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Author(s)		
Name	**Organisation**	**E-mail**
Oscar Amerighi	ENEA	oscar.amerighi@enea.it
Umberto Ciorba	ENEA	umberto.ciorba@enea.it
Maria Cristina Tommasino	ENEA	cristina.tommasino@enea.it

Abstract

This Models Characterization Report aims at creating an inventory of the existing tools that can cover transition planning and the specifications set out in WP1 (Deliverable D1.1). The inventory presented in this report examines 85 models and tools and relies partly on results of an open call to EU and non-EU modelling teams and partly on a review of the literature. The report contains a description of the identification and evaluation procedures, and an assessment and characterization of the models and tools identified. In addition, a set of matrices has been prepared in order to summarize useful information to support the decision and policy-making processes.

Inventory and characterization of existing tools

ATEsT Models Characterization Report

Deliverable D2.1

O. Amerighi

U. Ciorba

M.C. Tommasino

(ENEA, Italy)

http://www.atest-project.eu/

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Abstract

In the framework of the SET-Plan the European Commission has initiated action on planning the transition of European energy infrastructure networks and systems towards a low carbon future. This FP7 Support Action is named ATEsT (Analysing Transition Planning and Systemic Energy Planning Tools for the implementation of the Energy Technology Information System). The ATEsT project aims to provide a "toolbox" containing the methodologies, procedures and models required to support the decision making process for planning the development and roll-out of low carbon technologies and their supporting infrastructure. This Models Characterization Report aims at creating an inventory of the existing tools that can respond to the specifications about SET-Plan needs and priorities as set out in WP1 (Deliverable D1.1). The inventory presented in this report examines 85 models and tools and relies partly on results of an open call to EU and non-EU modelling teams and partly on a review of the literature. The report contains a description of the identification and evaluation procedures, and an assessment and characterization of the models identified. In addition, a set of matrices has been prepared in order to summarize useful information to support the decision making process.

Contents

Summary

The development and deployment of a diverse portfolio of low carbon energy technologies play a pivotal role to achieve the goals of the European energy and climate change policy - in terms of greenhouse gas emissions, security of energy supply and competitiveness. The launch by the European Commission of the Strategic Energy Technology Plan (SET-Plan), with its focus on strengthening and giving coherence to the overall effort in Europe in the advancement of new energy technologies, represents the first step towards the building of a low carbon future.

In the framework of the SET-Plan, the European Commission has initiated action on planning the transition of European energy infrastructure networks and systems towards a low carbon future. This FP7 Support Action is named ATEsT (Analysing Transition Planning and Systemic Energy Planning Tools for the implementation of the Energy Technology Information System). The ATEsT project aims to provide a "toolbox" containing the methodologies, procedures and models required to support the decision making process for planning the development and roll-out of low carbon technologies and their supporting infrastructure.

This Models Characterization Report builds an inventory of the existing models that can cover transition planning and the specifications about SET-Plan needs and priorities as defined in the Specification Report. This characterization will be an input to work package 3 (WP3) in order to perform an evaluation of the models and to propose tools and methods to be used for transition planning and systemic energy modelling.

The inventory presented in this report examines 85 models and tools and relies partly on results of an open call to EU and non-EU modelling teams and partly on a review of the literature. The report contains a description of the identification and evaluation procedures, and an assessment and characterization of the models and tools identified. The "ideal" model type and requirements that a model should satisfy to deal with a specific SET-Plan issue have been presented in an ideal model matrix toolbox and some examples of methodologies used to couple models have been provided. Based on the assessment of existing models and tools, matrices for model characterization have been filled to show the degree of coverage for the different specifications. These matrices give an overview of the main critical energy system modelling aspects that need to be further or better developed. The key findings for the different SET-Plan topics can be summarized as follows.

Strategic Planning

- The specifications included in this section are covered by a variety of models, mainly "technology rich" Bottom-up or Hybrid models focusing on the entire energy system and sector specific "technology rich" Bottom-up models. In general, the evaluation of existing models and tools suggests the existence of a trade-off between systemic approach and local dimension coverage with a prevalence of sectoral (electric system mainly) models for specific project analyses. Qualitative tools can play a role in analyzing some specific issues related to future evolution or acceptance of technologies. For the analysis of issues related to macro-economic effects, top-down and hybrid (with a dominant top-down component) models with an international dimension can be helpful.
- Bottlenecks related to technology diffusion represent a critical aspect not properly covered by identified models. This would require an in-depth analysis of the production chain for a given technology.

Technology Deployment and Transition Planning

- The specifications included in this section are the most challenging and difficult to analyze from a modelling viewpoint given the multi-dimensional nature of the issues considered and the high level of local detail required. As a general conclusion, it is possible to outline the lack of systemic approaches at local level and a scarce interrelation between technical and behavioural issues.
- Spatial Planning of technology deployment requires models with a high geographical detail at the local level. Some disaggregated and sector models provide information on technology and infrastructure development with a high territorial detail as well as on the capacity and the integration of existing

infrastructures. What is missing is a systemic approach that analyses competition between different energy carriers and new infrastructures location.

- Some hybrid I-A models and some top-down economic models can be useful in the assessment of issues like land use, territorial integration, availability of natural resources, and the effect of technology deployment on labor demand. Qualitative tools may be helpful mainly in analyzing synergies between technology, industry, social and policy changes.
- Infrastructure expansion for technology (CCS and Hydrogen) deployment can be considered a key priority for future research. The same applies for territorial integration and migration flows (in particular, concerning their impact at local level).
- Timing and market design issues are hardly covered as a primary focus by the quantitative models identified in the analysis. However, socio-technical scenarios can be used to account for time delays and different regulatory frameworks in a qualitative manner when building alternative transition paths for the energy system.
- Some of the specifications related to the Acceptance and Perception of a Technology are not satisfactorily dealt with by identified models mainly because of the lack of the appropriate level of spatial and sectoral detail that would be needed to cover them. Moreover, the specificity of some of these issues (e.g., landscape preservation, health impacts, siting and safety issues) would need dedicated sub-modules to be addressed properly.

Innovation and R&D

- R&D activities present an intrinsically high degree of uncertainty. Consider, for instance, the relationship between public and private R&D funding devoted to a particular technology or sector and the effective return (in terms of innovative technologies and/or products) of such investments. Such an uncertainty makes it difficult to quantify by means of a model the effectiveness of R&D spending and to make forecasts about the sectors or technologies that deserve particular attention (hence, funding) by public and private decision-makers.
- Horizon scanning methodologies are relevant to identify the risks involved in research activities, but only partially the risk of a technology breaking through.
- A very limited number of hybrid Integrated Assessment or econometric models are able to account for the effects of both R&D spending and public-private R&D funding in achieving EU policy goals. Many models, however, can analyse the consequences of learning resulting from R&D investments as long as learning parameters are an exogenous input to the model.
- The identification of sectors and technologies exposed to international competition and the definition of strengths and weaknesses of EU and national industries would require an extremely disaggregated representation of trade flows (branch level instead of sector level) as well as a detailed technology representation which are mostly missing from existing models.
- There is a lack of useful models designed to deal with technology specific R&D targets and monitoring of funding mechanisms or able to quantify the necessary amount of R&D spending needed to become or to stay competitive with non-EU countries.

International cooperation

- A good number of multi-country and global models with different analytical approaches developed both in Europe and by extra-EU research institutions cover as their primary focus the potentials of JI and CDM and technology market developments at the world level. In addition, socio-technical scenarios can be used as a complementary tool for qualitative assessment of the potentials of JI and CDM as well as of the effects of turning partial to perfect spill-over.
- A few Integrated Assessment econometric models are able to perform an evaluation of costs and benefits of R&D collaboration for both EU and non-EU countries.
- Although global macro-economic models with a description of some energy and environmental sectors or commodities are useful to evaluate the benefits of international cooperation initiatives, most of the specifications under the heading International Cooperation on R&D are difficult to analyze by relying on quantitative models. On the contrary, some of the specifications can be investigated by means of qualitative tools such as horizon scanning methodologies.

1. Introduction

In order to achieve the goals of the European energy and climate change policy, in terms of greenhouse gas emissions, security of energy supply and competitiveness, the development and deployment of a diverse portfolio of low carbon energy technologies play a pivotal role (*An Energy Policy for Europe* COM (2007)1).

The European Strategic Energy Technology Plan (SET-Plan), adopted by the Commission on 22 November 2007, is the European Union's response to the challenge of accelerating the development of a low carbon future, leading to the market take-up of low carbon energy technologies. This plan comprises measures relating to planning, implementation, resources and international cooperation in the field of energy technology.

1.1. ATEsT project

The implementation of the SET-Plan involves different pillars:

- Effective Implementation:
  - Creating European Industrial Initiatives (EII), focusing on technologies for which the barriers, scale of investments and risk can best be tackled collectively.
  - Creating a European Energy Research Alliance (EERA), to enable greater co-operation across Europe of the research work going on in universities, research institutes and specialized centres.
  - Planning the transition of European energy infrastructure networks and systems.
- Joint strategic planning:
  - Creating a European Community Steering Group on Strategic Energy Technologies, which allows Member States and the Commission to plan joint actions and coordinate policies and programmes.
  - Establishment of an information system on energy technologies and their innovation aspects, geared to supporting the decision-making of the SET-Plan (SETIS).
  - Annual SET Plan summits.
- Increase in resources, both financial and human, and enhance international cooperation.

In the framework of the SET-Plan implementation pillar, related to addressing future European energy infrastructure networks and systems transition planning, the European Commission has launched an FP7 Support Action named ATEsT (Analysing Transition Planning and Systemic Energy Planning Tools for the implementation of the Energy Technology Information System).

The aim of the ATEsT project is to address the methodologies and modelling toolbox required to support the decision making of the SET-Plan Steering Group in the priority area of transition planning of the deployment of low carbon technologies and their supporting infrastructures. ATEsT is a joint effort between European research institutes (CRES, ECN, ENEA, IER, VTT, PSI, CIEMAT, EIHP) and the JRC, the implementing body of the Information System of the SET-Plan (SETIS).

The “tools” that will be evaluated in the framework of ATEsT are methodologies for the analysis of energy policies and mathematical models that can be used in order to simulate the development of the energy system or analyse the transition planning in the energy system. The scope of the ATEsT project includes models and tools from both inside and outside Europe.

The objectives of the project are to:

1. Review models/tools used in European Countries, bearing in mind what is used outside Europe and what are the requirements of the SET-Plan.
2. Identify and recommend common tools and/or methods to be used in the Member States and in SETIS, and gain consensus on these models.

3. Identify and recommend existing sets of data (on technologies, energy resources, statistics, etc.), and provide a roadmap for the development of the data on a European and regional level.
4. Identify the roadmap for the improvement and development of the tools and methods in order to cover the needs of the SET-Plan implementation.

1.2. Contribution of Work Package 2

The first step of the ATEsT project was to determine the questions and issues of particular interest to the various parties relevant to the implementation of the SET-Plan. This was accomplished by work package 1 (WP1) and results are summarized in the ATEsT Specification Report (Schoots and Bunzeck, 2010).

The contribution of Work Package 2 (WP2) to the ATEsT project is to provide an inventory and a classification of existing models and tools that can cover the "list of specifications" set out in the Specification Report. This is an important point that must be kept in mind since the objective of ATEsT is to contribute to the implementation of the SETIS and not to perform a general benchmark of available models. This characterization will then be used by WP3 in order to perform an evaluation of the models and to propose tools and methods to be used for transition planning and systemic modelling.

In order to achieve this objective, the tasks have been divided in two main activities:

- *Identification of the existing models* that cover the transition planning and systemic energy modelling.
- *Characterization of the models*, based on their primary focus following the methodology that has been elaborated and presented during the stakeholder workshop that took place in Brussels in the context of WP1.

Throughout the report, the term "model" will generally be used to identify different types of tools, methodologies or procedures for the analysis of the energy system. More specifically, the terms "methodology" and "procedure" refer to a sequence of codified and systematic steps (shared by the scientific community) in investigating a given topic. The term "model" applies to quantitative mathematically-based (e.g., system optimisation, market simulation, mathematical programming, etc.) methodologies whereas the term "tool" will usually denote applications of methodologies intended to perform semi-quantitative (combining data and qualitative information) and/or qualitative assessments.

