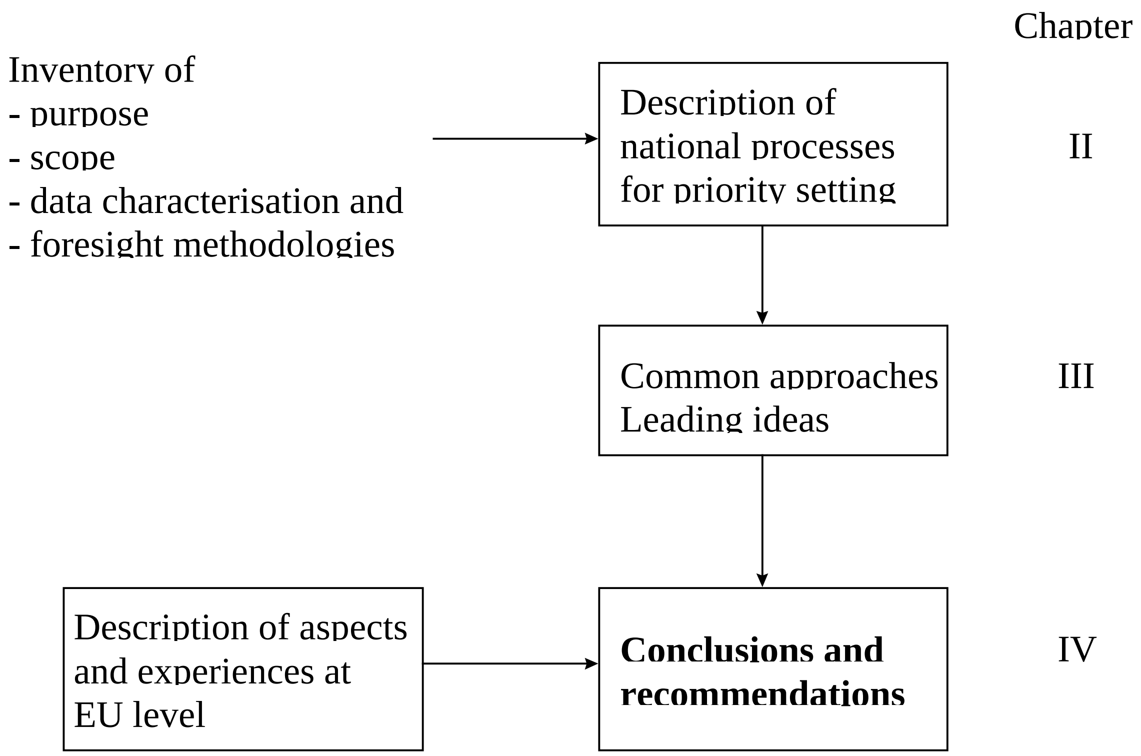


Figure 1. Schematic outline of the topic report

2. NATIONAL APPROACHES IN EU MEMBER STATES

2.1 INTRODUCTION

Technology characterisation and foresight is not a goal in itself, but is always carried out for specific reasons. Choices for the elements to be addressed in the process of technology characterisation and foresight very much depend on the insights that need to be gained.

The purpose and scope of the different activities determine to a large extent their characteristics and contents. Purposes can be, for example, policy-making and RTD strategy. The purpose reflects the way the responsible organisations (ministries, agencies, research institutes) intend to use the results and outcomes. Scope refers to the geographic and policy level and the time frame. Scope and purpose determine the way technologies have to be characterised, the type of data to be gathered, e.g. economical data and/or technical data and the specific characterisation of the data needed.

Besides this, the characterisation of technologies is also determined by the level of application, i.e. national energy demand and supply, or the level of specific sectors or energy services.

TC&F activities, as used in the process of energy RTD strategy development, can be divided into three steps. In an ideal situation, technologies are first characterised, then the possible impact and potential market deployment of the different technologies are analysed. Finally the results are used in a process of strategy and R&D programme development, as show schematically in Figure 2.

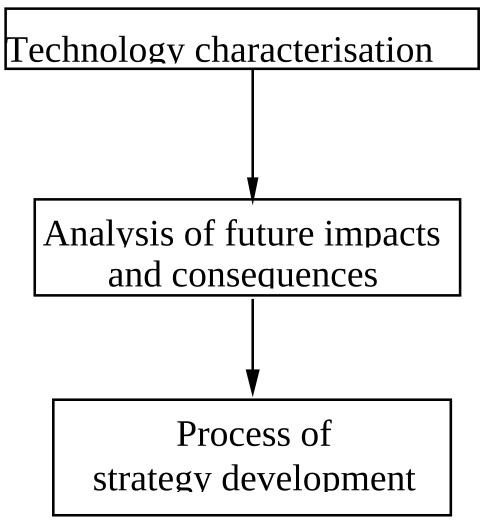


Figure 2. Steps in which TC&F activities are carried out.

This chapter first discusses definitions of technology characterisations. Section 2.3 gives an overview of the TC&F activities in the EU Member States. In relation to these activities, the purpose and scope of the activities are discussed in section 2.3, as well as technology classification and characterisation (2.4) and the methodologies used for technology characterisation, foresight and priority setting (2.5).

2.2 DEFINITIONS OF TECHNOLOGY CHARACTERISATION AND FORESIGHT ACTIVITIES

In the “Instructions for writing country reports”, technology characterisation and foresight (TC&F) activities are defined as “the modelling, studies, databases and other activities as used in your countries on the various levels denoted ..”.

The definition given in the example country report of the Netherlands is:
“TC is defined as the process of collection, validation and review of current and future data on energy technologies. Foresight refers to the analysis of the prospect for future deployment of these energy technologies and the consequences thereof with the help of a formal method or tool. This chapter will also address methods for priority ranking of energy technologies to assist priority setting for energy technology RD&D.”

In this definition, technology characterisation is interpreted as different to technology assessment. In the latter, the possible social impacts of new technologies are also studied, whereas technology characterisation generally refers to the process of data gathering on more technology-linked aspects (performance, costs, emissions, etc.).

In a number of countries, TC&F is interpreted (slightly) differently to the above definition. For example, Denmark considers only modelling activities to be TC&F activities. As a consequence, the country report focuses on one specific project, “Denmark’s energy futures”, which makes use of several other studies. These other studies could also be considered to be TC&F activities, according to the definition given above. Finland and France focus explicitly on activities that use formal methods or tools for foresight activities. In general, the focus in the country reports is on activities using formal methods or tools, that are funded by national governments. As a consequence, less attention is paid to activities at the micro level. Countries that lack direct government funding of energy RTD discussed fewer TC&F activities in the country reports, due to the lack of formal, nationwide activities.
Italy and Portugal explicitly separate modelling activities from TC&F activities, although both countries do describe modelling activities that have been carried out.
As a consequence, this report on TC&F activities focuses on all the aspects with regard to formal and ad hoc methods for current and future energy and technology data gathering and the analysis of the prospects for future deployment of energy technologies and their possible impact on energy, economy and the environment.

2.3 OVERVIEW OF ACTIVITIES, PURPOSE AND SCOPE

This section discusses the activities carried out in the different countries and their purposes and scopes. 2.3.1 gives an overview of TC&F activities at different levels in the different countries. Section 2.3.2 discusses the scope and purpose of these TC&F activities as discussed in the country reports. Finally, section 2.3.3 discusses the sectors or energy services which are studied by several countries and which belong to the activities described in 2.3.1.

2.3.1 Overview of activities

A wide variety of TC&F activities can be seen in the various countries. In the country reports, emphasis is put on nationwide studies and activities, which means that more detailed and informal studies are discussed in the country reports to a lesser extent. As the French report states, a large number of highly detailed studies at the level of products, technologies or firms have been left out of the country report, because of `the large number of studies that are carried out, which (...) are not always publicly available'. This probably is the case, although it is not explicitly mentioned for other countries. Additional information and examples from studies and reports are used in the analysis in this Topic Report.

Differences can also be seen between the Member States with regard to the number of TC&F activities described in the country reports. Finland, France, the Netherlands, Portugal, Spain and the UK describe more than 10 different TC&F activities each. On the other hand, Ireland reports “a total absence of formal TC&F activities”. Austria, Denmark, Germany and Norway mainly focus on one (comprehensive) TC&F activity. Sometimes, these activities are separated into several smaller studies.

The level of aggregation at which TC&F activities have been carried out varies from analysis at the level of individual technologies (or even elements within technologies) to analysis of the entire energy system at the national or, in some cases, even international level.
In the country reports, the TC&F activities are distinguished into different categories, which can be grouped as follows:
1. total national energy demand and supply;
2. one or more individual sectors;
3. one or more individual energy services, (groups of) energy sources and technologies;
4. specific aspects of specific energy technologies and systems (efficiency, environmental impact, socio-economic aspects, etc.).

The following paragraphs discuss the activities that are carried out at these levels.

National energy demand and supply (1)
Activities at this level focus on the total national energy demand and supply of countries. In this category, all countries discussed TC&F activities. Almost all these activities make use of quantitative simulation models in combination with scenarios. The sources for data collection and technology characterisation in this category are mainly the TC&F activities that are mentioned in other categories, e.g. sector (2) or technology studies (3). Activities in this category are usually carried out in large programmes, financed by governments. Good examples can be found in almost any country. In some countries, e.g. Portugal, activities at this level are carried out regionally.
Quantitative (simulation) models are combined with (highly) detailed technology data to calculate future energy demand and supply. Differences between countries occur in a supply vs. demand approach. For example Spain (NEP) and France use a demand-side approach, where most other countries choose an integrated demand-supply approach, as in the RD&D appraisal (UK), the Syrene study (the Netherlands) and ENERGIA (Portugal)[1].
Another distinction at this level can be made between the simulation of the national energy system and the assessment of RTD topics.
Good examples of the simulation of the national energy system are, among others, the National Energy Outlook (NEV) in the Netherlands and ENERGIA in Portugal.
A good example of an activity at this level covering both simulation of the entire energy system and the assessment of RTD topics is the 1992 UK Appraisal. This study has been undertaken by ETSU on behalf of the UK government, involving assessment of government funded R&D programmes and potential alternative R&D topics. A detailed assessment of the future commercial aspects of over 100 energy technologies or technology groups is made, as well as a simulation of the entire energy system in the UK, to assist identification of those technologies meriting government support.
Another good example is the Dutch SYRENE study, carried out by Novem on behalf of the Ministry of Economic Affairs. This study identifies robust technologies that can contribute to sustainable development under different future energy-system circumstances. Together with additional information on industrial skills, R&D capabilities, and evaluation of past activities, these SYRENE outcomes can be used for R&D priority setting.

One or more individual sectors (2)
Activities at this level are activities that focus on the energy system of one or more individual sectors, such as energy demand and supply for industry, households, transport, etc.
TC&F activities aimed at one or more individual sectors take place in all countries that listed activities. The most important sector in almost every country is the industrial sector. The transport, domestic, electricity and the renewables sectors are also mentioned several times as subjects of TC&F activities.
Where formal methods and tools (e.g. by quantitative simulation models) are common in activities in the previous category (total national energy demand and supply (1)), usually less formal methods are used in TC&F activities within this category. An illustration can be found in the UK country report: '.. sector studies have involved less formal methods, based on collection of data from consultations with industry and academic experts, and from literature.' This is the case in most countries. Literature searches and expert judgements are the most common tools for data collection and technology classification in this category.