The methodological approach adopted and the procedure followed in identifying and characterizing models is described in Chapter 2 of the report. In Chapter 3, an ideal model matrix toolbox relating model categories to SET-Plan topics is built as a benchmark for model characterization, coupling issues are discussed and some descriptive statistics on the models analyzed are illustrated. Chapter 4 summarizes the results on primary focus assessment whereas Chapter 5 provides information on the features of the models and on the level of detail a given topic can be addressed. Chapter 6 illustrates with an example how results from the analysis can be used by policymakers. Chapter 7 concludes with some general remarks. The material elaborated for models identification and characterization is collected in Appendix. Appendix A contains the documents (questionnaire and guidelines) prepared and used for the open consultation. The list of models analyzed in the report can be found in Appendix B. The evaluation matrices for primary focus assessment and for feature analysis are gathered in Appendix C and D, respectively.

2. Methodology

WP2 aims at making an inventory of existing models and tools that cover transition planning and systemic energy modelling. The main instrument to perform this task is through an open consultation. To this end, a classification form (or questionnaire) and detailed guidelines were prepared and then submitted to EU and non-EU modelling teams.

The preparation of the classification form took place in several steps. First, model features commonly used to classify energy system models have been identified based on a selection of contributions in the literature on this issue. A preliminary version of the classification form (or questionnaire), together with the corresponding guidelines, were written down and circulated among the ATEsT project partners before the stakeholders' workshop held in Brussels on January 2010. Then, based on the issues raised during the workshop, the classification form and the guidelines were revised to take into account the specifications summarized in the Specification Report. The final version of the classification form and guidelines can be found in Appendix A.

A selection of relevant models was agreed upon by the ATEsT project team for actively approaching their developing and/or maintaining teams to fill in questionnaires. The final list of models can be found in Appendix B.

The classification form and guidelines were submitted to these modelling teams, as well as made available on the ATEsT project website as an open call for other interested modelling teams. For relevant models on which the modelling team did not reply, classification forms were filled by the ATEsT project team based on literature references, web search, and experts suggestions.

2.1. A snapshot on existing classifications of energy models

The starting point to prepare the questionnaire for model identification and characterization was to have a look at a selection of the contributions in the literature on classification of energy models. The objective of this literature review was to identify the main features commonly used to classify energy system models and not to provide an exhaustive overview of the topics analyzed by existing models and tools. This is an important step in the characterization of the models and tools analyzed in this report as it subsequently allows investigating the relationship between the main features of a model and its ability to cope with the specific requirements of the SET-Plan as summarized in the Specification Report.

Several works deal with the issue of reviewing quantitative and/or qualitative tools used to investigate specific energy system issues. Chapter 7 of the IPCC Third Assessment Report (2001) on costing methodologies as well as Fraunhofer Gesellschaft ISI (1999) provide a good illustration of methodological issues in the estimation of the monetary costs of climate change. The work by van Beeck (1999) is a background paper for a research project on local energy planning in developing countries and its main objective is to help policymakers in identifying the energy systems that are best suited for some specific purposes. The World Bank policy research paper by Bhattacharyya and Timilsina (2009) critically reviews existing energy demand forecasting methodologies and energy system models with the aim of evaluating their appropriateness for capturing the specific features of developing countries. Lanza and Bosello (2004) describe the main technical and theoretical features of bottom-up and top-down modelling approaches (results, strengths and weaknesses, issues arising from integration). Van Regermorter (2008) stresses the importance of combining (soft or hard linkage) different model types, e.g., macroeconomic and energy technology models, when different impacts of the same policy need to be assessed. In van Vuuren et al. (2009), the authors compare top-down and bottom-up model outcomes in order to better understand the emission reduction potentials reported by the IPCC in its Fourth Assessment Report (IPCC, 2007). The paper by Connolly et al. (2010) includes a review of the different computer tools that can be used to analyse the integration of renewable energy into various energy-

systems under different objectives. One of the main conclusions is that the “ideal” energy tool for decision- and/or policy-makers is highly dependent on the specific objectives that must be fulfilled.
The following table adapted from Pandey (2002) is an example to illustrate a simple way of classifying energy-economy models based on a set of attributes/features of the model, i.e., paradigm (methodology, analytical approach), space (geographical coverage), sector coverage and time.

Figure 2.1: an example of classification of energy-economy models

Paradigm	Space	Sector	Time	Examples
Top-down simulation	Global, national	Macro-economy, Energy	Long-term	AIM, SGM, I–O models
Bottom-up optimization/ Accounting	National, regional, local	Energy	Long-term	MARKAL, LEAP
Bottom-up optimization/ Accounting	National, regional, local	Energy	Medium-term/ Short-term	Sector models (end-use, power, coal, etc.)

Source: Pandey (2002).

Based on this concise literature review, the most commonly used criteria to classify energy system models have been identified as the following ones:

- General and specific purpose/focus and main applications of the model (what the model is built for; what the model is specifically designed to do; what the model can additionally do).
- Theoretical background (methodological and analytical approach, solution method, endogenous and exogenous variables, constraints, etc.).
- Geographical coverage (project-related, country, global, etc.).
- Time horizon (day, year, multi-year periods).
- Sectoral coverage (level of disaggregation, energy carriers, emission species considered, etc.).
- Technology coverage (representation of technologies and technological change).
- Economic rationale/scope/coverage (demand effects, revenues of carbon tax, impact on employment, etc.).
- Capability to analyze policies (market-oriented, technology-oriented, climate and energy policies, etc.).
- Linkage possibilities and needs.
- Data requirements.

In this report, models and tools will be characterized both according to the main features commonly used for model classification and to their ability to cover specific SET-Plan issues as their primary focus.

2.2. Classification form and guidelines

A questionnaire and the corresponding guidelines were prepared based on the most commonly used criteria to classify energy system models from the literature review, on specific criteria/questions related to the ATEsT project’s purpose (i.e., with a focus on SET-Plan needs and priorities) and on the list of specifications provided by WP1. Preliminary versions of both the classification form and the guidelines circulated within the ATEsT project team and received feedbacks from several project partners and external experts in the energy field.

The final version of the classification form and guidelines (Appendix A) consists of seven sections:

A. “Identification”.

This section collects general information on the model's name, developers and users, funding bodies, years of implementation and of latest update, as well as bibliographical references for model description.

B. "Evaluation capabilities and main applications".
This section investigates the model's primary focus and main outputs (i.e., what the model is specifically designed to do) as well as the model's capability to account for some specific issues. Notably, the capability to model different kinds of energy and environmental policies (e.g., the EU-ETS, carbon border tariffs, incentive schemes to renewable energy sources, eco-labelling, norms and standards, etc.), the economic and societal effects (in terms of e.g., GDP change, job creation, etc.) of a change in the energy system, and, finally, the model's ability to account for the uncertainty related to technology development and to assess the risk of failures in the deployment of innovative energy technologies. The information collected in this section might be useful for policymakers interested in better understanding the potential impact of their policy decisions. For instance, in the context of Strategic Planning, for assessing the effects of various policy instruments on technology introduction and deployment; or in the context of Transition Planning, for investigating the impact that policies might have on the public acceptance and social perception of technologies.

C. "Specific capability to model and evaluate SET-Plan needs and priorities".
This section aims at investigating whether the model under consideration can be used to provide an answer to the list of specifications identified in the Specification Report. To this end, the section is divided into five subsections. The first four of them correspond to the overarching topics identified above, i.e., Strategic planning, Deployment and transition planning, Innovation and R&D, and International cooperation. The last one, Barriers to SET-Plan implementation, is a cross-sectional topic that looks at the model's ability to perform a bottleneck analysis in terms of infrastructure developments, resource potential and availability, and further requirements for the deployment of a given technology. In particular, three main categories of barriers are identified: physical barriers (e.g. resource potential of a geographical area to provide wind or solar power; limited and/or inappropriate infrastructure); technical barriers and technology complementarities (interdependency between different technologies: e.g. supporting wind turbines installation not successful in the absence of investments in electric grid development); market and societal barriers to technology deployment.

D. "Model scope".
This section is intended to summarize some important features of the model under consideration: its geographical scope (e.g., whether it is designed for local projects evaluation or for multi-country analysis) and time dimension (i.e., the time horizon and the time-step used in the analysis and in the solution); its boundaries in terms of energy supply and demand sectors, energy and other kinds of commodities, and emission species considered; and the level of detail in the representation of technologies (i.e., the way technologies and interdependencies between them are represented) and in the solution algorithm (e.g., number of regions and time slices). These are valuable information for policymakers and other decision-makers to the extent that they can look for the model which is best suited to their needs, i.e. depending on the kind of analysis they intend to perform. For instance, spatially detailed models with a local geographical scope are better suited for local energy projects evaluation and seem more appropriate to deal with Spatial Planning specifications. On the other hand, global and/or multi-country models with a multi-year time horizon are generally poorer than the previous ones in terms of local spatial detail but seem to be more appropriate for dealing with technology deployment and policy indicators in the context of Strategic Planning, or deployment pathways in Transition Planning, or for International Cooperation issues. As another example, if one wants to evaluate the environmental performance of a technology for Strategic Planning, it is important to have information on the emissions species considered (only CO_2, all GHG, other pollutants, etc.) by a given model.

E. “Theoretical background and structure”.
   This section collects information on the main theoretical assumptions upon which models are built. In particular, the analytical approach (e.g., top-down, bottom-up, integrated assessment models) and model type (e.g., partial or general equilibrium model); the degree of endogenization (endogenous versus exogenous variables); the possibility to perform sensitivity analysis; the characterization of technological progress (Autonomous Energy Efficiency Improvement, learning curves, etc.) and dynamics (e.g., perfect versus myopic foresight); the possibility of internal and external linkages (e.g., modular structure, macroeconomic model linked to forestry, agricultural and land use models). This information is needed to make a distinction between, e.g., technology-rich bottom-up models with a simple description of the economic system and top-down models with a simpler and/or more aggregated representation of energy technologies but more detailed on the economic system side. The former are often used to perform scenario analysis for the energy system, whereas the latter focus on market and economy-wide feedbacks. At the same time, it is crucial to have information on the possibility of building internal and external linkages (e.g., by relying on a sub-modular structure, or by using a macroeconomic model linked to forestry, agricultural and land use models) since a combination of results from different models might be required to evaluate SET-Plan specifications. This is strongly related to the issue of coupling different models to answer multidimensional questions involving different fields (e.g., technology, society, industry and politics). For example, this can be achieved by using the output of a given model as an input to another model, and eventually investigating possible feedback effects.

F. “Access”.
   This section gathers information on the accessibility of the model to external and potentially non-expert users. In fact, transparency and accessibility to all interested parties as well as broad acceptance are essential prerequisites of the tools to support decision and policy-making. The questions of this section cover platform and interface requirements to run the model, coding/programming language, information on source code and model access and cost of licences for software and/or dedicated databases, the skills or training time required to be able to use the model, and lastly, the main characteristics of the model database.

G. “Additional notes and comments”.

Each of the previous sections (except for section G) includes several questions to be answered by the modelling teams. For each question, a dedicated box was provided so that the respondent had the possibility to write down a brief description, comments, and/or explanations on how the model could deal with that specific issue. In some suitable cases, multiple choice questions were introduced to ease the task of filling in the form. In the guidelines, several options were suggested as examples useful to clarify the context of the questions. Finally, the respondent had the opportunity to skip questions that he/she deemed as not applicable or irrelevant for the model under consideration.

The questions of section C are crucial in linking analyzed models with the SET-Plan requirements. However, the information collected in the remaining sections of the questionnaire is important as well to find out the intended purpose of the model and its potential applications, or at least as a consistency check of the model’s capabilities. For instance, an electricity market model providing intra-day prices forecasts on a yearly basis will hardly be suited for capacity expansion analysis. In particular, sections B, D, and E of the questionnaire gather information that might be useful for policymakers and valuable to other SET-Plan stakeholders as well.

2.3. Models identification and open consultation

A list of EU and non-EU modelling teams was compiled based on the literature review of existing classifications as well as on experts' suggestions and web search (Appendix B). Key organizations were also invited to participate in the Advisory group of the project and in the project workshops in order to ensure that the project consortium will focus on all the existing types of models with the same intensity.

To identify the relevant models in the field, and in order to make sure that all the existing models will be taken into account, an open call was made with the support of the JRC through its IE and IPTS Institutes. The open consultation was launched by directly contacting this selection of EU and non-EU modelling teams inviting them to use the questionnaire to provide the relevant information on their models. In this call, the organizations that have developed and use models had the opportunity to bring them forward together with their specifications in order to be included in a concise inventory of existing energy models. To this end, the questionnaire and guidelines have been made publicly available on the project website (http://www.atest-project.eu/) as an open call for any interested modelling team. The original deadline for filling in the questionnaire was fixed for 30th April 2010, and then extended to 31st May 2010 due to a limited number of respondents at the first round. After the second deadline, questionnaires for a number of models identified in the list had not been compiled and returned to WP2. Hence, a literature review for these missing models has been conducted by WP2 and other ATEsT project partners in order to fill out the related questionnaires useful to finalize the models analysis.

2.4. Matrices for models characterization

The "list of specifications" identified in the Specification Report has been used entirely - except for a few duplications that have been deleted and for some issues that have been grouped and simplified - to construct a framework for the characterization of models and tools based on SET-Plan needs and priorities.

The final list of specifications is the outcome of a process of discussions that took place first within the ATEsT project team and then during a workshop with a group of stakeholders involved in energy policy making and modelling at national and EU level (Member States and Industrial Initiatives representatives, the SET-Plan Steering Group, the modelling community and other relevant stakeholders). It includes expectations and demands on the model toolbox and issues related to data and modelling. The expectations and demands are the actual specifications required to support the decision-making process of the SET-Plan Steering Group. Stakeholders' major concerns are about the effectiveness of research and development (R&D) funding and the role of public and private R&D; the role and the effectiveness of policy instruments in lowering costs and stimulating deployment of different technologies; the impact of specific individual technologies via policy indicators; the interaction between international cooperation and competition. In general, the reliability and transparency of the methodology, the availability of data, as well as the possibility of integrating quantitative assessment and qualitative information are crucial points for the acceptance and the credibility of the model toolbox.

Besides the general concerns on the model toolbox, the final list of specifications identifies four overarching topics (and a number of different specifications for each topic) that need to be considered:

- *Strategic planning*, that relates to technology performance (potential for cost reductions), interdependencies between energy technologies at various levels in the supply chain, the growth path of new technologies (and their overall impact on the energy system), and the effects of various policy instruments on technology introduction.
- *Technology Deployment and Transition Planning*, that looks into more applied issues such as: spatial planning (aimed at identifying the best suitable deployment locations for technologies, also in terms of infrastructures and grid connection); deployment pathways based on demonstration projects; administrative barriers and time delays in implementing a technology; market and organizational barriers; public perception and social acceptance of technologies.

- *Innovation and R&D*, that calls for targets and monitoring of R&D progress in specific technologies as well as for the identification of EU strengths and weaknesses in energy technologies compared to the rest of the world.
- *Reinforcing international cooperation* on energy technology R&D and deployment, in an attempt to share costs and benefits among different countries.

The framework that has been used in this report to characterize models consists of two sets of matrices relating the list of specifications both to the primary focus of the model and to the model main features.

- Matrices for *primary focus assessment* are used to evaluate whether a given model addresses a specification as (one of) its primary focus.
- Matrices for *feature analysis* are used to evaluate the level of detail (sectoral, geographical, temporal, etc.) at which a given specification can be investigated by the models identified in the analysis.

2.4.1. Matrices for primary focus assessment

Matrices for primary focus assessment relate models and tools to the list of specifications that are grouped by main SET-Plan themes. In each of the four matrices, the row entries are the names of the models identified in the analysis and the column entries correspond to the list of specifications collected in the Specification Report. The same distinction as in the Specification Report is kept between specifications that can be dealt with by relying on a “rapid assessment” (identified by the orange colour in the matrices) and specifications that might require a more “elaborate analysis”.

Matrix cells are filled by assessing whether the model under consideration can provide an answer to a given specification and, more specifically, whether this is its (or one of its) primary focus of analysis. For example, if the primary focus of model *x* is considered to be the possibility of taking into account SET-Plan Key Performance Indicators, then the cell at the intersection between the row “model *x*” and the column “SET-Plan Key Performance Indicators” will contain the acronym “PF”, standing for “primary focus”.

Figure 2.2 shows the matrix for primary focus assessment of the theme “Innovation and R&D”.

Figure 2.2: Matrix for primary focus assessment (Innovation and R&D)

Innovation and R&D		Specifications											
		GENERAL SPECIFICATIONS		R&D					INNOVATION				
Models (number and name)		Long-term economic perspectives of technologies	Risks involved in research activities (long term perspective)	Effects of R&D spending (patenting, deployment)	Effects of public-private R&D partnerships, effectiveness of stimulating cooperation, timing of inizialization of R&D support	Technology specific R&D interim and final targets	Decision parameters to modify the ambition level of targets and the time paths	Assessment and monitoring of R&D funding mechanisms (for technological development lagging behind)	Strengths and weaknesses of EU and national industries	Quantify necessary R&D spending on specific technologies in order to cover the gap between EU and RoW	Technologies needed to reach 2020 and beyond targets	Identification of industrial opportunities in the energy sector for EU	Identification of sectors/technologies needing particular attention due to worldwide competition
1	BALMOREL												
2	BEST												
3	COALMOD (COALMOD-World)												
4	COMPETES												
5	E2M2s												
6	E3ME												
7	E3MG												
8	EMELIE												
9	EMM												
10	ESTEEM												
11	GASMOD												
12	GEM-E3												
13	GEMED												
14	GEMINI-E3												
15	GET												
16	GRAPE												
17	Model for Power Plant and Transmission Expansion												
18	IMACLIM												
19	IMAGE-TIMER												
20	**Wilmar Planning Tool** (mainly consisting of Joint Market Model (JMM) and Scenario Tree Tool)												
21	LEAP												
22	MDM-E3												
23	"Long-term energy demand model" consisting in three sub-models: MURE-Residential, ISIndustry, TEP-Tertiary.												
24	NEWAGE												
25	OILMOD												
26	POLES												
27	POWERS												
28	PRIMES												
29	**RESolve-E** (formerly known as ADMIRE-REBUS)												
30	RESolve-T												
31	ROM												
32	TEMPO												
33	TIAM-World												
34	TIMES PanEU												
35	WILMAR												
36	WITCH												
37	STSc SocioTechnical Scenario												
38	Changing Behavior												
39	Horizon Scan												
40	iKnow												
41	IEE - Behave / PRECEDE-PROCEED Planning Model												
42	GoReNEST framework												
43	Climate Bonus / Carbon footprinting, monitoring, feedback & rewards												
44	GMM												
45	PACE												
46	ADAGE												
47	AIM												
48	IGEM												
49	MERGE												
50	MESSAGE												
51	GTAP-E												
52	UKENVI												
53	MoreHys												
54	ABARE-GTEM												
55	AMIGA												
56	COMBAT												
57	DICE												
58	DNE21+												
59	EDGE												
60	EFDA-TIMES												
61	EnergyPLAN												
62	ENPEP-BALANCE												
63	ENV-Linkages												
64	EPPA												
65	ETP model												
66	FUND												
67	GEM-CCGT												
68	INVERT												
69	IPAC												
70	MINI-CAM												
71	MIRAGE												
72	NEMESIS												
73	NEMS												
74	REMIND-R												
75	RICE												
76	SGM												
77	WEM												
78	WIAGEM												
79	SAMLAST												
80	REMARK												
81	ESPAUT												
82	MTSIM												
83	WASP												
84	CGEN												
85	GreenNET-Europe model												

The information summarized in the four matrices for primary focus assessment (Appendix C) allows policymakers and stakeholders to identify at a glance the models and tools designed to address the different specifications they might be interested in. For a deeper analysis of the level of detail at which a model addresses a given specification, policymakers and stakeholders can then turn to the matrices for feature analysis.

2.4.2. Matrices for feature analysis

Matrices for feature analysis are useful to get an insight on the level of detail a given specification can be dealt with by the identified models and tools. In each of the four matrices, the column entries correspond to the list of specifications from the Specification Report whereas the row entries represent model *features*, i.e., dimensions that characterize the model approach, structure and assessment capability

The list of features used to build the matrices summarizes the key information from the questionnaires sent to the modelling teams. This list is able to cover a group of dimensions large enough to provide insight on the model's usefulness for inclusion in the ATEsT toolbox. Although the list is not fully exhaustive with respect to the dimensions covered by the questionnaire, the evaluation of models been performed by taking into account all the information provided by the compiled questionnaires and based on a literature review for the missing models.

The list of features includes:

- "Model primary focus", to assess whether the model is able to address a given specification as (one of) its primary focus of analysis.
- "Technology detail", to understand for which parts of the energy system (end use technologies, supply side technologies, resources, infrastructure) the model is able to take into account technical elements.
- "Spatial dimension", to identify the level of geographical detail (micro level, region, country, multi-country, global) at which the model deals with a given specification.
- "Time frame", to identify the level of temporal detail (intra-day to year, year to multiple-year periods) at which the model deals with a given specification.
- "System boundaries", to define the coverage (sector level, energy system, entire economy) provided by model analysis and results.
- "Innovation and R&D effects", to identify whether the model takes into account the possibility of technology learning and the relationship between R&D investments and technology performance or costs.
- "Economic system detail", to identify the level of detail (sector, branches) the economic system is represented within the model.
- "Behavioural aspects", to check whether the model can deal with non technical characteristics (social acceptance, other behavioural aspects) of agents' decisions and behaviour related to energy technologies.
- "Environmental aspects", to verify whether the model can provide effects of technological choices on emissions and land-use issues.
- "Type of operation", to identify the kind of analysis and results (market simulation, system optimisation, qualitative assessment) the model is able to perform and provide.

Matrix cells are filled using the following steps. When evaluating a specific model (denoted here by the corresponding number), it is first assessed whether the model is able to address (or take into account information about) a given specification. If the answer is positive, then the different features of the model are identified in order to gain insight on its level of, e.g., geographical or spatial detail. Finally, the "primary focus" row allows to make a distinction between models and tools that have been developed to investigate that specific issue and models and tools that can somehow (boundaries, iterated runs, parameters manipulation, only partial information, etc.) provide useful information on that issue.

At the end of the assessment, the matrix provides an overview of the features covered by identified models and tools for the different specifications. For instance, for a selected specification (column), it is possible to know whether there are models that address it as their primary focus, as well as the level of geographical, temporal, or economic sector detail at which that specification is investigated. Alternatively, if one is interested in analyzing, e.g., "Market barriers" under Transition Planning at the regional level, the list of models and tools that are able to do that will be found in the cell at the intersection between the column "Market barriers" and the row "Region".

Figure 2.3 shows the empty matrix for feature analysis that has been used to investigate the list of specifications under the theme "Innovation and R&D".

Figure 2.3: Matrix for feature analysis (Innovation and R&D)

Innovation and R&D

		Specifications											
		GENERAL SPECIFICATIONS		R&D					INNOVATION				
Model features		Long-term economic perspectives of technologies	Risks involved in research activities (long term perspective)	Effects of R&D spending (patenting, deployment)	Effects of public-private R&D partnerships, effectiveness of stimulating cooperation, timing of inizialization of R&D support	Technology specific R&D interim and final targets	Decision parameters to modify the ambition level of targets and the time paths	Assessment and monitoring of R&D funding mechanisms (for technological development lagging behind)	Strengths and weaknesses of EU and national industries	Quantify necessary R&D spending on specific technologies in order to cover the gap between EU and RoW	Technologies needed to reach 2020 and beyond targets	Identification of industrial opportunities in the energy sector for EU	Identification of sectors/technologies needing particular attention due to worldwide competition
Model primary focus													
Technology detail	End Use techs												
	Supply side techs												
	Resources												
	Infrastructure												
Spatial dimension	Project/Local/Regional												
	Country/Multi-country/Global												
Time horizon	Intra-day to year												
	Year to multiple-year periods												
System boundaries	Sector level												
	Energy system												
	Entire economy												
Innovation and R&D	Technology learning												
	Performance/Cost/Uncertainty												
Economic system detail	Sectors												
	Branches												
Behavioral aspects	Social acceptance												
	Other behavioral aspects												
Environmental aspects	Emissions												
	Land use												
Type of operation	Market simulation												
	System optimisation												
	Qualitative assessment												

3. Preliminary results

Following the open call consultation and the subsequent literature review, 85 models that may cover the specifications set out in the Specification Report have been identified. Most of the models (68) have been developed by EU research institutions, whereas part of them (17) have been originally developed by modelling teams outside EU (mainly in the United States) and some have then been used and improved within European countries.