[1] Although the degree to which the focus is on demand or supply of course differs with the activity

Simulation and demand-supply modelling activities are not carried out in this category of activities. Only relatively simple spreadsheet models are sometimes used.
Good examples of activities being carried out at the sectoral level can be found in e.g. Portugal, where several studies in the textile, plastics, and porcelain and ceramic sectors are carried out. These studies are highly detailed studies with respect to technology description, energy efficiency and the status of the technology.

One or more individual energy services, sources and technologies (3)
Activities at this level focus on the demand and supply of heat, electricity, transport, etc. and on activities in the area of demand and supply of specific fuels (e.g. coal and clean coal technologies). TC&F activities in this category take place in almost all countries. The emphasis is on energy sources and technologies more than on energy services.
Many studies in this category are carried out as part of activities that are categorised at another level. For example Spain discusses the NEP energy infrastructure study at this level, which has been carried out as part of the National Energy Plan.
An important remark is that it is sometimes rather difficult to separate technology studies from sector studies. The Finnish country report is a good example where all sector studies are also categorised at the technology level.
The most important energy sources and technologies listed in the country reports are selected renewable studies (mainly biomass). Other technology studies involve clean coal technologies, fuel cells, advanced energy systems etc. Each country that discusses TC&F activities at this level has at least one biomass study listed. A good example of the importance of biomass in several countries is the Finnish country report, where several competitiveness studies regarding bioenergy are discussed.
Another example of an activity at this level is the SYRENE energy infrastructure analysis carried out under the SYRENE programme in the Netherlands. As part of this activity a system analysis has been carried out for space heating of new and existing dwellings and for regional distribution of energy carriers.

Specific aspects of certain energy technologies (4)
This category discusses activities that focus on the *impact* of energy technologies on specific aspects of society (e.g. environment, industrial competitiveness, social acceptance, etc.).
Probably because the focus is on nationwide activities in the country reports and not on activities that are carried out at a more “micro level”, as the French country report calls it, not all countries discussed activities in this category. Activities at this level are reported by Belgium, France, the Netherlands, Finland and Portugal, mostly carried out as part of larger programmes. But probably all countries have activities that are carried out at the “micro level”.
The European ExternE activity also belongs to this category. This activity, parts of which are carried out in several countries (besides Greece and the UK, also the Netherlands, Finland and Spain discuss ExternE in the country report, although at another level) focuses on the external environmental, economic and social costs of energy technologies, and is a typical example of an activity at this level.

Country-specific characteristics
In this section, some country-specific characteristics are discussed.

Austria: According to the Austrian country report, the most comprehensive study is “Trends, Innovation Potential and Technology Policy Programmes on Energy Technology”. This actually is the only real TC&F activity in Austria. Plans exist to adapt IKARUS and GEMIS to achieve an intensification of TC&F activities.

Belgium: TC&F activities in Belgium are mainly carried out at national level.

Denmark: The Danish country report states: “It will appear that no specific models of TC&F are used in the case of Denmark and that the preferred concept for creating a foresight is politically driven through the use of national overviews,...”. This means that only one TC&F activity is described in the country report: “Denmark’s Energy Futures”. This study has been carried out at national level.

Finland: The Finnish country report describes numerous TC&F activities. Regarding the number of activities at each level, more technology and sector/technology studies have been carried out than activities at the national level.

France: TC&F activities in France are mainly carried out at the sectoral level. Besides the activities described (conducted at a relatively macro level), the French country report states that "at a micro level a lot of technology foresight is performed". A distinction is made between modelling activities and "Interactive" exercises (often using results of modelling). The latter are mainly activities at the national level, though modelling activities are mainly sectoral studies. Only a few studies are carried out at the technology level.

Germany: Germany mainly focuses on one large programme, IKARUS. This activity is carried out at the national level, but several smaller studies have been carried out at the technology or sectoral level. Although some other, smaller activities are described, according to the country report IKARUS is the core of TC&F activities in Germany.

Greece: The TC&F activities that are mentioned first in the Greek country report, are activities carried out on behalf of the European Union, in the ExternE project. These activities concern specific aspects of energy technologies and systems (4). Furthermore, one sectoral, one technology and one national activity are listed. The intensity of TC&F activities is relatively low.

Ireland: The Irish country report: "In Ireland there are no formal activities in the area of technology characterisation and forecasting in the field of energy."

The Netherlands: The SYRENE programme is probably the most comprehensive TC&F activity in recent years in the Netherlands. This programme consists of several studies, which are carried out at different levels (national, energy services, LCA).

Norway: TC&F activities in Norway mainly focus on the use of MARKAL. Five out of six listed activities are MARKAL studies, which are carried out at the national level. The sixth activity mentioned is a sectoral study (industrial sector).

Portugal: The large number of activities, including many activities at the regional level, is remarkable.

Spain: In Spain, almost all activities discussed in the country report, are at the national level. The only sectoral study mentioned is the European study ExternE at the sectoral level. One regional activity is also discussed (SOLARGIS).

United Kingdom: The most important activities in the UK are the Appraisals of UK Energy RDD&D. These national studies also form a basis for other activities in the UK. Although the Appraisals are characterised as national, large parts are at the technology or sectoral level. Due to the comprehensive nature of this activity, the impact on other TC&F activities in the UK is relatively large. Other TC&F activities in the UK mainly focus on the technology level.

Table 1 shows an overview of the number of activities at the different levels as indicated in the country report.

Table 1. An overview of the number of activities at each level, as indicated in the country reports. (x: few activities; xx: some activities; xxx: many activities).

Level	
1. total national energy demand and supply	xxx
2. one or more individual sectors	xxx
3. one or more individual energy services, energy sources and technologies	xx
4. specific aspects of certain technologies	x

2.3.2 Overview of purpose and scope

2.3.2.1 Scope

The scope of the activities described earlier differs with regard to time frame, political level and geographical level. These three items are discussed below.

Time frame

Most of the TC&F activities have time frames up to the year 2030. Only a few activities continue after 2030. Most countries have several activities with different time frames. However, in some countries activities focus on the short term (up to 2000), such as Spain, or the long term (>2010), such as Germany and the Netherlands.
The Spanish activities which concentrate on the short term are National Energy Plans, in which the main guidelines are to establish the basic decisions to provide the country with reliable, affordable and clean energy. In other countries, such national energy plans look further into the future (Portugal-2020; the Netherlands-2020). The Dutch activities which focus on the long term up to 2030 include a variety of activities, such as the SYRENE national scenario study, the Energy and Material Scenario (EMS) study and the biomass MARKAL study. The Norwegian long-term studies deal with cost-effective technologies for achieving national emission reduction goals.
Some studies focus on the years *after 2030.* Examples are some Dutch studies which deal with central and decentral applications of PV systems, and one Finnish activity which deals with power and heat production in residential areas (scope 2050). The available activities for the very long term focus on the (combined) production of electricity and heat.

Geographic and political levels

In the country reports, geographic (regional, national and worldwide) and political levels (national, programme, institute) are distinguished. However, since the allocation of most studies to geographic and political levels strongly overlap, they are discussed here together.
In the countries considered most activities focus on the national level, though some activities concentrate on a regional or international level. The large number of studies with a national scope has implications for the data type and level of detail of most data gathered under the framework of activities described in the country reports. The following describes the characteristics of the studies on the national or international level as described in the country reports. Later on, in the section dealing with data characterisation, the link between scope, purpose and data characteristics will be discussed.

Studies on national (geographic) level

Studies on a national geographic level include all kinds of studies. However, some groups of studies can be distinguished (see the section which describes the overview of activities). The first group of activities relates to 'the total national energy demand and supply'. It includes 'the national energy plans'/ 'national energy scenarios' which play a role at a national political level. Such studies are often based on national models such as MARKAL, EFOM, MIDAS and IKARUS. A second and third group of activities relate to one or more (mostly one) individual sectors or technologies such as renewable energies, buildings, transport, PV systems or combined heat and power production (CHP) in industry. Their political level may be at national or programme level.

Studies at international level

A few international studies are available. One Dutch international study is an intersectoral energy conservation study in industry, another Dutch global study is 'the foresight study on energy conversion technologies' which mainly concentrates on electricity generation. Two Portuguese international studies also exist. One predicts the energy sector for the next 25 years based on four different socio/political scenarios; it includes all sectors. The other considers long-term prospects for renewable energy in the European Community and the countries of Eastern Europe (except USSR).
In addition, some studies exist which could be characterised as international but are here classified as national. Such studies describe the national situation but the results are also valid for other countries, therefore the results are discussed in relation to aspects such as foreign policies. Examples of such studies are the Finnish SEEP-LCA database, several studies based on the Primes model carried out by countries such as Finland, and the ExternE studies carried out by Greece, England, Finland and the Netherlands. In the ExternE study, the methodology is

geographically independent. However, this methodology is applied for different countries and thus, results are geographically dependent.

2.3.2.2 Purpose

The purpose of the TC&F activities can be described at different levels. Purposes of TC&F activities are influenced by politics and society. If political interests change, e.g. if environmental issues become important, purposes of TC&F will change. Studying purposes will therefore inform us of political interests and society trends.
We discuss here the purposes of the individual activities as well as the overall purposes of TC&F activities. With regard to individual activities, we distinguish between activities at the national level and those at sector or technology level. Differences between the purposes at the different levels are summarised in Table 2.

Purposes at the national level (1)
At the national level, with regard to the activities concerning 'the national energy demand and supply', the TC&F purposes as described by different countries are:

- 'to support the development of energy policy and RTD strategy' (Finland);
- 'to set priorities for long-term government and industry R&D programmes' (UK);
- 'to support general energy and environmental policy goals' (the Netherlands);
- 'to support policy-making and 'RTD strategy' (Portugal);
- 'to design national and international measures to reduce energy-related emissions of radiative active trace gases' (Germany);
- 'to set priorities for R&D programmes according to the needs of the energy planning' (Spain);
- to evaluate fiscal and non-fiscal measures in the National Programme of reduction of CO_2 emissions (Wallonia);
- etc.

The purposes stated by Finland, Portugal and the Netherlands do not differ much and are all covered by the description 'to support the development of general energy, environmental and policies'. Those of the UK and Spain are different since they explicitly mention RTD priority setting as a goal. The methodology of priority setting in the 'UK appraisals' is discussed thoroughly. Unfortunately, it is not clear from the country report the way priorities are set in the Spanish study 'NEP RTD in energy'. The purposes stated by Germany and Wallonia focus on specific instruments instead of general policies.
The main observation is that activities at the national level are usually directed towards supporting the development of national energy and environment policies and, to a lesser extent, the evaluation of more specific energy and environmental policy instruments. Only a small number of countries carry out explicit applications in the process of R&D priority setting.

Purposes at sector level (2) or technology level (3)
At the levels relating to 'one or more sectors or technologies', examples of the RTD objectives described by different countries are:

- 'to set priorities for strategic measures in the transport sector' (Germany);
- 'to evaluate the possible role of various kinds of PV systems' (the Netherlands);
- 'to estimate environmental externalities of end-use energy technologies' (Greece);
- 'to review the potential for energy efficiency in various sectors' (UK).

The main observation is that the purposes at national or sector/technology level do not differ much. However, purposes related to sectors or technologies concentrate more on the development and evaluation of specific policy instruments or the possible role of specific technologies.

General TC&F purposes
At the national and sector/technology level, the general TC&F purposes stated in the country reports stress the contribution of technologies to efficient energy use and environmental goals. With the final objective to provide the country with energy (an objective which is generally not explicitly mentioned), almost all countries mention general political goals, most mention environmental quality and some mention costs and conservation in discussing their general purpose. Reliability of the energy system, although important in providing a country with energy, is often not mentioned explicitly.