A preliminary assessment of the models has been conducted by using as a benchmark a matrix for the "ideal" model. The ideal model matrix toolbox relates the main SET-Plan issues and required outputs from models to the different types of models and tools identified in the analysis. The possibility of "coupling" models to provide an answer to the specific requirements from the Specification Report has been also discussed and an example from the UKERC "Energy 2050" project has been provided. A characterization of the models based on their analytical approach as well as on their geographical and time coverage and techno-economic detail has been performed.

The preliminary analysis carried out in this section may thus constitute a benchmark for the subsequent characterization of models according to their ability to cope with the list of specifications from the Specification Report.

3.1. Ideal model matrix toolbox

In the first instance, a toolbox for the "ideal" model was built based on a consultation and discussion among the ATEsT project partners. This was achieved by identifying the types of model that are best suited to provide the required outputs as emerging from the Specification Report. In most cases, different types of models have been considered as relevant for dealing with the same issue, in which case results can be used either in a stand-alone (S) or in a possibly-combined (PC) manner.

A simplified way to illustrate the ideal model toolbox is by using a matrix representation where the ATEsT specifications set out in the Specification Report are related to types of models and tools (Figure 3.1). Following the Specification Report, the four SET-Plan "Strategic blocks" have been divided in subsets of issues. The main required outputs from models and the type of models that best provide a given output are then identified for every issue. Combining models and tools with a different primary focus may enable to address certain issues as well. The matrix structure points out these possible linkages.

The different types of models and tools identified in Figure 3.1 can be briefly described as follows:

- *Disaggregated* models are very detailed models that address specific issues such as plant design, resource potential assessment, infrastructure expansion or reinforcement, etc. Results from these models can generally be used as inputs to other more "systemic" models and can provide a sound reference for constraints such as capital cost, efficiency, resources, barriers, and so on.
- *Sector level* models are used to analyze *parts* of the energy system at different levels of detail: for instance, models for grid operation simulation or for the electricity system by itself, or models for *singl*e markets (coal, gas, oil, etc.) or for single sectors (transport, residential, etc.).
- *Energy system* models are intended to address and analyze the evolution of the energy system by combining its different parts (multiple sectors and fuels) with a focus on competition and complementarities between energy technologies.
- *Macro-economic* models include both the energy system and the rest of the economy possibly with feedback effects between them. Typically, the energy system is described as one component of the economic system (with obvious implications concerning the level of detail of the former).
- *Energy behaviour* tools are designed mainly to make people aware of their energy consumption decisions (with a focus on the demand side of the economy). This category also includes semi-quantitative tools dealing with social acceptance issues.

- *Socio-technical scenarios* (STSc) address the way transition paths may unfold in a process of interaction between a range of actors and the rules they act upon (technical, regulatory, forms of provision, cost models, infrastructure requirements, etc.). The purpose of STSc is to illustrate how various transition routes may be set in motion through a variety of multi-level linkage patterns.
- *Horizon Scanning methodologies* point to the systematic examination of potential threats, opportunities and likely future developments, including (but not restricted to) those at the margin of current thinking and planning. The aim is to identify the potential impacts of *wild cards* (WI) and *weak signals* (WE) on Europe and the world: WI are situations/events with perceived low probability of occurrence but potentially high impact if they were to occur; WE are unclear observables warning people about the probability of future events (including WI).

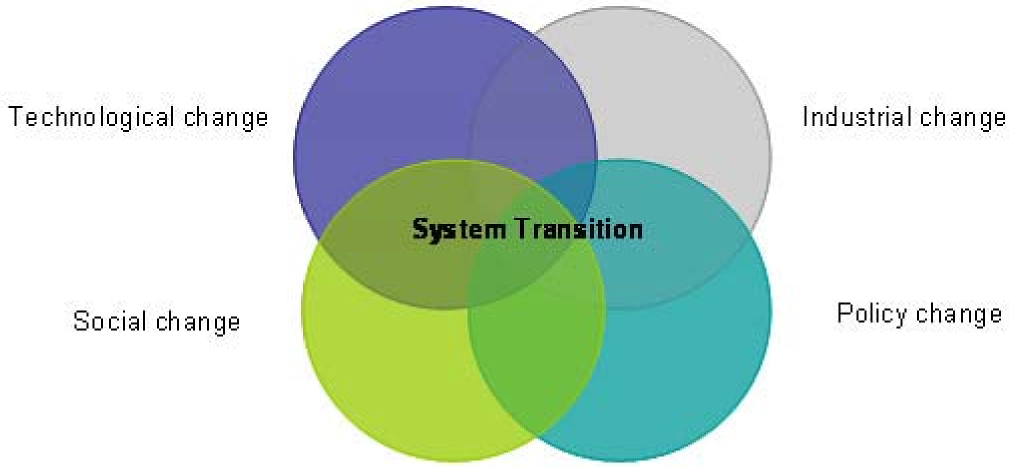
Figure 3.1: Ideal model toolbox

	Issues	Required outputs	Type of Model/Tool	Modelling focus integration: Stand-alone (S), Possibly Combined (PC)
Strategic Planning	Technology performance and development potential	Performance/economic data on technologies	Disaggregated models	(S)
	Technology deployment	Technical/physical/economic evaluation of resources; technology short- and long-term potential	Disaggregated models, Sociotechnical scenarios	(S) or (PC)
	Policy Indicators	Comprehensive analysis of the energy system; technology mix	Sector, Energy system, Macro-economic models, Sociotechnical scenarios	(S) or (PC)
Technology Deployment and Transition Planning	Spatial planning	Trans-national electricity interconnections, infrastructure requirements; territorial integration and land use	Disaggregated, Sector models	(S) or (PC)
	Deployment pathways	Capacity and infrastructure expansion, effects on migration and labor demand	Disaggregated, Sector, Macro-economic models	(S) or (PC)
	Timing	Effects of regulatory and administative barriers on lags between investment decisions and energy production	Disaggregated, Sector, Sociotechnical scenarios	(S) or (PC)
	Market designs and organisational changes	Required changes to overcome market and organisational barriers	Sector, Macro-economic models, Sociotechnical scenarios, Energy behavior tools	(S) or (PC)
	Acceptance/perception of a technology	Behavioral responses and social acceptance and perception of technologies related to risk, employment and safety issues	Sociotechnical scenarios, Energy behavior tools	(S) or (PC)
Innovation and R&D	R&D	R&D investments effectiveness, risks, targets, public vs private role	Sector, Energy system, Macro-economic models, Horizon scanning methodologies	(S) or (PC)
	Innovation	EU strengths and weaknesses, industrial perspectives, competitiveness, sectoral and regional trade	Sector, Macro-economic models	(S) or (PC)
International Cooperation	International cooperation on R&D	Strategic approach (collaboration vs free riding in knowledge creation and diffusion), identification of centres of excellence	Energy system, Macro-economic models, Horizon scanning methodologies	(S) or (PC)
	International cooperation on technology deployment	Spillover effects and potential for flexible mechanisms	Energy system, Macro-economic models, Sociotechnical scenarios	(S) or (PC)

3.2. Coupling issues

In general, different model categories are useful to answer different types of policy questions. The need to couple models and tools from different categories arises when a type of analysis can be defined as a multi-dimensional one, involving several fields (as it can be the case for transition planning, that calls for technological, social, industrial and policy changes, see fig. 3.2), or the chain of causal relationships to be analyzed is quite long and composite (as in the case of R&D investments, an issue requiring an analysis of the effectiveness on technology deployment and competitiveness, of the possible trade-offs with other investments, and of the systemic effects at the macroeconomic level).

Figure 3.2: Linkages between technological, industrial, policy and social changes



Since integrating all relevant dimensions into a single model is usually not very effective, a number of more specialised models can be coupled to overcome this hurdle. Different models and tools with a deeper level of detail on some specific issues can be used to fully exploit their complementarities, contributing to the evaluation of a policy in its various aspects.

As a general rule, it is possible to couple any two models that share common variables and the reason for doing this, as well as the way of doing it (i.e., iterative, from disaggregated to aggregated or the other way around) depends on the question for which the coupling has being done. In principle, when two models share bidirectional links they can also be coupled by relying on an iterative procedure.

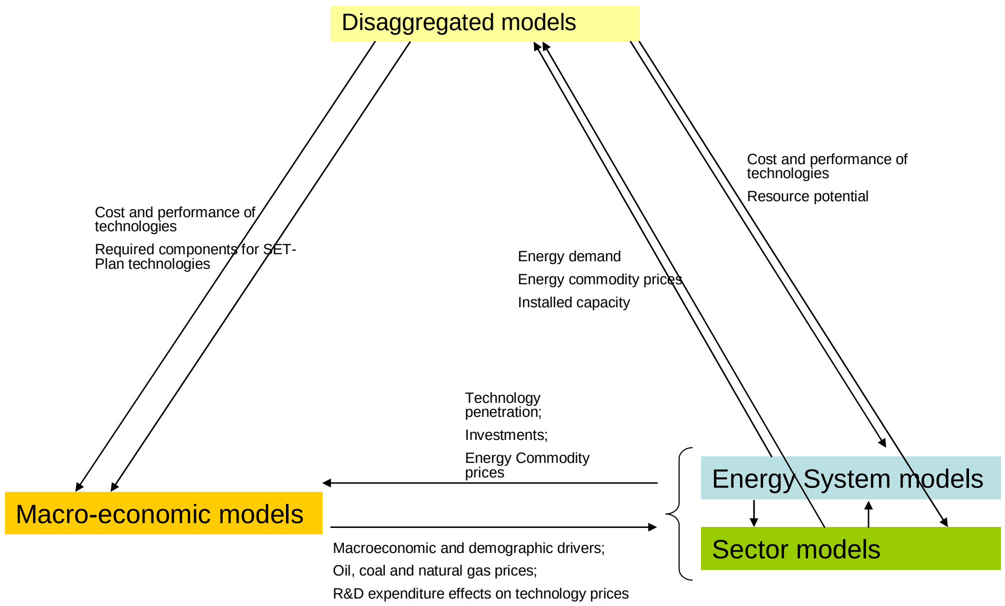


Figure 3.3: Possible model linkages

Figure 3.3 illustrates some possible coupling schemes useful for SET-Plan needs. The linkages between different types of models are described below.

Linkage between disaggregated models and system/sector models
System and sector models could receive as inputs:
1) data on technologies (costs, performance) from disaggregated models focused on technical components;
2) data on resource potentials from disaggregated models with an accurate spatial description.

Linkage between disaggregated models and macro-economic models
Macro-economic models could receive as inputs:
1) data on required components for SET-Plan relevant technologies (useful to integrate or modify existing Input-Output tables) from disaggregated models focused on technical components;
2) data on technologies (costs, performance) from disaggregated models focused on technical components.

Linkage between system/sector models and macro-economic models
Macro-economic models could receive as inputs:
1) oil, coal and natural gas prices from global system models;
2) technology penetration and investments from system/sector models;
3) energy commodity prices from system/sector models.
4) technology cost reduction related to R&D from system/sector models with endogenous two factor learning curves.

Linkage between system/sector models and disaggregated models
Disaggregated models aimed at planning the location and development of energy infrastructures could receive data concerning energy demand, installed capacity and energy commodity prices from system/sector models.

Linkage between macro-economic models and system/sector models
System/sector models could receive as inputs from macro-economic models:
1) main macroeconomic and demographic drivers;
2) oil, coal and natural gas prices;
3) optimal R&D investments by region/country (based on a strategic game-theoretical approach);
4) R&D expenditure effects on technology production costs (for example, assuming an effect of R&D on the output-augmenting parameter).

Linkage between system models and sector models
These two groups of models can provide each other (bidirectional links) many information concerning commodity prices, technology costs, potentials and boundaries, energy demand, investments, installed capacity, etc.

In addition to the alternatives illustrated above, it is possible to couple models in order to enlarge geographical coverage (provided that physical and economic regional links are fully taken into account) or sector models for the same territory. The latter procedure has to be followed very carefully because it does not rely on a systemic approach and could not consider interrelations between technologies and competition between different energy carriers.

The examples provided obviously do not exhaust all the possible combinations which should be evaluated on case by case basis. Moreover, socio-technical scenarios, horizon scanning methodologies, and other semi-quantitative and/or qualitative tools can provide useful information to complement and integrate the results from quantitative models' analyses.

An interesting example of coupling exercise can be found in studies such as the UKERC "Energy 2050" project. The objective of this project is to evaluate how the UK can move to a resilient ('secure') and low-carbon energy system over the period to 2050 while taking into account a primary goal of UK energy policy, i.e., achieving an 80 per cent reduction in carbon emissions by 2050.

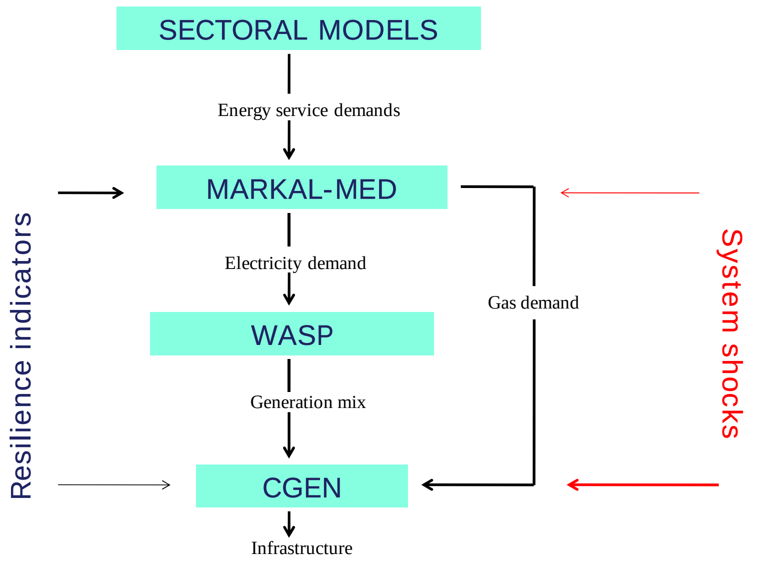
Resilience is by definition a multidimensional issue strongly related with security of supply analysis. It has a physical aspect (how the system reacts to unexpected shortages of physical deliveries of energy) as well as an economic aspect (how the system reacts to energy prices shocks and how to evaluate the economic damage of not dispatched energy). The project aims at testing the response of the UK energy system (under different scenarios) to hypothetical shocks (e.g., the loss in gas infrastructure) while ensuring at the same time that energy is delivered reliably.

An integrated analysis to investigate the resilience issue has been undertaken by linking a number of UKERC energy models (Figure 3.4). Sector models are used to establish energy service demands that feed into the MARKAL-MED model. The electricity demands from MARKAL-MED are then fed into a more detailed model of the electricity system, the Wien Automatic System Planning (WASP) model used to explore, in more detail, the levels of generation investment needed to maintain reliable supplies. Finally, the national generation mix from WASP, together with gas/electricity demands from MARKAL-MED, represent inputs into the Combined Gas and Electricity Network (CGEN) model. The latter is a cost-minimising model used to assess where electricity generation capacity should be located and how much gas and electricity infrastructure (pipes, compressors, gas storage, power transmission lines, import terminals) should be constructed.

The resilience indicators (value of not dispatched energy) are used to constrain the models. Each representation of the energy system at a given point in time can be subject to "shocks" to assess the costs and benefits of building in resilience.

To sum up, the coupling schemes adopted in this example are the following ones:
1) from sector models to system models, in order to feed the latter with sector energy services demand;
2) from system models to sector models, in order to feed the electricity demand evaluated by the MARKAL-MED model to a sector model of the electric system;
3) from sector models (of the electricity system) to disaggregated models, in order to identify the optimal location of grid and natural gas infrastructure expansion.

Figure 3.4: An example of coupling (UKERC "Energy 2050" project)



3.3. Overview and first characterization of the models

This section contains an overview and a first characterization of the models based on some of their features, notably, the analytical approach, the geographical and time coverage and the techno-economic detail. Identified models have also been grouped according to the types of models and tools discussed above.

In the first instance, the models identified in the present report have been grouped according to their *analytical approach* (Figure 3.5). The different analytical approaches that have been used to characterize models can be briefly described as follows:

- *Bottom-up:* models traditionally technology-oriented, treating energy demand as either given, for example expressed as useful energy demand, or as a function of energy prices and national income. Technologies are typically described as a set of linear activity models based on engineering data of life cycle costs and thermodynamic efficiencies.
- *Top-down:* models with primary focus on market and economy-wide feedbacks and interactions, often sacrificing the technological richness of the bottom-up approach; typically they represent technology by using relatively aggregated production functions for each sector of the economy.
- *Hybrid*: mainly top-down models that include some technological or environmental explicitness.
- *Hybrid - Integrated Assessment:* mainly bottom-up models with high technologic details and combining economic, technological and environmental details, mostly used to evaluate the impact of climate change policies portrayed by a “damage function", but also models with an endogenous climate module representing the impacts of climate change in physical terms.
- *Semi-Quantitative:* analytical approach that consider not only quantitative aspects, but also qualitative ones, such as social acceptance issues related to energy projects.
- *Qualitative*: analytical approach for uncountable aspects of the energy system transition, such as social, energy system governance or policy-planning issues.

Figure 3.5 lists the different analytical approaches in relation with the model types and sorts the model accordingly.

Figure 3.5: Overview of identified models

Type of model	Models	Approach
Disaggregated models	BALMOREL, CGEN, ESPAUT, GreenNET-Europe model, MTSIM, REMARK, SAMLAST, WASP, WILMAR, Wilmar Planning Tool (JMM, STT).	**Bottom-up**
Sector level	BEST, COALMOD, COMPETES, EMELIE, EMM, GASMOD, Long term energy demand model (MURE,ISI,TEP), Model for Power Plant and Transm. Expansion, MoreHys, OILMOD, POWERS, RESolve-E, RESolve-T, ROM, TEMPO.	**Bottom-up**
Energy system	E2M2s, EFDA-TIMES, EnergyPLAN, ENPEP-BALANCE, ETP model, GET, GMM, GRAPE, IMAGE-TIMER, INVERT, LEAP, MDM-E3, MESSAGE, MINI-CAM, POLES, PRIMES, TIAM-World, TIMES PanEU, WEM,	**Hybrid-IA, Bottom-up**
Macroeconomic	ABARE-GTEM, ADAGE, AIM, AMIGA, COMBAT, DICE, DNE21+, E3ME, E3MG, EDGE, ENV-Linkages, EPPA, FUND, GEM-CCGT , GEM-E3, GEMED, GEMINI-E3, GTAP-E, IGEM, IMACLIM, IPAC, MERGE, MIRAGE, NEMESIS, NEMS, NEWAGE, PACE, REMIND-R, RICE, SGM, UKENVI, WIAGEM.	**Top-down, Hybrid, Hybrid-IA**
Energy behavior	ESTEEM, Changing Behavior, IEE - Behave/PRECEDE-PROCEED Planning Model, Climate Bonus/Carbon footprinting, monitoring, feedback & rewards.	**Semi-Quantitative**
STSc	STSc SocioTechnical Scenario, GoReNEST framework.	**Qualitative**
Horizon scanning	Horizon Scan, iKnow.	**Qualitative**

It needs to be stressed that a model may fit in more than one type of model category: for example, a grid operation model can be classified either as disaggregated or as sector level model. Similarly, each type of model category may well rely on different analytical approaches.

Figure 3.6 characterizes identified models according to the spatial detail/geographical coverage (from local to global) and the techno-economic detail (from aggregate production and cost functions to emissions and detailed energy flows). Energy behaviour tools, STSc and Horizon Scanning are not included in this figure and in Figure 3.7 because of their great flexibility in representing techno-economic details, geographical and timing scale.

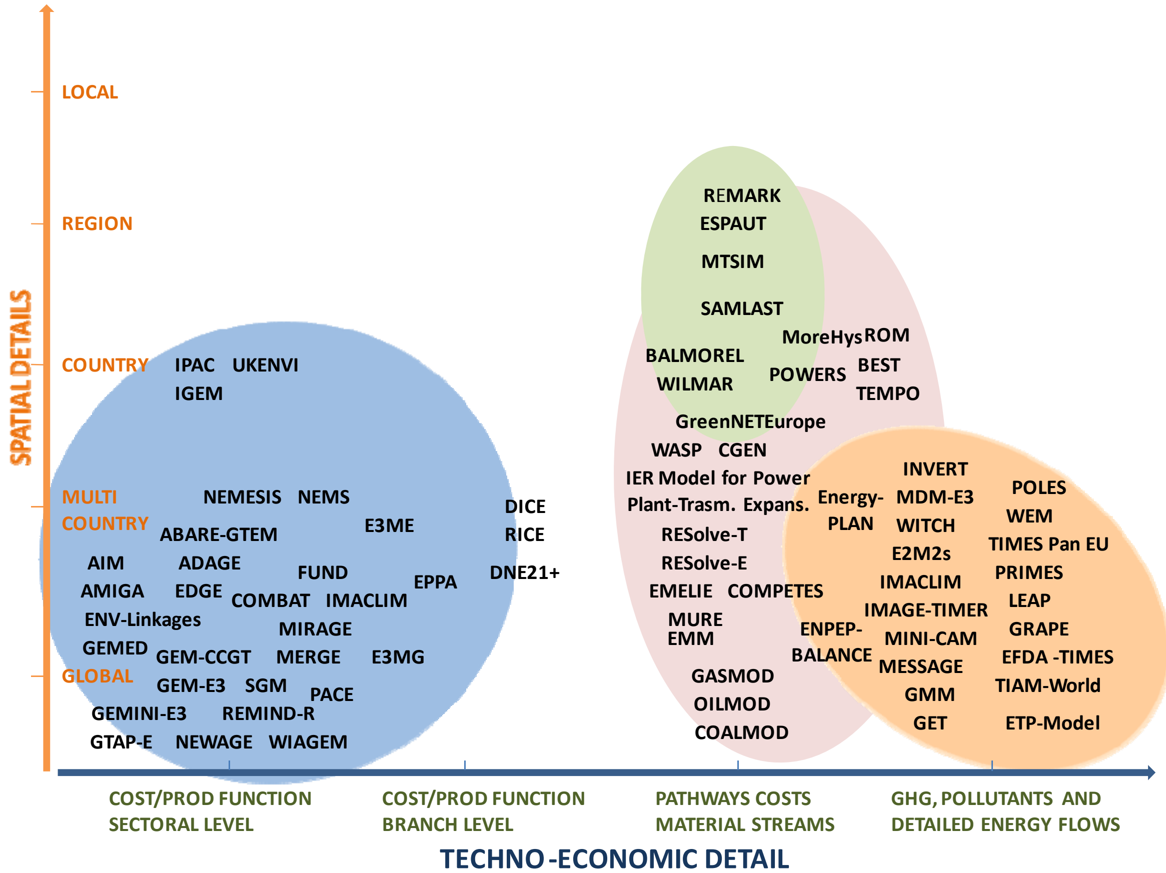


Figure 3.6: Techno-economic detail and geographical coverage of identified models

It should be noticed that there is a prevalence of technology-rich models. Disaggregated models (green area), Sector level models (pink area) and Energy system models (orange area) usually are rich in terms of technology details and their geographical coverage varies from local to global depending on the type. The blue area identifies the macro-economic type of models that are characterized mainly by a poorer technology detail and by a multi-country to global geographical coverage.