General remarks with respect to the purposes

The purposes indicated, both at the national energy demand and supply level and at the sectoral or technology level, have a very general character. In practice however, purposes, defined as the way results are used, may be more specific. The 'support for policy planning and support for energy R&D' can and often will be 'an advice for investment decisions' and activities serving 'general energy and environmental goals' can, for example, be used to decide about subsidies for energy conservation technologies. Many of the purposes mentioned at the national, sector and technology levels could be seen as objectives. A more specific description, such as 'advice for investment decisions' can then be considered the actual purpose.
Not incorporated explicitly in objectives, but becoming more important these days, are the likely (expected) market penetration and diffusion of new technologies and the strength of the national RTD institutes and industries. In some countries, these aspects are already slightly influencing national priority setting. They are expected to become more important in future and thus to be incorporated in national policy goals.
Also of interest is the shift in the UK purposes, scope and use of activities observed since 1970. First, the perspective was national with a limited consideration of international markets and export potential (1970-1980). Then, with the lessening of government concern about security of supply and the increased prominence of the government policy of reliance on market forces, R&D policy also changed. Since the mid-1980s contributions to national energy supplies have been more focused on economic potential than on technical potential. Since then, the most economically robust technologies have been recommended for government support. Such robust energy technologies are selected based on the economic prospects over the next 30 to 40 years under a variety of energy price scenarios. Economic potential here includes the market status of the technology (cf. subsection 'methodologies used'.) Therefore, economic potential has a wider definition than in most other activities in many other countries. Market studies are being performed using traditional economic indicators such as the internal rate of return and the payback period.

Table 2. Differences between the purpose at the national and sector/ technology level. reports. (x: few activities; xx: some activities; xxx: many activities).

Purpose of 'Activities at the national level'	Purpose of 'Activities at sectoral and technology level'
• Focusing on general goals: to support the development of energy and environment policy	• Often focusing on more specific goals: to support the development or evaluation of specific policy instruments.
• Focusing on a wide area of technologies	• More often focusing on specific technologies or energy systems.

2.3.3 The sectors and energy services considered in the country reports

As indicated in the overview of activities, in most countries several TC&F activities are carried out at national level. In many of those activities, *'all sectors and technologies'* are considered. In addition, most countries have activities at sector and technology level, some being country specific. Others are of interest for several countries. The sectors and technologies studied most by the different countries are renewable energy technologies, electricity technologies, industrial technologies, the building/residential sector and the transport sector. These sectors and technologies are discussed below. Technology characterisation at the sectoral level is discussed in the next section dealing with technology classification and data .

The renewable energy sector
France, Greece, Portugal, United Kingdom and the Netherlands discuss studies dealing with renewable issues separately. Renewable energy studies discussed in the country reports are studies dealing with wind solar energy, wave energy, biomass and ethanol.

The electricity generation sector
In this category, studies concerning the planning of electricity generation are carried out. Such electricity planning studies are mainly carried out at national level.
Electricity generation studies are also available which focus on electricity production technologies or on the production of combined heat and power. Activities in the field of combined heat and power (CHP) production mainly take place in Portugal, Finland and the Netherlands. Activities in the field of electricity generation take place everywhere. A more efficient energy use in relation to the climate problem is a driving force behind these studies. Because of this relation with the climate problem, the electricity generation studies often overlap studies in the renewable energy sector.

Industry
'Industry' covers a wide range of technologies and subsectors. Studies in the industrial sector are therefore very diverse. In general, studies focus on one industrial sector. Some sectors or group of industrial technologies studied include the petrochemical industry (the Netherlands), basic metal industries (Finland), clean coal and natural gas technologies (Greece) and CHP (United Kingdom, the Netherlands, Finland)). There are only a few studies available which concentrate on cross-cutting technologies in industry (the Netherlands, United Kingdom).

The building/residential sector
France, Greece, Portugal, Finland and the Netherlands discuss studies dealing with the building/residential sector separately.

The transport sector
France, Germany, Greece, Portugal, Finland and the Netherlands discuss studies dealing with transport issues separately.

Other sectors
Sectors which receive little attention are the household and consumption sectors. This may be due to the diversity of the sector. However, since the position of households is in fact at the end of production chains, it may be useful to study the direct and indirect energy use of households. In the Netherlands, energy consumption by households is now receiving more attention than a few years ago.
Sectors studied by only one or a few countries, because they are country-specific, are the plastic industry, textile and ceramics industry (Portugal) and the paper industry.

2.4 OVERVIEW OF TECHNOLOGY CLASSIFICATIONS AND TECHNOLOGY CHARACTERISATION

2.4.1 Technology classifications

TC&F activities frequently focus on the technologies that are involved in the energy system being considered. To structure the technologies within these studies, a technology classification is frequently used. Also within modelling activities, a classification is needed to structure the model. Therefore, all countries use technology classifications in their activities. Hardly anywhere is a formal classification method used. The classification method used greatly depends on the activity. In this section we will discuss different classification methods as used in the Member States.

There are several ways to classify energy technologies. Thinking in an energy chain perspective, one can distinguish:
- extraction and treatment technologies;
- conversion technologies;
- energy transportation, distribution and storage technologies;
- end-use conversion and conservation technologies, including the use of applications.

However, for specific activities other ways are often used to classify technologies, such as by sector, by energy-service or a combination thereof. Examples of some technology classifications are, for example the DG XII/DG XVII classification for non-nuclear energy R&D programmes and the IEA classification for energy RD&D budgets. Table 3 gives an overview of the DG XII/DG XVII classification (at the two-digit level).

Table 3. DG XII/DG XVII Classification (two digits)

Two digit classification	**Category**
1.	Energy RTD strategy
1.1	Global analysis for energy RTD policy options
1.2	Socio-economic research for energy
2.	Rational use of energy (RUE)
2.1	RUE in buildings
2.2	RUE in industry
2.3	Energy industry, fuel cells and storage
2.4	RUE and new fuels in transport
3.	Renewable Energies (RE)
3.1	Integration of RE
3.2	Solar Photovoltaics
3.3	Wind energy
3.4	Energy from biomass and waste
3.5	Hydroelectric plants
3.6	Geothermal energy
3.7	Advanced energy storage
3.8	Further options
3.9	Cross-cutting technologies
4.	Fossil fuels
4.1	Solid fuels extraction, preparation and transport
4.2	Clean technologies for solid fuels and gas
4.3	Generic combustion
4.4	Hydrocarbons (oil and gas, oil shales and tar sands)

4.5	Storage
4.6	Cross-cutting technologies
5.	Dissemination of energy technologies

Although classifications differ from activity to activity, some general remarks can be made.

It is important is to realise that the technology classification used in an activity is determined by the methodology chosen. If, for example, MARKAL is used for an activity at the level of total national energy demand and supply, the technology classification used is the one prescribed by the MARKAL format.

Activities taking the entire energy chain into account are carried out in all countries except Greece. Even countries that discuss relatively few TC&F activities have listed at least one activity covering the entire energy chain. According to the country reports no formal classification methods are used in any country except Portugal and Norway, where the formal DG XII/DG XVII classification is used. In no other country does a centralisation of approaches exist. Therefore, in the country reports, the technology classifications are described using examples. Most of the classifications described in the country reports follow the outline of the energy chain. Differences mainly occur in the elaboration of this perspective. The technology classification used in Finnish and Greek TC&F activities is limited to the four categories of the energy chain, with some additions if required by the activity. The UK, France and the Netherlands, for example, use an elaborate classification method that is comparable with the DGXII/DGXVII classification used in Norway and Portugal for the TC&F activities described.
Another distinction is explicitly made in some TC&F activities in, for example, France and Greece, where supply vs. demand-side technologies are explicitly separated. In France, this has led to a focus on demand-side activities.
The classification as used in the Appraisal of UK energy RDD&D is given in Table 4 as an example of a classification method discussed in the country reports.

Table 4. The classification method as used in the Appraisal of UK Energy RDD&D (one-digit level)

1.	Fossil fuel technologies
2.	Nuclear power
3.	Transmission, distribution and storage
4.	Energy efficiency in buildings
5.	Energy efficiency in industry
6.	Transport
7.	Renewable energy

The classifications used in France and the Netherlands differ only in the details. For example, the classification method used in the Syrene study in the Netherlands adds greenhouses and appliances to end-use conversion and conservation.

2.4.2 Technology characterisation

In TC&F activities, different types of data are used, which may be either very technology-specific or of a more general nature. In the country reports, three types of data are distinguished:

1. technology-bound data

"technical" technology data

- technology description: energy function, system boundaries, sizes, type of fuel input, etc.;
- energy parameters: energy efficiencies, temperature levels, fuels used, etc.;
- environmental parameters: gaseous emissions, solid wastes, noise;
- other parameters: use of materials, status of technology, R&D budgets, risks, market penetration, etc.

"non-technical" technology data

- socio-economic parameters: market barriers and drivers, public acceptance;
- economic parameters: investment costs, O&M costs, lifetimes, materials inputs, etc.;
- status figures: status of the technology, time of first availability, R&D risks, etc.;

- RTD economy data: estimated RTD costs, industrial interest and profits, scope for international co-operation, etc.

2. scenario data
   - economic growth factors;
   - sector growth factors;
   - population growth and related demographic factors;
   - traffic and transport fuel prices.
   - price scenario's
3. statistical data
   - energy consumption by sector;
   - energy efficiency indexes;
   - degree of market penetration of specific technologies.

Which data are collected, how they are obtained, the accuracy, the reliability and the level of detail are highly dependant on the type of TC&F activity for which they are used. A difference also exists in the amount of quantitative data available in different studies. The lack of consistency and lack of an integral approach is often considered to be a weakness.

In most countries, no national databases exist consisting of technical and economic data of all technologies for the whole energy system. Constructing such a database, and keeping it up to date is very time consuming. In addition, the validation of such technology data is difficult and time consuming. Other problems with data collection are the commercial confidentiality of some technology characteristics.

In general, the following observations on the extent of data collection in TC&F activities can be made:

1. technical and energetic parameters are often dealt with in great detail;
2. (socio-)economic and environmental parameters are dealt with in more general detail, but are identified as being of increasing importance;
3. commercial, market and behavioural parameters are considered very important, but at present are addressed in no great detail.

For the same TC&F activities, differences occur between the various countries regarding the level of detail at which data are gathered. This level is indicated in the country reports using the following categories:
x: little detail
xx: some detail
xxx: great detail

This section discusses the type of data gathered and the level of detail for activities carried out in the different Member States on the categories as distinguished in section 2.3.1.

National energy demand and supply (1)
At the national level, the types of data gathered are in general non-technical technology data in relatively great detail and technical technology data in less detail. Also, statistical data regarding current energy efficiencies and market penetration are used in some detail. The scenario data are at least collected in some detail. Although the level of detail is also highly dependent on the methodology chosen for a TC&F activity[2], the nature of TC&F activities in the area of national energy demand and supply can be illustrated by Table 5. This table shows that the data gathered at the level of national energy demand and supply are split up to give the different data as derived from the descriptions in the country reports. Of course, this table gives a general overview. For specific activities, the general indication given in this table may not be appropriate.