Figure 3.7 shows an additional characterization of the models based on the relationship between their spatial detail and the time scale of the analysis.

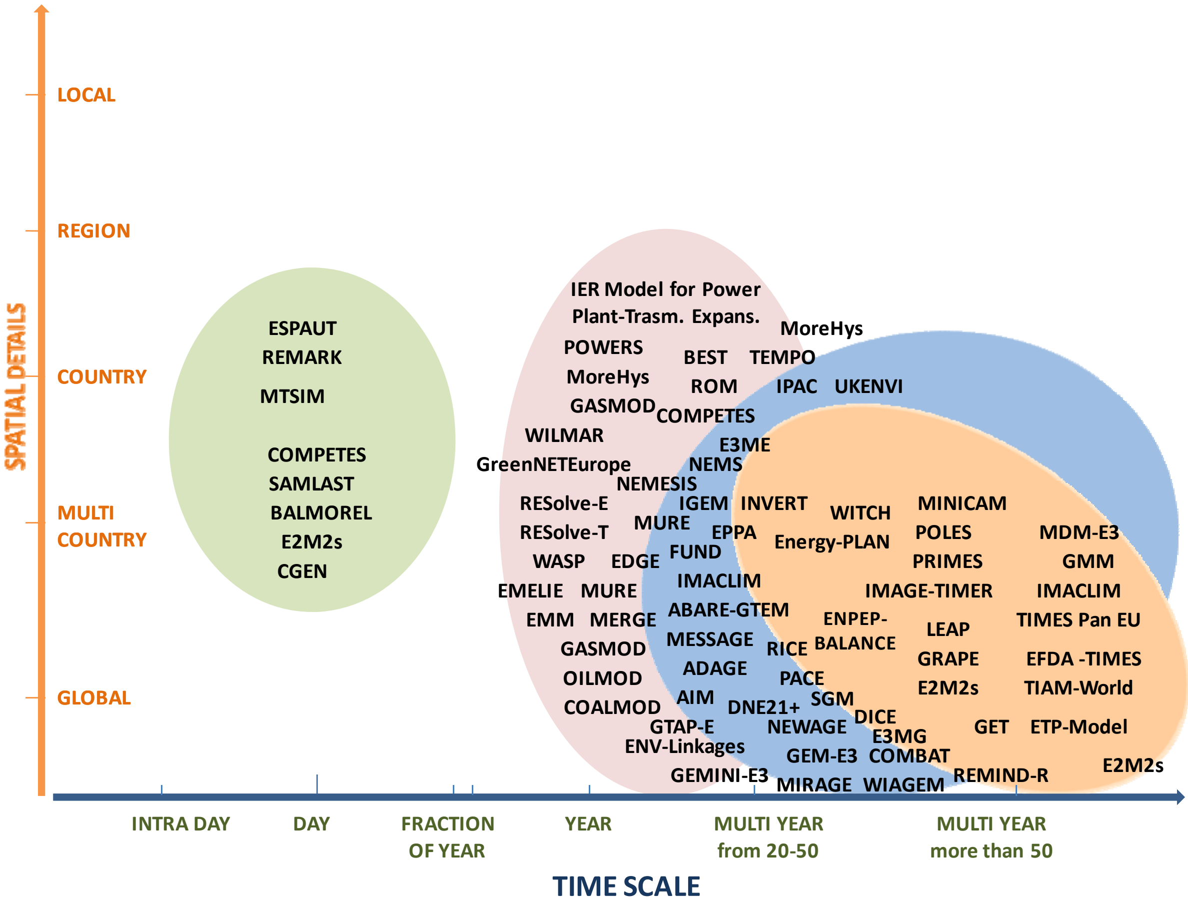


Figure 3.7: Geographical and time coverage of identified models

The same colours as in Figure 3.6 have been used to define the time coverage of models in relation to their spatial detail. Multi-annual issues are well covered, whereas shorter time scales up to intra-day are not covered with the exception of grid simulation models (e.g., SAMLAST, MTSIM, CGEN) or electricity market models that can account for intra-day load flows (e.g., BALMOREL, COMPETES, E2M2s).

It must be pointed out that some categories of disaggregated models are not analyzed in the present report. This is the case, for example, of engineering models, which involve a very high degree of technological detail and may describe certain technologies at the level of individual sub-processes or component, and of tools like feasibility studies.

As for the disaggregated models focused on infrastructure expansion included in the report, they may be considered as reference examples of the instruments and approaches used by national Transmission and Distribution System Operators (TSOs and DSOs), given that the electricity grid planning is a multi-dimensional process and each TSO and DSO has its own criterion to evaluate all costs and benefits of investments. In particular, investments in grid infrastructures have a typical lifetime of 30 years or more, so that planning grid expansion is related to the perspectives on the future development in fuel prices, production systems and consumption demand.

A few examples for nuclear and hydrogen infrastructures (WASP and Morehys, respectively) are included in the analysis as well as the CGEN model for natural gas and electricity networks. Models for infrastructures expansion correlated to the carbon and capture storage (CCS) technologies are not explicitly mentioned because they are applications of the Markal family of models still at an early stage of implementation. Interesting studies to estimate the feasibility of CO_2 storage and transport infrastructures are based on a GIS/MARKAL toolbox. The toolbox integrating ArcGIS, a geographical information system (GIS) with elaborated spatial and routing functions, and a MARKAL model (MARKAL-NL-UU) has been implemented as the temporal and spatial dimensions are needed to be taken into account explicitly when considering CCS infrastructures (Broek et al., 2010). Similarly, within the FENCO ERA-NET project "*Analysis of potentials and costs of storage of CO2 in the Utsira aquifer in the North Sea*", the Pan European TIMES (PET) model and national MARKAL/TIMES models for the United Kingdom, the Netherlands, Germany, Denmark and Norway have been used to evaluate common European CO2 infrastructure in contrast with national infrastructures (Kober and Blesl, 2010). The TIMES PanEU has also been used to analyze the perspective of power plants with CCS in Europe: technical and economic uncertainties of CCS technologies have been incorporated by using the Parametric Programming routine. Parametric Programming represents an advanced analysis of the effects of input parameter variations on the model solution. In this way, uncertainties on efficiency losses and additional investment costs compared to the reference power plant without CCS can be taken into account (Kober and Blesl, 2010).

4. Primary focus assessment

The ability of identified models to address the list of specifications has been evaluated separately for each SET-Plan topic. The matrices used for primary focus assessment can be found in Appendix C. The following sections summarize results on:

- specifications that are *covered* (at different level of detail) by identified models and that represent the primary focus of analysis of these models;
- specifications that are *not covered* by identified models, either because no model has as its primary focus the analysis of a given specification or because a very limited number of models (one or at most two, often only based on a qualitative approach, or designed for specific sectors or technologies) deal with the given specification.

For each specification, the names of identified models that cover that specification have been listed. In Section 5, a deeper analysis of the modelling features and of the level of detail at which a given specification is dealt with by identified models has been performed.

4.1 Strategic Planning

The main objectives of Strategic Planning lie in the evaluation of technology performance (potential for cost reductions), of the interdependencies between energy technologies at various levels in the supply chain, of the growth path of new technologies (and their overall impact on the energy system), and of the effects of various policy instruments on technology introduction and adoption.

In order to assess the usefulness of identified models for Strategic Planning, general specifications together with three key topics, each of them including a condensed list of specifications (distinguished according to the need for either a rapid assessment or an elaborate analysis), have been evaluated.[1]

- *General specifications*
  - Elaborate analysis of:
    - Resilience of the energy system against shocks of energy prices and supply of primary energy sources.
    - Resilience of the energy system against shocks of power system failures and extreme weather events.
- *Technology performance and development potential*
  - Rapid assessment of:
    - SET-Plan Key Performance Indicators.
  - Elaborate analysis of:
    - Investment, O&M costs, technical and environmental performance.
    - Potential for cost reduction as a function of time/technical improvements through RD&D/deployment/learning effects.
    - Overall efficiency gain and efficiency gain per tech/per kWh.
- *Technology deployment*
  - Rapid assessment of:
    - Technical barriers and technology complementarities (impact on the energy system structure; interdependency between different technologies: e.g. wind turbines and electric grid development).
  - Elaborate analysis of:
    - Maximum potential of a given technology and the time horizon of the pathway, regional specificities.
    - Bottlenecks to technology deployment (industry not ready to follow the demand).

[1] Here and in the following sections, the list of specifications used for model primary focus assessment as well as the distinction between rapid assessment and elaborate analysis are adapted from the Specification Report.

- *Policy indicators*
    - Rapid assessment of:
        - Impact of different stimuli (feed in, quotas, fiscal measures etc.) on technology deployment/cost.
        - Impact of different stimuli (feed in, quotas, fiscal measures etc.) on share of RES in TPES.
        - Total investment required to reach cost competitiveness.
        - Risk assessment ("change of plans", system failure, lock-in situations).
    - Elaborate analysis of:
        - CO2 reduction per technology.
        - Security of supply.
        - Impact of global economic crisis on the energy system (input).
        - Impact on economic growth, development and employment (output).
        - LCA analyses.
        - Impact on water, particulates, soil, etc.
        - Competitiveness considerations for regional industry.

4.1.1 Specifications covered

The specifications covered and the list of models that address a given specification as their primary focus of analysis is provided below.

- *General specifications*
    - Resilience of the energy system against shocks of energy prices and supply of primary energy sources: **EMM; Model for power plant and transmission expansion (IER); Wilmar Planning Tool; LEAP; Long-term energy demand model (three sub-models: MURE-Residential, ISIndustry, TEP-Tertiary); POLES; PRIMES; TIAM-World; TIMES PanEU; WILMAR; GMM; AIM; MESSAGE; DICE; DNE21+; EFDA-TIMES; ENPEP-BALANCE; ETP model; IPAC; NEMS; RICE; WEM; SAMLAST; REMARK; ESPAUT; MTSIM; WASP; CGEN; GreenNET-Europe model.**
    - Resilience of the energy system against shocks of power system failures and extreme weather events: **EMM; Model for power plant and transmission expansion (IER); Wilmar Planning Tool; LEAP; Long-term energy demand model (three sub-models: MURE-Residential, ISIndustry, TEP-Tertiary); ROM; TIAM-World; TIMES PanEU; WILMAR; GMM; AIM; MESSAGE; DICE; EFDA-TIMES; ENPEP-BALANCE; ETP model; IPAC; NEMS; RICE; WEM; SAMLAST; REMARK; ESPAUT; MTSIM; WASP; CGEN; GreenNET-Europe model.**
- *Technology performance and development potential*
    - SET-Plan Key Performance Indicators: **BALMOREL; Model for power plant and transmission expansion (IER); LEAP; Long-term energy demand model (three sub-models: MURE-Residential, ISIndustry, TEP-Tertiary); POLES; PRIMES; RESolve-T; TEMPO; TIAM-World; TIMES PanEU; GMM; MESSAGE; DNE21+; EFDA-TIMES; ENPEP-BALANCE; ETP model; IPAC; WEM.**
    - Investment, O&M costs, technical and environmental performance: **BALMOREL; E2M2s; EMELIE; EMM; GET; Model for power plant and transmission expansion (IER); Wilmar Planning Tool; LEAP; Long-term energy demand model (three sub-models: MURE-Residential, ISIndustry, TEP-Tertiary); POLES; PRIMES; RESolve-E; RESolve-T; TEMPO; TIAM-World; TIMES PanEU; WILMAR; GMM; PACE; ADAGE; AIM; MESSAGE; MoreHys; EFDA-TIMES; ETP model; INVERT; IPAC; MINI-CAM; NEMS; WEM.**
    - Potential for cost reduction as a function of time/technical improvements through RD&D/deployment/learning effects: **BALMOREL; EMELIE; EMM; GET; Model for power plant and transmission expansion (IER); LEAP; Long-term energy demand model (three sub-models: MURE-Residential, ISIndustry, TEP-Tertiary);**

POLES; PRIMES; RESolve-E; RESolve-T; TEMPO; TIAM-World; TIMES PanEU; GMM; PACE; MESSAGE; DNE21+; EFDA-TIMES; ETP model; IPAC; MINI-CAM; NEMS; WEM.
    - Overall efficiency gain and efficiency gain per tech/per kWh: **BALMOREL; BEST; E2M2s; EMELIE; EMM; GET; Wilmar Planning Tool; LEAP; Long-term energy demand model (three sub-models: MURE-Residential, ISIndustry, TEP-Tertiary); POLES; POWERS; PRIMES; RESolve-E; TEMPO; TIAM-World; TIMES PanEU; WILMAR; GMM; PACE; ADAGE; AIM; MESSAGE; UKENVI; AMIGA; EFDA-TIMES; EnergyPLAN; ETP model; INVERT; IPAC; MINI-CAM; NEMS; REMIND-R; WEM.**
- *Technology deployment*
    - Technical barriers and technology complementarities (impact on the energy system structure; interdependency between different technologies: e.g. wind turbines and electric grid development): **BALMOREL; EMELIE; GRAPE; Model for power plant and transmission expansion (IER); Wilmar Planning Tool; LEAP; Long-term energy demand model (three sub-models: MURE-Residential, ISIndustry, TEP-Tertiary); PRIMES; TIAM-World; TIMES PanEU; WILMAR; GMM; AIM; MESSAGE; EFDA-TIMES; EnergyPLAN; ENPEP-BALANCE; ETP model; IPAC; MINI-CAM; NEMS; WEM; SAMLAST; REMARK; ESPAUT; MTSIM; WASP; CGEN; GreenNET-Europe model.**
    - Maximum potential of a given technology and the time horizon of the pathway, regional specificities: **BALMOREL; BEST; E2M2s; EMELIE; EMM; Model for power plant and transmission expansion (IER); Wilmar Planning Tool; LEAP; Long-term energy demand model (three sub-models: MURE-Residential, ISIndustry, TEP-Tertiary); POLES; PRIMES; RESolve-E; RESolve-T; TIAM-World; TIMES PanEU; WILMAR; GMM; PACE; ADAGE; AIM; MESSAGE; MoreHys; DNE21+; EFDA-TIMES; EnergyPLAN; ENPEP-BALANCE; ETP model; IPAC; MINI-CAM; NEMS; REMIND-R; WEM.**
- *Policy indicators*
    - Impact of different stimuli (feed in, quotas, fiscal measures etc.) on technology deployment/cost: **IMACLIM; LEAP; Long-term energy demand model (three sub-models: MURE-Residential, ISIndustry, TEP-Tertiary); POLES; PRIMES; TIAM-World; TIMES PanEU; GMM; PACE; ADAGE; AIM; MESSAGE; AMIGA; EFDA-TIMES; ETP model; INVERT; IPAC; MINI-CAM; NEMESIS; NEMS; REMIND-R; WEM.**
    - Impact of different stimuli (feed in, quotas, fiscal measures etc.) on share of RES in TPES: **BEST; E2M2s; EMELIE; IMACLIM; LEAP; MDM-E3; Long-term energy demand model (three sub-models: MURE-Residential, ISIndustry, TEP-Tertiary); NEWAGE; POLES; PRIMES; RESolve-E; TIAM-World; TIMES PanEU; GMM; PACE; ADAGE; AIM; MESSAGE; EFDA-TIMES; EnergyPLAN; ENPEP-BALANCE; ETP model; INVERT; IPAC; MINI-CAM; NEMESIS; NEMS; REMIND-R; SGM; WEM; GreenNET-Europe model.**
    - Total investment required to reach cost competitiveness: **EMELIE; LEAP; Long-term energy demand model (three sub-models: MURE-Residential, ISIndustry, TEP-Tertiary); TIAM-World; TIMES PanEU; GMM; MESSAGE; EFDA-TIMES; ENPEP-BALANCE; ETP model; WEM.**
    - Risk assessment ("change of plans", system failure, lock-in situations)[2]: **BEST; E2M2s; EMELIE; EMM; WILMAR; SAMLAST; REMARK; ESPAUT; MTSIM; WASP; CGEN; GreenNET-Europe model.**

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[2] It must be stressed here that sensitivity analysis can be performed with almost any model. Generally speaking, this can provide a range for how outputs could change if there is a change in some of the inputs (e.g., failure of CCS technology, a very rapid nuclear phase out following an accident).

- CO2 reduction per technology: **E2M2s; EMELIE; EMM; GET; Wilmar Planning Tool; LEAP; Long-term energy demand model (three sub-models: MURE-Residential, ISIndustry, TEP-Tertiary); POLES; PRIMES; RESolve-T; TEMPO; TIAM-World; TIMES PanEU; WILMAR; GMM; AIM; MESSAGE; EFDA-TIMES; EnergyPLAN; ENPEP-BALANCE; ETP model; INVERT; IPAC; MINI-CAM; NEMS; REMIND-R; WEM.**
- Security of supply: **POLES; PRIMES; RESolve-T; ADAGE; AIM; DICE; ENPEP-BALANCE; EPPA; IPAC; MINI-CAM; NEMS; RICE; WEM; SAMLAST; REMARK; ESPAUT; MTSIM; WASP; CGEN; GreenNET-Europe model.**
- Impact of global economic crisis on the energy system (input): **E3ME; E3MG; GEM-E3; GEMED; GEMINI-E3; LEAP; Long-term energy demand model (three sub-models: MURE-Residential, ISIndustry, TEP-Tertiary); POLES; TIAM-World; TIMES PanEU; GMM; AIM; MESSAGE; GTAP-E; UKENVI; ABARE-GTEM; AMIGA; COMBAT; DICE; EDGE; EFDA-TIMES; ENV-Linkages; ETP model; GEM-CCGT; IPAC; MINI-CAM; NEMS; RICE; WEM; WIAGEM.**
- Impact on economic growth, development and employment (output): **E3ME; E3MG; GEM-E3; GEMED; GEMINI-E3; IMACLIM; MDM-E3; NEWAGE; PACE; ADAGE; AIM; IGEM; GTAP-E; UKENVI; ABARE-GTEM; AMIGA; COMBAT; DICE; EDGE; ENV-Linkages; EPPA; GEM-CCGT; IPAC; NEMS; REMIND-R; RICE; SGM; WIAGEM.**
- Impact on water, particulates, soil, etc.: **GRAPE; AIM; DICE; MINI-CAM; RICE.**
- Competitiveness considerations for regional industry: **E3ME; E3MG; GEM-E3; GEMED; GEMINI-E3; GRAPE; PACE; ADAGE; AIM; GTAP-E; UKENVI; ABARE-GTEM; AMIGA; EDGE; ENV-Linkages; GEM-CCGT; WIAGEM.**

4.1.2 Specifications not covered

The specifications under Strategic Planning that are not properly/sufficiently covered by the models identified in the analysis are the following ones.

- *Technology deployment*
  - Bottlenecks to technology deployment (industry not ready to follow the demand): **MoreHys.**
- *Policy indicators*
  - LCA analyses: **GRAPE.**

Bottlenecks related to technology deployment require an in-depth analysis of the production chain for a given technology (e.g., resource issues such as silicon for solar PV panels, manpower, etc.).[3] Among identified models, only one, focused on hydrogen (MoreHys), aims at directly analyzing this type of problems. Nevertheless, for some other technologies, second best solutions can be found by using top-down models with an input-output representation of intermediate inputs requirement and that describe technology competition in the sector analyzed. The price for using this second solution is a loss of specificity. At the same time, there exist models that take somehow into account constraints to technology penetration and diffusion[4].

The only identified model that focuses on LCA analyses (at a country to global level) is GRAPE.[5] Second best options in terms of potentially useful information on this specification can be found in other

[3] Bottlenecks could also be related to the speed of infrastructure build-up, social and behavioural changes needed, etc. A simple bottleneck might also be the lack of political focus on issues that would remove (politically-induced) bottlenecks (e.g., modifying unfavourable/disputable taxation/regulation).

[4] For example, TIAM includes some exogenously defined growth constraints to represent such limits in the speed and extent of penetration of some technologies.

[5] This result can be interpreted as a drawback of the models identification procedure that has focused mostly on energy system models. In fact, the LCA approach is generally more useful for the evaluation of specific technological options and can hardly be applied to complex systems such as nuclear power generation.

Integrated-Assessment hybrid models such as IMACLIM or, at the local level, in qualitative tools such as Climate Bonus/Carbon footprinting.

4.2 Technology Deployment and Transition planning

The main objective of Transition Planning is to contribute to the understanding of applied issues such as: spatial planning (aimed at identifying the best suitable deployment locations for technologies, also in terms of infrastructure and grid connection); deployment pathways based on demonstration projects; administrative barriers and time delays in implementing a technology; market and organizational barriers; public perception and social acceptance of technologies.

Investments supporting commercial-scale demonstration projects on different technologies are crucial for technology deployment. At the same time, adequate infrastructures (transport and grid networks) are an essential prerequisite as well. Hence, it is crucial to have models and tools that allow policymakers to evaluate the investments needed in infrastructure development. To this end, information and results from Network Operators models for grid operation and investment planning in combination with feasibility studies might play an important role here.

In order to assess the usefulness of identified models and tools for Transition Planning, five key topics have been evaluated, each one including a condensed list of specifications (distinguished according to the need for either a rapid assessment or an elaborate analysis).

- *Spatial Planning*
    - Rapid assessment of:
        - Physical barriers (e.g. resource potential of a geographical area to provide wind or solar power; limited and inappropriate transport network)
        - Capacity expansion (infrastructure)
        - Grid-connection capacity
    - Elaborate analysis of:
        - Cost effective technology deployment
        - Availability of natural resources
        - Territorial integration
        - Migration flows
        - Effects on labour demand
        - Land use and population density
- *Deployment Pathways*
    - Rapid assessment of:
        - SET-Plan sectoral targets
        - Evolution of grid and transport networks
        - Supply chain logistics (interaction between local demand and global supply, time dependence, impact of changes in the energy system)
        - Links between the energy system and the economy (changes in demand, sectoral changes)
        - Synergies between technology, industry, social and policy changes
        - Public-private agent behaviours and partnerships
    - Elaborate analysis of:
        - Effects of 1st demonstration projects in Europe and scenarios to close gaps between demonstration and commercialization
- *Timing*
    - Rapid assessment of:
        - Time lag between investment decision and entering into operation of installations
        - Effects of different regulatory frameworks in Member States
- *Market design and organisational changes*

- Elaborate analysis of:
  - Market barriers (market design and organizational changes required; behavioural change)
  - Level playing field for all market participants within and among Member States
- *Acceptance/perception of a technology*
  - Rapid assessment of:
    - Social barriers (people's perceptions on technologies; social acceptance of technologies)
    - Quantification of employment (from supply chain perspective, regional approach and accounting for impact of the transition)
    - Public acceptance (awareness and understanding of technology use and implications)
    - Public participation (stakeholders involvement and resistance) and governance issues
    - Perceptions on reliability of a technology as energy source
    - Energy prices (for different groups)
    - Influence of competing technologies
    - Risk perception (investments, immaturity of technologies, reputation of operator or initiator, risk management)
    - Management of local supply chain (economic efficiency, sustainability, social responsibility, system operation concerns)
    - Land-use intensity
    - Divergence of views on landscape preservation
    - Siting issues
    - Concerns on health impacts
    - Safety issues and related perception
    - Distribution of local costs and benefits (fairness, equality)

4.2.1 Specifications covered

The specifications covered and the list of models that address a given specification as their primary focus of analysis is provided below.