[2] e.g. using Markal implies data gathering of the status figures and economic parameters in great detail

Table 5. Division of the data as collected in TC&F activities at the level of total national energy demand and supply. (x: little detail, xx: some detail and xxx: great detail)

technology data	**level of detail**
technology description (e.g. energy function, type of fuel input)	x
energy parameters (e.g. energy efficiencies, fuels used)	xx
environmental parameters (e.g. gaseous emissions, solid wastes)	x
other parameters (e.g. use of materials, status of technology)	x
socio-economic parameters (e.g. market barriers and drivers)	xx
economic parameters (e.g. investment and O&M costs)	xx to xxx
status figures (e.g. time of first availability, R&D risks)	xx
RTD economy data (e.g. estimated RTD costs, industrial interest and profits)	x
scenario data [a]	xx to xxx
statistical data [a]	xx

a. A further split cannot be derived from the country reports

From this table it becomes clear that the non-technical technology data are at least available in some detail, where technical data are mostly absent or gathered in little detail. This can be caused by the fact that activities at the national level often make use of activities at the technology and sectoral levels.
An exception has to be made for large, nationwide programmes, such as the Appraisal (UK), Syrene (NL) and IKARUS (Germany), which have highly detailed technology data. The main reason for this exception is that although these programmes are mainly categorised as TC&F activities being carried out at a national level, they also include sector and technology studies.

Activities at the sectoral, and the individual energy services, sources and technologies level (2 and 3)
At these levels, the data collected mostly consist of technology data. Of these technology data, the technical technology data are gathered more frequently and in greater detail than the non-technical technology data. Studies at the technology level use greater detailed data than at the sectoral level. Socio-economic data are very rarely incorporated into technology and sectoral level activities. With regard to scenario data, these are almost never collected, because scenarios and other simulation tools are not used in most activities at these levels. Only Portugal and Finland discuss one activity (Estimativa de Disponibilidade de Biomassa Florestal Residual no Pais, respectively the Bioenergy Competitiveness Study), where forecasting tools are used to calculate some scenarios.
Statistical data, with regard to historical developments in the sector, energy prices etc. are at most collected in little detail, mainly in activities at the sectoral level (e.g. the Portuguese sectoral activities are good examples).
Data collection takes place using (technology) systems analyses, engineering studies (at the technology level only) and literature studies. Expert panels are almost never used, which in itself is rather logical when looking at the nature of the data.
Results from technology or sectoral studies are frequently incorporated into studies at the national energy demand and supply level.

Specific aspects of certain energy technologies and systems (4)
Although not many activities in this category are discussed in the country reports, the nature of this category implies that rather detailed data are needed.
The Finnish SEEP-LCA activity consisted of developing a database that can be used for other LCA (life cycle analysis) activities in Finland. The LCA activities in the Netherlands and France are specific LCA activities regarding energy technologies.
The technology data in the SEEP-LCA activity is not as detailed as in most activities at the technology level (3). The Dutch and French country reports give no details of the data collected in the LCA activities. However, according to documents regarding the Dutch SYRENE LCA study, the technology data are collected at a rather detailed level. Contrary to most other activities, LCA activities also require environmental data to be collected, at least in some detail.
Other activities at the level of specific aspects of certain energy technologies are market surveys. Two studies have been carried out in Portugal, one on district heating/cooling potential and the other on solar collectors. Technology descriptions, energy parameters, economic parameters and the degree of market penetration were the data gathered for this activity, ranging from some detail to great detail.

The Greek activities at the level of energy, economy and the environment are activities in the ExternE programme. Data for technology descriptions are gathered in great detail, as well as risks, environmental parameters and demographic factors. Furthermore, only non-economic technology data were gathered.

2.5 THE METHODOLOGIES USED

Different methodologies are used either for the characterisation of technologies, foresight activities or priority setting. Such methodologies can vary from formal modelling to more ad hoc methods, using experts' views and experience. This section focuses on all possible methods in current use in the countries. The methodologies for technology characterisation (or data collection), foresight or forecasting and priority setting are discussed separately.

2.5.1 Methodologies for technology characterisation

There are practically no formal procedures for technology characterisation related to established RTD priority setting processes. Studies are carried out, in most countries without a standardised form of data collection or technology characterisation.

However, some general remarks can be made with regard to the methodologies used for the collection of data at the various levels as distinguished in section 2.3.1.

Total national energy demand and supply (1)
The technology selection, i.e. the choice of technologies to be taken into account in activities at this level, is based on literature and expert judgements.
The technology and scenario data needed for studies at the total national energy demand and supply level, are also derived from literature and expert judgements.
The *literature* is often taken from TC&F activities at the sectoral level (2) or the level of one or more individual energy services, (groups of) energy sources and technologies (3). As an example, a quotation from the Finnish country report: "The technology data for the national energy scenarios in the EFOM activities were mainly collected from data provided by other activities listed in Table 4.B". Statistical data are also used.
The *experts* can be from universities, the private sector and the energy sector. In most country reports no distinction is made between the various expert types. Also no distinction is made between the various possibilities for using experts (formal Delphi-methods, consistency check made by experts on the reports, etc.).
For example, direct contacts with industrial experts are mentioned in the Norwegian MARKAL studies and the large programmes Syrene (NL), the Appraisal (UK) and IKARUS (Germany). Exchange of information with the energy industry is used in the BCS activity in Finland.
Some countries also list other data collection methods. In Portugal, technology system analysis has been used for data gathering in the National Energy Policies and ENERGIA 1995-2015 activities. For these activities, not only literature and expert panels were used for data collection, but the technical technology data were gathered by actually doing the technology analyses, usually carried out at the technology or sectoral level. More interactive methods to collect qualitative data are discussed in the UK (Technology Foresight), the Netherlands (VCE) and France (Souviron Exercise) activities. The latter consisted of 20 regional debates, together involving 6,000 people and six national conferences, organised in 35 round tables involving in total 218 people in the debates and some 2,000 in the audience. The aim was to bypass the experts' view. An interactive activity of this size is rather unique, according to the country reports.

Activities at the sectoral, individual energy services, sources and technologies levels (2 and 3)
Data collection takes place using (technology) systems analyses, engineering studies (at the technology level only) and literature studies. Expert panels are almost never used, which in itself is rather logical, considering the nature of the data.
Technology systems analyses at this level are usually carried out using less formal methods, such as spreadsheet or Aspen models, with input data from engineering studies or literature.

Engineering studies include other experiments in e.g. power plants and heat stations (as in the BCS activity in Finland).
Literature is mainly taken from other activities at the same level, or at a more micro-level.
Results from technology or sectoral studies are frequently incorporated into studies at the national energy demand and supply level.

Specific aspects of certain energy technologies and systems (4)
Due to the fact that few activities in this category are discussed in the country reports, no general remarks on the methodologies used for data collection can be made. Most of the data collected for the activities described in this category in section 2.4.2. are collected using literature studies. LCA activities usually make use of existing literature for the data needed. In the ExternE project, simulation models were also used to generate the data needed.

Table 6 shows an overview of the data collection methods, as well as a global indication of the detail level of the data collected in activities at the various levels.

Table 6. Indication of the level of detail and the data collection methods in the activities at the different levels (x: little detail; xx: some detail; xxx: great detail; 0: not gathered)

	method of data collection	technical-technology	non-technical technology	scenario	statistical
national (1)	literature studies [a] expert inputs	x-xx	xx-xxx	xx-xxx	xx
sector (2)	technology analysis system analysis literature studies	xx	0-x	0	x
energy services, sources and technologies (3)	technology analysis engineering studies literature studies	xxx	0-x	0	0
specific aspects of certain energy technologies and systems (4)	no general methodology				

a. These literature studies are mainly derived from activities at the sectoral level (2) and energy services, sources and technologies (3) level.

2.5.2 Methodologies for foresight

Most countries use formal methodologies for foresight, such as energy system modelling to systematically analyse the subject. There is a huge variety in energy system models. Models commonly used, that is, models used in various countries, are models such as EFOM, MARKAL, MIDAS, MEDEE and the integrated impact assessment model (in the ExternE study). These models will be discussed later. In addition, many countries use more informal methodologies for foresight, such as informal spreadsheet models and LCA models.
In the country reports, three groups of foresight methodologies can be distinguished. The first consists of models based on simple or more complex mathematical methods. A second group is formed by the expert panels. A third are the so-called economic indicators such as internal rate of return, payback period and market status, the last being a less formal economic indicator.
These three groups of foresight methodologies are discussed below. Finally, the methodology life cycle analysis (LCA) is discussed. It is a methodology which has been discussed in relation to foresight activities by only a few countries, but it is interesting to note here due to its specific characteristics.

Foresight methodologies group 1: models
As mentioned, various models are used to model integrated energy systems. They use different formal methods for foresight activities. In the following, the EFOM, MARKAL, MIDAS, MEDEE and ExternE models are discussed. These models were selected since they are used in several countries (i.e. the models were used in studies in at least three different countries.). Table 7 shows which models are used in which countries.

Table 7. Models frequently used for foresight activities in the different countries.

Country	MARKAL	EFOM	MIDAS	ExternE
Austria				
Denmark				
Finland		X		X
Flanders	X			
France			X	
Germany		X		
Greece			X	X
Ireland				
Italy	X			
Netherlands	X	X		X
Norway	X	X		
Spain			X	X
Portugal		X	X	
United Kingdom	X			X
Wallonia			X	

EFOM

EFOM has been developed in the European Union. It is a linear optimisation energy system model including both demand-side technologies and supply-side technologies. The EFOM model has been used for the EU Crash programme to calculate CO_2 reduction strategies. Results have given useful indications of the relative importance of various technology groups in the future energy system.

Both Finland and the Netherlands explicitly mention that results from the EFOM model have not been formally used for RTD priority setting but have been used to support the energy and environmental policy planning by the Ministry of Trade and Industry and the Ministry of the Environment.

MARKAL

Like EFOM, MARKAL is a linear optimisation energy system model. It provides detailed results from both the supply and demand side of the energy system. Several MARKAL models exist: a 'standard' MARKAL model', the MARKAL-MACRO model and a stochastic MARKAL model, which has been developed recently.

The standard model calculates the contributions of energy technologies to fulfil an energy demand and the required costs of these contributions. The technologies are characterised by their energy conversion efficiencies, their estimated investment and maintenance costs now and in the future. Starting point for the calculations is the useful energy demand which has to be fulfilled taking into account certain restrictions, e.g. CO_2 reduction goals. Optimal strategies, that is the most cost-effective strategies to meet energy demand and other requirements, are calculated based on a linear optimisation.

MARKAL is supported by the Energy Technology Systems Analysis Programme which is an implementing agreement of the IEA. Currently, the ETSAP team is investigating the possibility of taking into account a more complete treatment of the external social and environmental costs of energy technologies using the experience of the ExternE study (see below).

Compared to 'the standard MARKAL model', the MARKAL macro model is an extended version. The model includes macro-economic implications. The macro-economic model provides substitution possibilities of capital, labour and energy. Optimisation in the MARKAL macro model is based on utility maximisation. It is a non-linear optimisation model.

The stochastic MARKAL model allows users to take into account uncertainties in emission reductions which result from e.g. uncertainties in policy goals and uncertainties with regard to climate change. The stochastic version supports decision-making under uncertainty. Probabilities have been implemented and thus, *expected* costs instead of *estimated* costs can be calculated. The model optimisation is based on the lowest expected costs and allows for developing strategies under uncertain CO_2 emission reduction goals.

In all MARKAL models, priority ranking of the technologies is based on costs. The lower the costs per ton of CO_2 reduction, the more attractive a technology is. This implies that a technology is selected if its costs are low compared to costs of other technologies which provide the same energy service.

MIDAS

MIDAS is an integrated econometric energy model for foresight developed by DGXVII of the European Union.

MIDAS covers the whole energy system, including the interaction between the demand and supply side, costs and prices. It follows an econometric approach to formulate optimal behaviour of future demand and a technical-economic approach to formulate optimal behaviour of energy supply. On the supply side, the model considers alternative technologies, new or existing, and establishes dynamic paths for capacity expansion and renewal. In demand technology, technology is implicit except for the electricity appliances in domestic and transportation applications.

ExternE
There is a growing interest in adopting a more sophisticated approach for the quantification of the environmental and health impacts of energy use and their related external costs (costs that are not included in the current energy prices). This is being driven by the following factors:

- the need to integrate environmental concerns when choosing between different fuels and energy technologies;
- the need to evaluate the costs and benefits of stricter environmental standards;
- increased attention to the use of economic instruments for environmental policy;
- the need to develop overall indicators of environmental performance of different technologies to enable comparisons between technologies;
- different policy initiatives to encourage competition and the market mechanism in the energy sector (e.g. privatisation, limiting of subsidies, liberalisation of energy markets).

Externalities are defined as:
'The costs and benefits which arise when the social or economic activities of one group of people have an impact on another, and when the first group fail to fully account for their impacts'.

The ExternE project commenced in 1991 as a collaborative study between the European Commissions and the US Department of Energy.

For the calculation of external costs, two approaches are developed. These approaches are usually described as 'top-down' and 'bottom-up'. Top-down uses aggregated data, for example national emission and impact data, to estimate the damage costs of particular pollutants.
Bottom-up uses technology-specific emissions data for individual locations. This is used together with pollution dispersion models, detailed information on the location of the receptors and thoroughly reviewed dose-response functions to calculate the physical impact of incremental emissions. These impacts are then given an economic value.

The objectives of the ExternE project were:

- to develop a unified methodology for quantifying the environmental impacts and social costs associated with the production and consumption of energy;
- to use this methodology to evaluate the external costs of incremental use of different fuel cycles in different locations in the European Union;
- to identify critical methodological issues and research requirements.

To reach these objectives, the two approaches (bottom-up and top-down) have been combined. For several fuel cycles (coal, nuclear fuel, oil, natural gas, lignite, wind and hydro), all burdens and impacts of the specified system that fall within the system boundaries are identified. Next, the most important have been investigated in detail. For these impacts and other environmental burdens, the impact pathway which consists of an emission, a dispersion, an impact and cost step is studied. In the dispersion step, atmospheric dispersion and chemical reaction models are used. The impact step is based on dose-response functions. The cost step describes the economic valuation of the technologies and determines the fraction of the damages that have not yet been internalised, the so-called external costs. Finally, the numbers are summed over all receptors (population, crops, buildings, etc.) that may be affected by this burden. This methodology is known as the damage function methodology.
The developed methodology is an ideal methodology to compare different technologies, because it is:

- consistent;
- transparent;
- comprehensive.

Results based on the ExternE methodology can thus be used for foresight activities.

Foresight methodologies group 2: expert panels
Expert panels are mainly used for technology characterisation but are sometimes used for foresight activities too. The way such expert panels work varies greatly. Sometimes they are informal discussion groups. Sometimes they are strictly organised.
Norway and the Netherlands describe more strictly organised methodologies to use expert knowledge, Norway with regard to 'studies for energy efficient technologies in Industry' and the Netherlands with regard to 'SYRENE national energy scenarios'. In both studies, experts were responsible for technology characterisations. Next, other experts, selected from specialists from research institutes and industry, reviewed the technology characterisations relevant to them. Also in the technology foresight study of the UK, experts not responsible for the collection of technology characterisation in the first place were asked to join discussions or give second opinions.

Foresight methodologies group 3: economic indicators
The economic potential of a technology is of interest for foresight activities. The economic potential depends on investment and maintenance costs and market-related aspects. Some economic indicators are integrated in computer models. However, sometimes, economic indicators such as the internal rate of return and the payback period, are the only indicators used for foresight activities. Market studies in which the economic potential of a technology is studied is an example of such an activity.

The use of LCA for technology characterisation and priority setting:
a methodology discussed by only a few countries but of interest here due to the special focus
Although it has not been discussed thoroughly by the countries, due to the focus on nation-wide activities or to the fact that there are not sufficient experiences to report, a methodology of interest in relation to data characterisation and priority setting is life cycle analysis (LCA). Characteristic for this methodology is that it describes a product or technology from the cradle to the grave, i.e. it describes a product's energy and environmental impacts during the construction, use and disposal phases. Next, impacts on the environment, such as CO_2 and SO_2 emissions, are summarised at the level of environmental problems, such as acid rain and global warming. Finally, the last part of the methodology concerns the integration of the different environmental problems.
The characterisation of a technology by LCA differs from other methodologies, except the ExternE methodology, because of the cradle-to-grave approach. In other words, the scope is wider than in most other methodologies. On the other hand, it considers technology in isolation and not in a system. Only the ExternE study is not different from the LCA methodology with respect to the basic characteristics. In fact , it can be considered as a cost LCA.
Depending on purpose and scope, the LCA methodology may be of special interest to the user. In relation to priority setting, the methodology may also be interesting since dealing with the integration of different environmental impacts may be part of priority setting processes.

2.5.3 Methodologies for priority setting

The three groups of methodologies used for foresight, i.e. the *foresight of energy technologies prospects,* as discussed in the previous paragraph, are used in the process of *priority setting* in a large number of countries. Priority setting in technology selection is a complex process based on all kinds of aspects such as the technological potential and cost of investments, public acceptance of a technology, the influence of industries and non-profit organisations, general policy goals, etc. Many countries mention explicitly that no formal methods exist for the characterisation of technologies priority setting in energy politics.
Outcomes produced by the methodologies mainly form **the basis for debates** between decision-makers from politics, science and industry. In such debates, priority setting is based on:
- primary energy policy goals, such as safety and the long-term security of energy supply;
- secondary policy goals, such as environmental aspects (emission targets, environmental acceptability), energy conservation and employment;
- the projected role of different energy technologies in future energy scenarios;
- the projected impact of the different technologies on energy supply and demand, economy and environment;
- the market and industrial opportunities of the technologies;
- socio-economic indicators, such as public acceptance;
- established interests and political positions.

The United Kingdom is the only country which described a methodology to structure RDD&D priority setting completely. The methodology is part of the UK Appraisals and takes into account MARKAL model scenario results. It is a systematic approach developed to deal with these scenario outcomes and some other technical and economic aspects such as environmental benefits and export potential. Although it is not used nationwide, the methodology is worthy of study. It has been used to advise the Department of Energy's R&D allocations in subsequent years. However, also in the United Kingdom, final decisions on the future allocation of funding for R&D programmes are based on both the outcome of the formal Appraisal process *and more strategic and political aspects taken into account by government ministers.*

A formalised method introduced by the UK to assist R&D priority setting
In the UK appraisals, a more formal methodology has been developed which is useful for RD&D priority setting. This methodology is not the nationwide standard methodology but is it is worthy of study here since it is a good methodology to integrate technical, financial and market information.

In the methodology, the following steps can be distinguished.

1. Technology characterisation of a wide range of technologies.
   In principle, the technologies described are all technologies available or potentially available to meet the UK's energy requirements.
2. Scenario studies
   Five scenarios were developed to represent a wide range of future economic and social backdrops against which to test the economic robustness of the energy technologies. Based on these scenario studies, technologies are characterised as being robust, vulnerable, fragile or unpromising. Robust technologies offer a potential contribution in all scenarios and at all discount rates. Unpromising technologies offer no contribution under any scenario. Vulnerable and fragile technologies lie in between. In addition, the technologies are classified according to the size of their largest potential contribution and by the time scale of their deployment.
3. The RDD&D appraisal process determines the areas most appropriate for existing government support. It consists of an MCA (multi-criteria analysis) of risk versus payback, a comparison between the content of the existing government-funded RDD&D programmes and the RDD&D opportunities identified during the study and a simple cost-benefit test of the existing government RDD&D programmes.

3a. In the MCA, risk is measured as technical risk, market risk, financial risk and import propensity (expert judgement) and payback is measured as the scale of timing of potential contribution, the environmental benefits of the technology and the export potential (expert judgement). Individual R&D programmes are represented on a matrix covering low, medium and high paybacks and risks. It was argued that the government funded portfolio of R&D programmes should lie on the diagonal of this matrix representing a fairly even balance of payback and risk.

3b. A cost-benefit test is carried out by equating the benefit to the difference between the total system costs calculated by the MARKAL model with and without the relevant technology or technology group.

Step 3 is illustrated by figure 4.

The results of the process described is a review and appraisal of a range of energy technologies and is intended to stimulate debate. It is a valuable work of reference for appraising current and future energy RDD&D programmes.

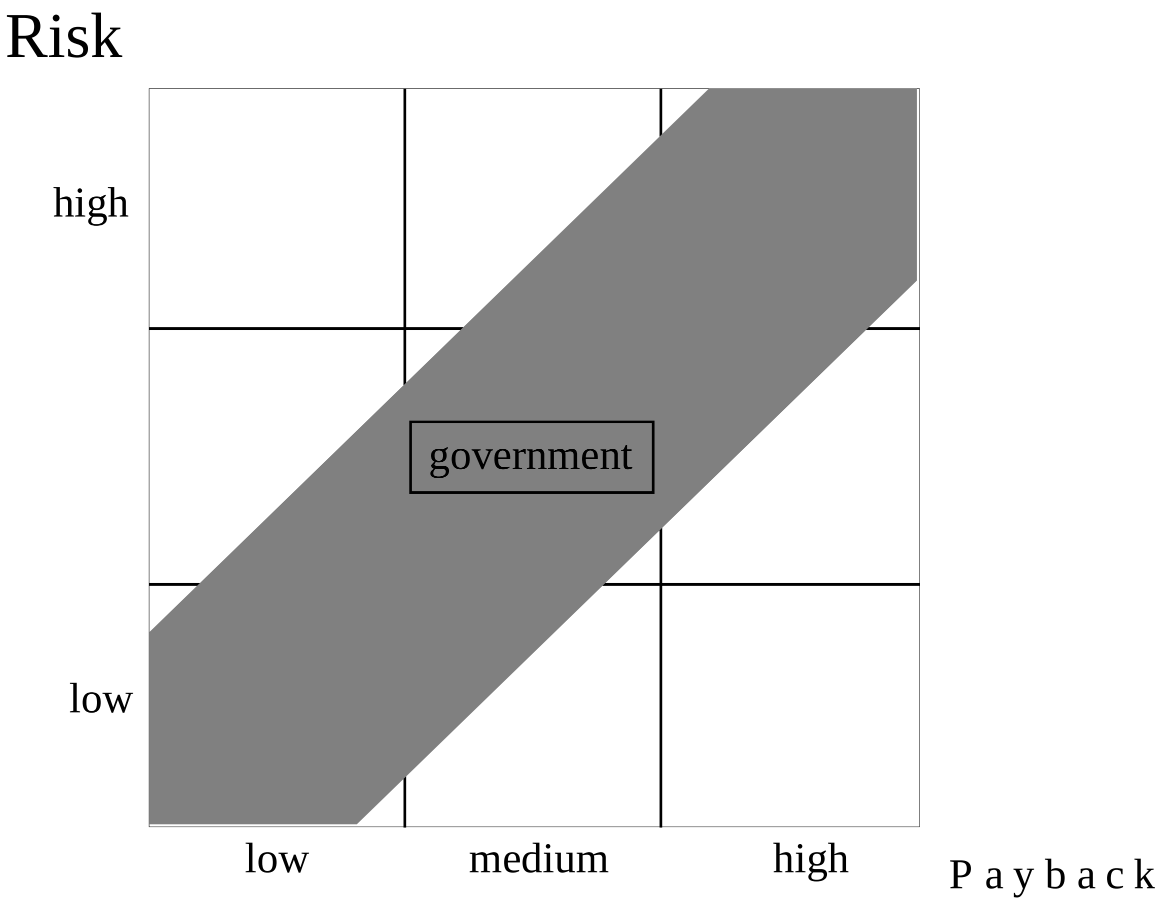


Figure 4. Government funded R&D programmes in relation to risk and payback.

3. EVALUATION OF THE NATIONAL APPROACHES

The characteristics of TC&F activities in the European countries were described in Chapter 2. This chapter gives an analysis of the TC&F activities which goes one step further. Section 3.1 summarises the trends that emerge from the country reports. As such it can also be regarded as a summary of Chapter 2. Section 3.2 gives an overview of the strengths and weaknesses in the current practice of TC&F in the countries as identified by the country teams. Finally, Section 3.3 discusses the changes in TC&F that have recently occurred and the opportunities to improve the current work approach. This last section combines the information in Section 3.1 and 3.2 to set recommendations for TC&F activities in the EU countries.

3.1 OVERVIEW OF THE COMMON APPROACHES IN THE COUNTRY REPORTS

Overview of activities

Almost all activities identified belong to one of the following categories.
1 Total national energy demand and supply
2 One or more individual sectors
3 One or more individual energy services, energy sources and technologies
4 Specific aspects of certain energy technologies and systems.

Most countries perform studies at each of the first three levels. However, a few countries are not reporting studies at the level of individual technologies.
Renewable energy technologies, technologies for electricity generation and industrial technologies receive most attention in TC&F activities. Fossil fuel production, transport and distribution of energy carriers and the technologies in the building/residential and the transport sector seem less interesting due to the limited number of TC&F activities performed for these sectors.

Scope and purpose

- Most of the identified studies that deal with technology characterisation and foresight are studies on a national scale. In most cases TC&F activities have time frames that do not go beyond the year 2030. Only a few studies have longer time frames. Studies with a long time frame dealt with e.g. central and decentral applications of solar photovoltaics (PV), combined heat and power (CHP).
- National energy plans usually have a time horizon of 10 to 15 years. The national energy plans form an important part of the total group of studies that deals with TC&F and in many cases they have a long tradition. They are generally updated every three to six years to keep up with recent developments.
- At the national level, technology characterisation and foresight studies usually serve general environmental and policy goals. Such general policy goals are e.g. to provide the country in a reliable way with clean and affordable energy. Reduction of CO_2 emissions is increasingly becoming a driving force behind the energy conservation programmes. At the moment, CO_2 emission abatement is a the most important environmental goal.
- Policy objectives behind TC&F activities at the sector or the activity level do not differ much from those at the national level. However, purposes related to sectors or technologies focus more on the development and evaluation of specific policy instruments or the possible role of specific technologies. With regard to environmental aspects, sector or activity activities more often consider other emissions, such as NO_x emissions, than CO_2 emissions.
- The primary purposes of TC&F activities are changing over the years. With a lessening of concern about security of supply and the increased prominence of the government policy to rely on market forces, R&D policy has also changed. Recently, several studies started to pay attention to the economic potential of technologies and industrial interests. It is noted, however, that in the long term, the policy objective to provide the country with energy may become of renewed interest to policy-makers because of the uncertainties about long-term energy supply.

- Results of TC&F studies are used to facilitate national, expert or political debates on desired future developments including the discussions on R&D priorities for energy technologies. In general, priority setting of technologies is never completely based on TC&F activities. Insights from TC&F activities are useful and often essential contributions to the decision process.

Technology characterisation and data collection in relation to scopes, purposes and activities

- Formal procedures for the priority setting process of TC&F activities are rearely found in the countries. In most countries different studies are carried out without a standardised form of data collection or technology characterisation. The lack of formal procedures is frequently identified as a shortcoming by individual countries. The level of detail of the data needed in different studies and in the different countries differs. A difference exists in the amount of quantitative data available in different studies. The lack of consistency and lack of an integral approach is often considered to be a weakness.
- In general, the following observations on the extent of data collection in TC&F activities can be made:
  1 technical and energetic parameters are often dealt with in great detail;
  2 economical and environmental parameters are dealt with in more general detail, but are identified as of increasing importance;
  3 commercial, market and behavioural parameters are considered very important, but at present are only addressed in little detail.
- In most countries, no national databases exist with technical and economic data of all technologies of the whole energy system. Constructing such a database, validating it and keeping it up to date, is very time consuming. Another problem faced when data are collected is the commercial confidentiality of some technology characteristics which does not allow the use of the best data. Technology data for future years are often based on expert opinions. Data based on expert estimates cause difficulties in the validation and cross-checking of the data.
- As indicated before, most TC&F activities focus at the national level. At this level, the scenario and economic data are required with relatively good detail and technology data with less detail. In national TC&F activities, international market information may be included. The international aspects which currently become more important are the strength of the national R&D in relation to other countries and the likely market penetration and diffusion of a technology on the international markets. There is very little data available with respect to these issues. A second international issue of increasing importance is the reduction of greenhouse gas emissions.

Foresight methodologies and models used

- Methodologies exist for each of the three steps of TC&F activities (technology characterisation, analysis of consequences and priority setting). For technology characterisation and priority setting, there are few formal procedures or methodologies in use.
- Methodologies, such as some energy system models and the LCA methodology, are helpful tools for ranking technologies based on technical and economic aspects. However, in practice priority setting is the result of such rankings, industrial and market opportunities, policy interests, socio-economic impacts and barriers, etc.
- In general three groups of ranking methodologies exist: formal models or methodologies, experts panels and economic indicators.
- Most countries use at least one of the models EFOM, MARKAL, MIDAS or MEDEE. Regarding EFOM and MARKAL, at least one of these is used by 50% of the countries, include both the demand and supply side of the energy system. The models minimise costs taking into account all kinds of constraints relevant for the energy system. A trend exists towards including 'external costs' and other economic indicators.
- A few countries use a combination of scenario analyses and formal ranking methodologies to identify technologies which can contribute significantly to future energy systems. However, for real priority setting, the likely market penetration and diffusion of the technology (national and international) and the strength of the national RTD institutes and industries are of strong influence. International collaboration in combination with national strengths is probably a prime mover in the developing interest in the market risk, market status and the export potential of technologies.
- Modelling and foresight studies are not prime movers for priority setting in energy RTD. At a national level, the studies are often used to facilitate national or experts debates on desired future developments in energy

technology. Outcomes of Technology Characterisation and Foresight activities at best play an indirect role. Expert consultations and policy objectives are dominant. In addition, identification of specific technologies of interest often takes place within the framework of a specified R&D programme. (Such programmes, of course, are also influenced by policy objectives.)

- One country (UK) applied a more formal methodology for priority setting at the national level. This methodology combines the main aspects which are relevant for priority setting. The methodology includes technology characterisation, scenario studies, risks (market, technical and financial risk) and payback (the timing of potential contribution, export potential, environmental benefits).

Due to the complex and 'political' nature of the governmental RTD priority setting process it is difficult to assess the impact of TC&F-activities on the final energy RTD-priorities. However, the country reports raise the question of whether the existing TC&F activities can better meet the needs of the clients involved in this process.

3.2 NATIONAL STRENGTHS AND WEAKNESSES OF THE METHODOLOGIES REGARDING TECHNOLOGY CHARACTERISATION, FORESIGHT AND PRIORITY SETTING

The methodologies used for technology characterisation or foresight activities have been discussed in section 2.4. This section evaluates strengths and weaknesses of the methodologies and consists of two parts. Subsection 3.2.1 first discusses strengths and weaknesses of several methodologies on data characterisation and foresight discussed in the country reports. Second, it discusses technology characterisation and energy modelling at the EU level. Third, it discusses LCA, a methodology which got little attention in the country reports since the reports focus on activities at the national, sectoral, and groups-of-technologies level but which may be of special interest depending on the intended scope and purpose. Subsection 3.2.2 discusses strengths and weaknesses of priority setting processes. Finally, subsection 3.2.3 discusses strengths and weaknesses reported by the individual countries.
The findings presented in this section are based on the country reporting and additional insights from prior JOULE projects, IEA conferences and experiences for a few non-EU IEA countries.

3.2.1 Methodologies for technology characterisation and foresight

The methodologies for technology characterisation

- The lack of a consistent and integral approach in the collection of technology data is often mentioned as one of the main shortcomings of TC&F activities. Establishing and maintaining a database requires substantial efforts. Technologies are often difficult to compare because technology characterisation may often be based on different system boundaries and biased information. There are various ways to improve the comparability and validity of the data, e.g. by asking for cost breakdowns and requiring cross-checking with other technologies and by performing peer reviews. Many countries lack a standard database including all technologies of the energy system and perceive this to be a shortcoming.

Expert panels used for technology characterisation and foresight

- Expert panels are used for data collection and technology priority setting. The use of expert panels in these processes facilitates a greater dialogue between the users of technological solutions (industry, government) and providers (academia, research organisations). Above all, contrary to computer models, experts are able to take into account various kinds of aspects, such as technological parameters and public acceptance in the process of technology selection. But the use of expert panels also has its disadvantages. Since expert panels estimates are based on personal opinions, the method is not very transparent, is subjective and very time consuming.
- A way to combine the advantages of expert panels and cope with its disadvantages at the same time is to collect data from literature and industry and then use review panels consisting of people with special expertise or insight for discussion and advice.

Computer models used for foresight

- Most countries use computer models, such as EFOM and MARKAL, to support the energy and policy planning at a national level. These models describe the whole national energy system; they cover both supply and demand side. A strength of such nationwide computer models for ranking technologies is the existence of an instrument by which knowledge of technologies can be structured and by which these technologies can be compared taking into account e.g. costs, CO_2 emissions reduction potential and a limited number of other characteristics and conditions. By using a computer model, one is able to study the possible impacts of new technologies in relation to all other technologies used on the same energy market.
- A frequently quoted weakness of the energy system models is linked with the models' limitation in modelling the commercial penetration of energy technologies in the market. Models that simulate the behaviour for the demand side of the energy system are better able to model this than least-cost optimisation models, although the parameters for the commercial uptake are still difficult to validate.
- A potential weakness of the nationwide computer models as experienced by some countries, is the danger of hidden assumptions (and mistakes) in the comprehensive model which are not clear to the user of the model. This may lead to problems that data are used out of context and could lead to wrong conclusions.

In general, model results do influence decision-making processes but they do not give straightforward answers. They create a basis for debates and describe technical potentials taking into account technical parameters and costs.

- Models are unable to consider strengths and weaknesses of, for instance, national R&D institutes and national industries, public acceptance of new technologies, institutional barriers, etc. These aspects all influence political decisions as much as technical potential and costs of new technologies do. This exclusion of commercial opportunities, behavioural factors and other non-technical influences in methodologies used for technology ranking is considered to be a limitation of these methodologies. Models could cover parts of these aspects but it is generally accepted that they will not be able to cover them all.
- For decision-making and priority setting, one can use the strengths of computer models. However, at the same time, one should be aware of the weaknesses of the models and accept that they will not be suited to answer all questions or to judge, for instance, investment decisions at the national level. Some possibilities exist for improvement of the model use and to diminish weaknesses. Good support of model users by experts may decrease the use of models results out of context and good manuals and up-to-date descriptions of the models can also improve the models' use.
- One 'problem' related to model use is difficult to avoid. This is the process of collecting data of all relevant technologies modelled and to keep these data sets up to date.
- A weakness according to several country reports and arising from the existence of several computer models, each model with its own strengths and weaknesses, is the fact that no systematic effort has been provided to develop a standard methodology or to choose the right model for the right application, if there is one. However, what is right may also depend on insights which may change according to time and place. The use of a wider range of models to handle the same kinds of problems, but with focus on slightly different aspects, is recommended.

Technology characterisation and energy modelling at the EU level

- Results from technology characterisation activities at the level of the Member States cannot automatically be translated to an EU methodology. Additional problems exist when looking at technology characterisation at the EU level. Friedman (1994) distinguishes problems that need to be approached in greater depth. For an elaboration of these problems, see Box 1.

LCA, a different approach

K. Friedman, in: IEA-Novem workshop on Technology Characterisation and Databases in Energy Modelling, Schiphol, The Netherlands, 8-9 September 1994

Problems that need to be approached in greater depth

- At a fundamental level, the definition of a technology is a difficult problem. How is a technology defined? What are the boundaries of a technology in terms of current and future markets? Can common definitions of energy technologies and their characteristics be developed and agreed upon? Will such definitions allow comparisons across characterisations? Does one use specific or representative technologies? Can range estimates be provided? Should descriptions of the markets for technologies be included (e.g. extent of market penetration and constraints that impede it)?
- How dependable are the data? One observes, for example, that the providers of technology data are also often technology advocates, suggesting that validation processes are called for. Furthermore, some data are quite perishable if they are not updated.
- How many technologies should be characterised? Clearly for some tasks it is desirable to have information on many technologies; but the collection and organisation of the information required to characterise them adequately is very expensive. It is necessary to consider the trade-off between the depth and quality of characterisations and the number of them that are done.
- Can data sets be shared? How sensitive are the characteristics of technologies to specific national contexts?
- Models based on technology characterisations are often used in an international context in which comparability of results across different countries and different models is of considerable importance. Such comparability is dependent on the use of data that are consistently defined.
- The above problem is made more difficult because many energy/environmental models are not adequately documented or transparent. Dealing with this issue is more difficult in the cases of proprietary models.

- The methodologies described above mainly play a role at the national level or at best regional level. The methodologies are used and discussed by many countries. Another technology characterisation methodology worthy of mention here is life cycle analysis. An LCA of a product or technology describes its energy and environmental impacts from the cradle to the grave. Depending on the intended purpose and scope of an activity, this methodology to characterise a technology may be of special interest. LCA studies cannot include energy system interactions. Therefore, they cannot replace energy system models.

3.2.2 Priority setting methods

Methodologies for priority setting

Priority setting in technology selection is a complex process based on all kinds of criteria such as the technological potential, costs, environmental impact, development state of the technology, the strengths and weaknesses of national R&D institutes and national industries, public acceptance of a technology, institutional barriers, the influence of industries and non-profit organisations, general policy goals, etc. No standard methodology exists to combine all these aspects. This can be considered as both a weakness as well as a strength.

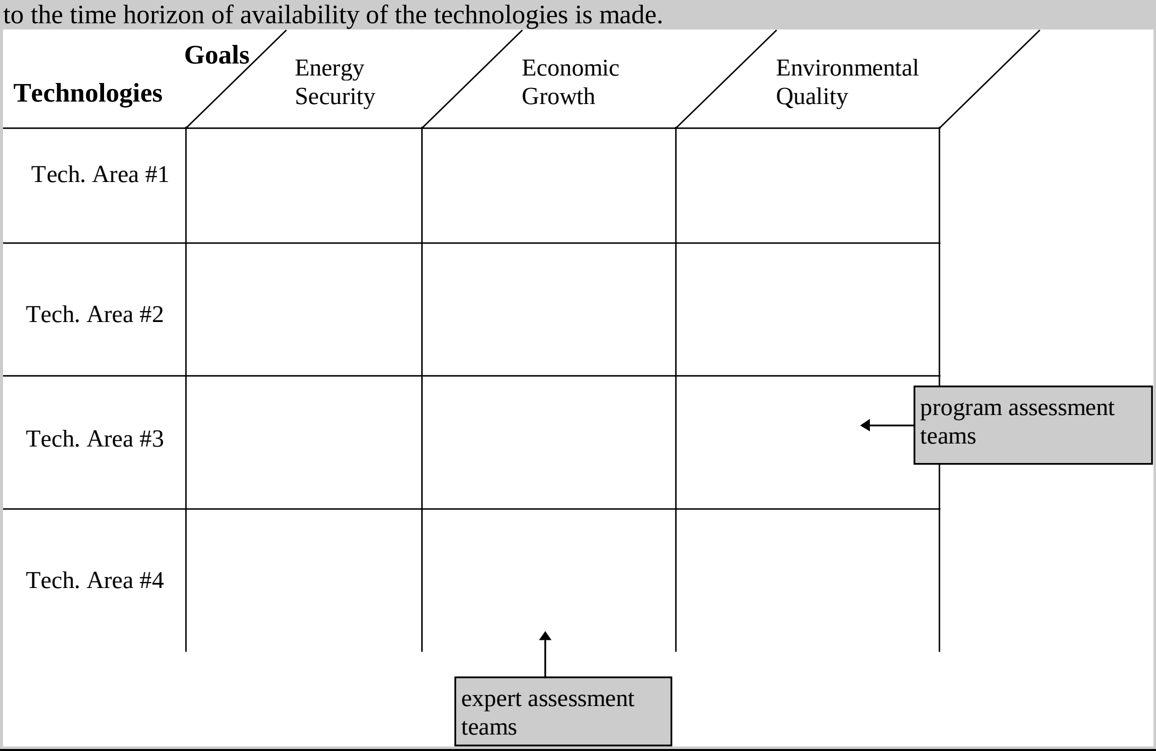
- Two different approaches exist in general: more structured and less structured approaches. Some countries favour the less structured approaches. As the country report of France states, different methods and practices should be deployed in the field of energy technology foresight and characterisation. According to France one should leave room for the debate by different practitioners about alternative visions and one should confront technologies with different but 'scientifically' equally valid methods.
- A disadvantage of the qualitative approach is that decision-making based on debates instead of formal procedures is less transparent and remains more subjective. The more structured quantitative approach makes use of energy system models. The prospects of energy technologies are analysed within different energy scenarios. Further, the industrial strengths, export benefits etc. are analysed in a structured way. The United Kingdom and the Netherlands mostly apply the more structured methods.

A methodology developed in the United Kingdom discussed before seems a good methodology to cope with the advantages of both approaches, i.e. leaving room for discussion, and disadvantages, i.e. the lack of a formal methodology. Application of this methodology structures debates more than model technology ranking methodologies alone will do. However, it is not forcing or, in other words, still leaves room for debates.

The methodology used in the US at the Department of Energy, a global description of which is given in Box 2, is an example of a relatively structured approach, solely based on expert opinions.

A Comparative Assessment of Potential Contributions of Advanced Technologies To National Energy, Economic & Environmental goals, by dr. Robert E. Marlay, Office of Technology Policy, U.S. Department of Energy

The priority setting method as is used by the US Department of Energy is a typical example of the second approach, in which no modelling tools are used. In this process, a two-track approach is used. First, Program Assessment Teams give priorities to energy technologies. Secondly, Expert assessment teams give priorities to topics in the field of economic growth, environmental quality and energy security.
Based on the following matrix, technologies are ranked, according to the highest priority. A further division with regard to the time horizon of availability of the technologies is made.



Methods to estimate benefits of R&D
Various other studies (e.g. Ashton, 1994) have identified the shortcoming to assess the benefits of R&D. Assessment of the benefits of R&D could be an important aspect of TC&F activities.

Priority setting at the EU level
A methodology for priority setting at the level of the different Member States cannot automatically be used at the EU level. Marsh et al (1994) looked at "Methodologies for Assessing the formulation of an EU Energy R&D strategy". The objectives of this study were:
- to review national approaches to the formulation of R&D strategies particularly in the area of energy technologies;
- to recommend appropriate methodologies for the formulation of the EU's energy R&D strategy;
- to review and advise on strategy proposals formulated by the Commission.

To come to priority setting at the EU level, three "fundamental questions" are covered in the report:
- at what level of R&D decision-making should the methodology be directed?
- what constitutes an energy R&D programme?
- what is the scope of the R&D to be covered by the methodology?

From the study, three important aspects of priority setting at the EU level are derived.

1. The EU may have energy R&D objectives needs that are different from those of the Member States.
2. EU energy R&D objectives are probably best assessed at EU level.
3. Some R&D activity is better conducted at the EU level.

Priority setting at the EU level has some additional aspects that have to be taken into account, if compared with the priority setting process at the level of the separate Member States.

3.2.3 Strengths and weaknesses reported by individual countries

Austria
Austria does not consider it necessary, as a small country, to cover all kinds of energy technologies in R&D. The current approach of TC&F is considered satisfactory to provide the information required for R&D decisions.

Finland
Finland possesses a good reference data set on the best available energy conversion technologies and has wide experience with the applications of technology-oriented energy system models. It considers as weaknesses the difficulty to collect technology characterisations based on uniform criteria and the lack of standard methodologies for the ranking of energy technologies. Further, it identifies the time and resource consuming continuous maintenance and updating of database as a bottleneck in TC&F activities.

France
France has highly detailed bottom-up data available for a wide range of demand-side technologies. These are both technical quantitative data and policy-oriented qualitative data.
Contrary to other countries, France does not use integrated energy system models for national studies. France considers this to be a weakness. France stresses that the lack of a quantitative approach leaves more room for alternative visions and confrontation of different 'scientifically' equally valid methods for TC&F. France notes that it has made a choice in the past for the establishment of a nuclear electricity system. This choice implies that a large number of technological choices are fixed at least for the duration of the pay-off of nuclear investments. Consequently, TC&F activities on energy R&D in France are also carried out with this important consideration in mind.

Norway
The major weakness of TC&F activities in Norway is the limited activity in the field of TC&F for priority setting of RD&D in Norway. Ex ante evaluations are considered much more important.

Portugal
A fundamental weakness in the TC&F activities in Portugal is the lack of organisational structures and sufficient financial support to establish qualified and permanent teams to perform TC&F studies. Energy models have never been used in Portugal for R&D priority ranking. Further, Portugal still misses a reliable and updated database on energy technologies.

Spain
In Spain, research lines are closely linked to the main energy needs of the country. This is guaranteed as most of the participants in the project selection process are parties in the energy sector. Spain misses instruments to analyse long-term aspects of the energy system. In Spain the TC&F activities have focused too much on the electricity sector, other sectors should be considered more. Environmental objectives have not yet been considered much.

United Kingdom
The main strengths of the 1992 Appraisals lay in its rigorous and comprehensive data collection and validation, its use of scenarios for sensitivity testing, its transparent prioritisation methodology and peer review by independent advisory committees. Although the workings of the energy system model itself were a `black box' to outside observers, and thus potential weaknesses, this could be avoided as the modelling process took the form of an iterative dialogue between modellers and technology experts, until the experts were satisfied that the model

constraints were realistic and the results were valid. A limitation of the approach was in the scale of effort which made the exercise time consuming, requiring two years to complete. A restriction lay in the modelling of the commercial uptake of technologies, particularly in the demand side. Data on technology uptake rates are difficult to obtain. The multi-criteria analysis is probably the most sophisticated one of all TC&F examples considered, but it is still considered very simple. It could be refined by considering more environmental impacts and socio-economic impacts.

The Netherlands
The wide range of TC&F activities is regarded as a strength. The joint learning process that results from the frequent interaction between analysts and clients is also regarded as a strength. The Netherlands considers the limited cross-referencing between studies and the limited use of insights and results between different TC&F activities as a weakness. The SYRENE study used a comprehensive data set of technology characterisations based on literature surveys and expert estimations. A weakness of the SYRENE study is the lack of one formal methodology prescribed for data collection and a lack of an integral analysis and validation of data, such as cross checking between data provided by different authors. This weakness is also identified by other Dutch TC&F activities such as the 'foresight study on energy conversion technologies' that concludes that unbiased techno-economic information is not available. Various possibilities have been identified by the Dutch to improve the validity and comparability of the data.
The Netherlands consider the fact that MARKAL does not distinguish different market parties as an important weakness. A weakness of SYRENE was the limited possibilities to perform sensitivity analysis with the technology data as this would have been taken too much time. Priority setting could be improved considerably by including other aspects such as industrial strengths, export potential etc.

4. CONCLUSIONS AND RECOMMENDATIONS

4.1 CONCLUSIONS

In Figure 2, introduced in section 2.1, an overview is given of the three steps in which TC&F activities take place. In Figure 5, this is elaborated to an overview of the kind of activities that take place in each step, and the relationships between them. Also a general indication of the methodologies as used in the several activity groups is given.

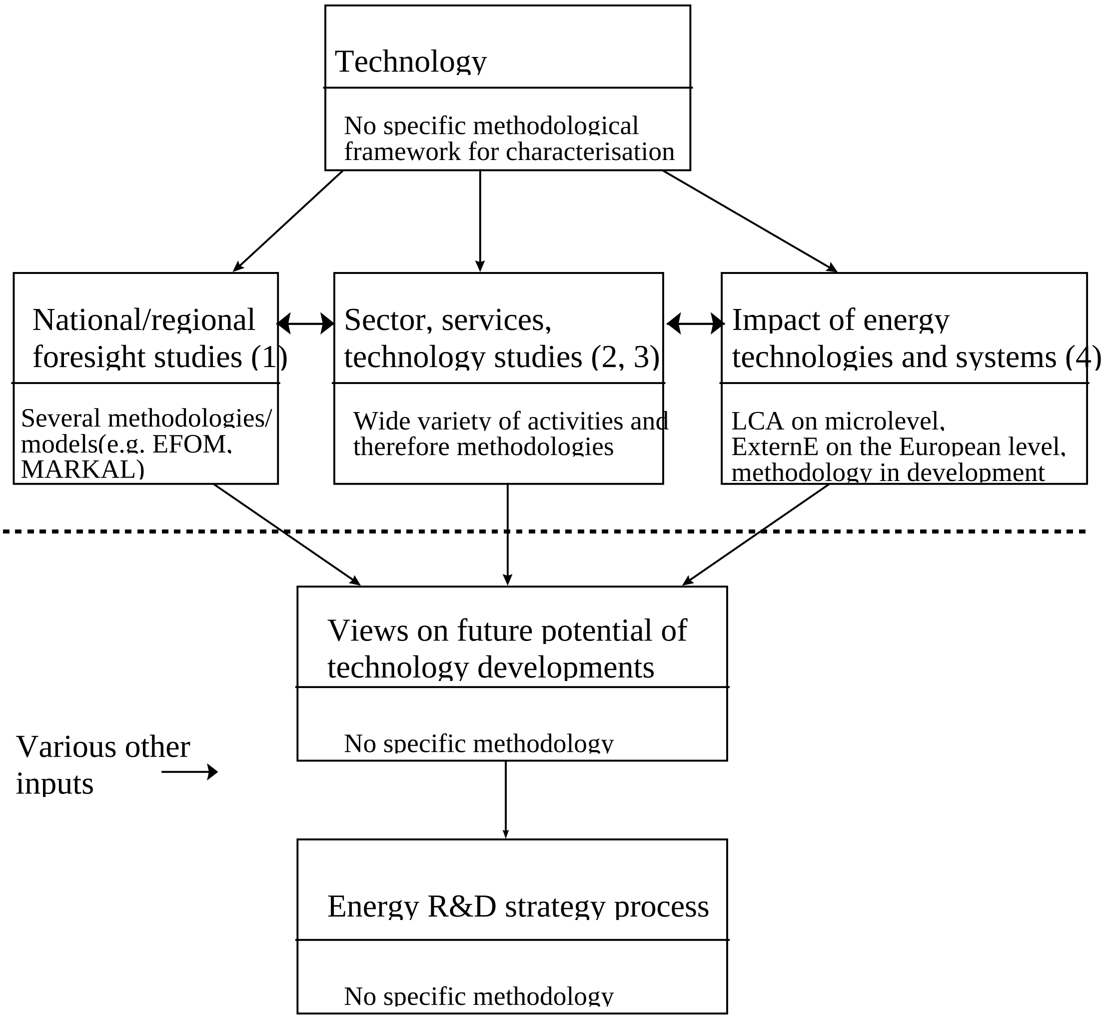


Figure 5. Overview of the type of studies undertaken within Technology Characterisation and Foresight activities and the methodologies used.

This Topic Report deals with activities in the field of technology characterisation and foresight and their use in the process of energy RTD strategy development. In these processes, various kinds of other inputs and influences play a role, as indicated in figure 5.
These ‘other’ elements are not included in this report. Based on the analysis of TC&F activities, the following conclusions can be drawn.

1. **Technology characterisation**
- Priority setting activities require the characterisation of energy technologies. Several Member States spend much effort on technology characterisation.
- Problems with technology characterisation are:
  - in most countries there is no consistent and integral approach for data collection or technology characterisation; this is especially relevant for the foresight of future cost and future market potential of technologies;
  - the establishment and maintenance of data(bases) requires substantial efforts and is time consuming;
  - expert judgements are often used and perceived as subjective and not very transparent.
- Little (international) exchange of technology characterisation data or co-operation in data gathering has been found.

2. The analysis of future impacts and consequences
- For the analysis of future impacts and consequences four different groups of studies can be distinguished. These groups all make use of technology characterisations.
- Activities at the national/regional level make more use of activities at the levels of sectors, services and technology studies than the activities at the sectoral level, and the levels of services and technologies make use of activities at the national level.
- Activities at the level of impact of energy technologies and systems usually do not interact with activities at the other levels.
- The perspective of the purpose and scope of activities has changed. Security of supply and cost efficiency have been the main concerns in TC&F activities. Nowadays, environmental issues and economic and market opportunities have become the most important objectives.

3. Methodologies
- At the national/regional level several methodologies are broadly used, including modelling activities with models such as EFOM, MARKAL, etc.
- For activities at the level of sectors, services and technologies, a wide variety of methodologies are applied.
- Methodologies at the level of the impact of energy technologies and systems are in development. On the micro level, life cycle analysis is used frequently.

4. Process of RTD strategy development
- Models and foresight studies are not prime movers for priority setting in energy RTD. Energy RTD strategy development is often seen as a political process. TC&F methodologies can supply inputs to these processes, or facilitate national or expert debates.
- The impact of modelling results on R&D priorities may depend strongly on the attractiveness of the presented results to the decision-makers.
- Only one example has been found of using a specific integral methodology to support the process of RTD strategy development.
- There is no "ideal" methodology for energy RTD priority setting. Good practices consist of various combinations of analytical and consulting methods.
- Much experience exists with regard to energy R&D priority setting in various Member States. These experiences can be used to improve the co-ordination between European and national energy RTD strategies.

4.2 RECOMMENDATIONS

Based on the analysis and the conclusions drawn above, four major recommendations could be formulated to contribute to the improved use of TC&F activities in the process of energy RTD strategy and programme development on the European and national level.

1. **Support the data exchange and co-operation in data collection between Member States and between the EU and national activities.**

   Technology characterisation and technology data collection is time consuming and the quality of the data determines the quality of the results of the studies carried out. Much data are not country specific but international, so international exchange could improve efficiency and offers more possibilities to check and review the data and the various sources.
   Member States should be involved in any international data collecting activity, because countries seems to be reluctant to use models or data developed or collected elsewhere.

2. **Develop a benchmark for energy foresight models**

   WHY:
   - There are several models in use, developed for different purposes.
   - The different models are hard to compare, which needs insight in model structure and assumptions made. This will require substantial effort.
   - Standardised procedures to compare models, laboratories, components and products are in use everywhere.

   WHAT:
   - Develop a set of input and output requirements to synchronise the data is used in different modelling activities.
   - Develop a test procedure, including a set of input and output data.
   - Describe the tolerance (reliability and uncertainty) levels for the results.
   - Carry out a benchmark procedure with some of the models.
   - Set up a benchmark organisation.
   - Categorise models with respect to their main purpose.

3. **Investigate coherence and interaction aspects between different models/methodologies**

   WHY:
   - There are, most of the time, 'separated worlds' that deal with energy modelling, LCA studies, external cost studies, sector/services/system studies.
   - Results from the different studies cannot be used, although sometimes very useful, in other types of studies.
   - A common approach for data collection and presenting output could enhance the reliability and comparability of the results.
   - Priority setting must and will integrate all aspects and not just one or two.

   WHAT:
   - Compare input data on technology, scenario assumptions and fuel prices between several type of studies.
   - Compare the overlap in methodology, for example on cost calculations.
   - Analyse what type of data or output could/should be used in the other models.
   - Analyse the differences in results for priority setting between the outcomes of several studies (energy models, LCA/ExternE, sector studies).

4. **Analyse national energy RTD strategy processes and opportunities for co-ordination and synergies**

WHY:
To understand the process, it is essential to know what factors have influenced the decisions and what the actual impact is of the methods used. To improve co-ordination it is necessary to know the differences between the priorities in the Member States.

WHAT:
- Evaluate the outcomes of the national energy models (ranking of technologies) with the outcome of the R&D priority setting process (money spent on R&D for several technologies).
- Evaluate the process between energy studies and the actual decisions about the budget. Try to find out what arguments have influenced the decisions.

5. REFERENCES

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Ashton, 1994

6. APPENDIX 1 COUNTRY REPORTS

The countries from which the country reports are used in this topic report, as well as the organisations responsible for the reports, are listed in Table A.1.

Country	Organisation
Austria	Austrian Energy Agency (EVA)
Belgium	• Institut Wallon • Flemmish Institute for Technology Research (VITO)
Denmark	Energy Centre Denmark (ECD)
Finland	Technical Research Centre of Finland (VTT)
France	Agency for Environment and Energy Management (Ademe)
Germany	Research Centre Jülich (KFA)
Greece	Centre for Renewable Energy Sources (CRES)
Ireland	The Irish Energy Centre (Forbairt)
Italy	Italian National Agency for New Technology, Energy and the Environment (ENEA)
The Netherlands	Netherlands agency for energy and the environment (NOVEM)
Norway	Institute for energy technology (IFE)
Portugal	Centre for Energy Conservation (CCE)
Spain	Centro de Investigaciones Energeticas, Medioambientales y Tecnologicas CIEMAT
United Kingdom	Energy Technology Support Unit (ETSU)

Table A.1 The countries from which the country reports are used in this topic report, as well as the organisations responsible for the country reports.