- *Spatial Planning*
  - Physical barriers (e.g. resource potential of a geographical area to provide wind or solar power; limited and inappropriate transport network): **BALMOREL; E2M2s; EMELIE; EMM; Model for power plant and transmission expansion (IER); LEAP; Long-term energy demand model (three sub-models: MURE-Residential, ISIndustry, TEP-Tertiary); TIAM-World; TIMES PanEU; WILMAR; GMM; AIM; MESSAGE; MoreHys; EFDA-TIMES; EnergyPLAN; ENPEP-BALANCE; ETP model; IPAC; MINI-CAM; NEMS; REMIND-R; WEM; SAMLAST; REMARK; ESPAUT; MTSIM; WASP; CGEN; GreenNET-Europe model.**
  - Capacity expansion (infrastructure): **Model for power plant and transmission expansion (IER); STSc; MoreHys; SAMLAST; REMARK; ESPAUT; MTSIM; WASP; CGEN; GreenNET-Europe model.**
  - Grid-connection capacity: **BALMOREL; STSc; MoreHys; MINI-CAM; SAMLAST; REMARK; ESPAUT; MTSIM; WASP; CGEN; GreenNET-Europe model.**
  - Cost effective technology deployment: **MoreHys; DNE21+; INVERT; MINI-CAM; NEMS.**
  - Availability of natural resources: **EMM; AIM; DICE; MINI-CAM; NEMS; RICE.**
  - Effects on labour demand: **E3ME; E3MG; IMACLIM; ADAGE; AIM; NEMESIS.**
  - Land use and population density: **GRAPE; AIM; MINI-CAM.**
- *Deployment Pathways*
  - SET-Plan sectoral targets: **BALMOREL; E2M2s; Wilmar Planning Tool; LEAP; Long-term energy demand model (three sub-models: MURE-Residential,**

ISIndustry, TEP-Tertiary); PRIMES; RESolve-T; TIAM-World; TIMES PanEU; WILMAR; GMM; AIM; MESSAGE; EFDA-TIMES; ENPEP-BALANCE; ETP model; IPAC; MINI-CAM; WEM; SAMLAST; REMARK; ESPAUT; MTSIM; WASP; CGEN; GreenNET-Europe model.
    - Evolution of grid and transport networks: **STSc; SAMLAST; REMARK; ESPAUT; MTSIM; WASP; CGEN; GreenNET-Europe model.**
    - Links between the energy system and the economy (changes in demand, sectoral changes): **BEST; E2M2s; E3ME; E3MG; EMELIE; GEM-E3; GEMED; GEMINI-E3; ADAGE; AIM; IGEM; GTAP-E; UKENVI; ABARE-GTEM; AMIGA; DICE; EDGE; ENV-Linkages; EPPA; GEM-CCGT; NEMESIS; RICE; SGM; WIAGEM.**
- *Market design and organisational changes*
    - Market barriers (market design and organizational changes required; behavioural change): **BEST; E3ME; E3MG; GRAPE; STSc; Changing Behavior; Climate Bonus/Carbon footprinting, monitoring, feedback & rewards.**
    - Level playing field for all market participants within and among Member States: **E3ME; E3MG; GRAPE; STSc; Changing Behavior; INVERT.**
- *Acceptance/perception of a technology*
    - Social barriers (people's perceptions on technologies; social acceptance of technologies): **ESTEEM; GRAPE; Changing Behavior; Climate Bonus/Carbon footprinting, monitoring, feedback & rewards.**
    - Quantification of employment (from supply chain perspective, regional approach and accounting for impact of the transition): **E3ME; E3MG; GEM-E3; GEMED; GEMINI-E3; IMACLIM; MDM-E3; NEWAGE; ADAGE; AIM; GTAP-E; UKENVI; ABARE-GTEM; AMIGA; EDGE; ENV-Linkages; GEM-CCGT; NEMESIS; SGM; WIAGEM.**
    - Public acceptance (awareness and understanding of technology use and implications): **ESTEEM; STSc; Changing Behavior; Climate Bonus/Carbon footprinting, monitoring, feedback & rewards.**
    - Public participation (stakeholders involvement and resistance) and governance issues: **ESTEEM; STSc; GoReNEST framework.**
    - Perceptions on reliability of a technology as energy source: **GET; DNE21+; WASP.**
    - Energy prices (for different groups): **BEST; COALMOD; E2M2s; E3ME; E3MG; EMELIE; GASMOD; GEM-E3; GEMED; GEMINI-E3; OILMOD; GTAP-E; UKENVI; ABARE-GTEM; AMIGA; ENV-Linkages; GEM-CCGT; WIAGEM.**
    - Distribution of local costs and benefits (fairness, equality): **E2M2s; E3ME; E3MG; EMELIE; ESTEEM; GEM-E3; GEMED; GEMINI-E3; IGEM; GTAP-E; UKENVI; ABARE-GTEM; AMIGA; DICE; ENV-Linkages; GEM-CCGT; RICE; WIAGEM.**

4.2.2 Specifications not covered

The specifications under Technology Deployment and Transition Planning that are not properly/sufficiently covered by the models identified in the analysis are the following ones.

- *Spatial Planning*
    - Territorial integration: **AIM; MINI-CAM.**
    - Migration flows: **/.**
- *Deployment Pathways*
    - Supply chain logistics (interaction between local demand and global supply, time dependence, impact of changes in the energy system): **SGM.**
    - Synergies between technology, industry, social and policy changes: **STSc; GoReNEST framework.**
    - Public-private agent behaviours and partnerships: **STSc; GoReNEST framework.**
    - Effects of 1st demonstration projects in Europe and scenarios to close gaps between demonstration and commercialization: **/.**

- *Timing*
    - Time lag between investment decision and entering into operation of installations: **STSc.**
    - Effects of different regulatory frameworks in Member States: **STSc.**
- *Acceptance/perception of a technology*
    - Influence of competing technologies: **STSc; MINI-CAM.**
    - Risk perception (investments, immaturity of technologies, reputation of operator or initiator, risk management): **/.**
    - Management of local supply chain (economic efficiency, sustainability, social responsibility, system operation concerns): **ESTEEM; STSc.**
    - Land-use intensity: **GRAPE; MINI-CAM.**
    - Divergence of views on landscape preservation: **/.**
    - Siting issues: **MoreHys.**
    - Concerns on health impacts: **DICE; RICE.**
    - Safety issues and related perception: **/.**

The specifications included under the headings Spatial Planning and Deployment Pathways are difficult to analyze because of the high level of spatial detail required and the multi-dimensional nature of the issues analyzed. In general, it is possible to outline the scarcity of systemic approaches at local level and a poor interrelation between technical and behavioural issues. Territorial integration and migration flows (in particular, their impact at local level) seem to require further research and modelling efforts by the scientific community[6]. The same holds for other specifications that are not covered at all by identified models or that are covered just by means of qualitative tools such as STSc and the GoReNEST framework.

The specifications on Timing are dealt exclusively with qualitative tools of analysis (STSc). In fact, STSc can be used to account for time lags and different regulatory frameworks in a qualitative manner when building alternative transition paths for the energy system. On the other hand, quantitative models hardly cover these specifications. For instance, bottom-up models can use “construction time” as one of the parameters for identifying a technology (e.g., time for building a coal-fired power plant), but this affects to a limited extent the resulting evolution of the energy system due to the long (or very long) term horizon of the analysis.

Some of the specifications related to the Acceptance and Perception of a Technology are not satisfactorily dealt with by identified models mainly because of the lack of the appropriate level of spatial and sectoral detail that would be needed to cover them. Moreover, the specificity of some of these issues (e.g., landscape preservation, health impacts, siting and safety issues) would need dedicated sub-modules to be addressed properly.

4.3 Innovation and R&D

Innovation and R&D decision-making are core activities of SETIS (and the basis of the SET-Plan) through, for instance, the monitoring and review of technology performance through Key Performance Indicators and capacity mapping activities. In particular, this topic calls for targets and monitoring of R&D progress in specific technologies as well as for the identification of EU strengths and weaknesses in energy technologies compared to the rest of the world.

In order to assess the usefulness of identified models and tools for Innovation and R&D, these two topics have been further evaluated individually, together with general specifications, each one with a condensed list of specifications (distinguished according to the need for either a rapid assessment or an elaborate analysis).

[6] Migration flows rarely are an endogenous variable of energy, or even integrated assessment, models. These variables are, at best, reflected in some background assumptions of the analyzed scenarios.

- *General specifications*
  - Elaborate analysis of:
    - Long-term economic perspectives of technologies
    - Risks involved in research activities (long-term perspective)
- *R&D*
  - Rapid assessment of:
    - Effects of R&D spending (patenting, deployment)
    - Effects of public-private R&D partnerships, effectiveness of stimulating cooperation, timing of initialization of R&D support
  - Elaborate analysis of:
    - Technology specific R&D interim and final targets
    - Decision parameters to modify the ambition level of targets and the time paths
    - Assessment and monitoring of R&D funding mechanisms (for technological development lagging behind)
- *Innovation*
  - Rapid assessment of:
    - Strengths and weaknesses of EU and national industries
    - Quantify necessary R&D spending on specific technologies in order to cover the gap between EU and the rest of the world
    - Technologies needed to reach 2020 and beyond targets
  - Elaborate analysis of:
    - Identification of industrial opportunities in the energy sector for EU
    - Identification of sectors/technologies needing particular attention due to worldwide competition

4.3.1 Specifications covered

The specifications covered and the list of models that address a given specification as their primary focus of analysis is provided below.

- *General specifications*
  - Long-term economic perspectives of technologies[7]: **E3ME; E3MG; ADAGE; IGEM; DNE21+; EPPA; REMIND-R.**
- *R&D*
  - Effects of R&D spending (patenting, deployment): **E3ME; E3MG; WITCH; IGEM; MERGE; NEMESIS.**
  - Effects of public-private R&D partnerships, effectiveness of stimulating cooperation, timing of initialization of R&D support: **GEM-E3; ADAGE; IGEM; MERGE; AMIGA; NEMESIS.**
- *Innovation*
  - Strengths and weaknesses of EU and national industries: **E3ME; E3MG; ADAGE; IGEM; DNE21+; EPPA; NEMESIS.**
  - Technologies needed to reach 2020 and beyond targets: **EMELIE; GET; POLES; POWERS; PRIMES; TIAM-World; TIMES PanEU; WITCH; GMM; ADAGE; MESSAGE; MoreHys; DICE; EFDA-TIMES; ETP model; INVERT; MINI-CAM; REMIND-R; RICE.**
  - Identification of industrial opportunities in the energy sector for EU: **E3ME; E3MG; ADAGE; IGEM; DNE21+; EPPA; REMIND-R.**

[7] In general, long term economic perspectives of technologies are an input to the models since the modeller decides the specific investment costs for a technology, its learning potential, and so on. The possibility of reaching the economic performance indicators used in the models remains far from certain for a number of innovative, commercially untested technologies.

    - Identification of sectors/technologies needing particular attention due to worldwide competition: **E3ME; E3MG; GEM-E3; GEMED; GEMINI-E3; ADAGE; GTAP-E; ABARE-GTEM; AMIGA; EDGE; ENV-Linkages; GEM-CCGT; NEMESIS; REMIND-R; WIAGEM.**

4.3.2 Specifications not covered

The specifications under Innovation and R&D that are not properly/sufficiently covered by the models identified in the analysis are the following ones.

- *General specifications*
    - Risks involved in research activities (long-term perspective): **Horizon Scan; iKnow.**
- *R&D*
    - Technology specific R&D interim and final targets: **/.**
    - Decision parameters to modify the ambition level of targets and the time paths: **/.**
    - Assessment and monitoring of R&D funding mechanisms (for technological development lagging behind): **/.**
- *Innovation*
    - Quantify necessary R&D spending on specific technologies in order to cover the gap between EU and the rest of the world: **/.**

Qualitative methodologies such as HorizonScan and iKnow represent the only appropriate tool to analyze the risks involved in research activities from a long-term perspective. On the other hand, there is a lack of useful models specifically designed to deal with technology specific R&D targets and monitoring of funding mechanisms or able to quantify the necessary amount of R&D spending needed to become or to stay competitive with non-EU countries. This is mainly due to the fact that R&D is an intrinsically uncertain activity – and this makes it difficult to provide forecasts for specific technology needs – and existing models are mostly based on historical data and trends on R&D funding.

4.4 International Cooperation

To facilitate the transition of the energy system toward a low carbon future, but also to attain its Climate and Environmental objectives, the EU may benefit from international cooperation with third countries both in the R&D field and in the field of energy technology development and deployment.

In order to assess the usefulness of identified models and tools for International Cooperation, the two topics have been addressed individually, each one with a condensed list of specifications (distinguished according to the need for either a rapid assessment or an elaborate analysis).

- *General specifications*
    - Rapid assessment of:
        - Potentials of JI and CDM (for making targets outside the EU)
- *International cooperation on R&D*
    - Rapid assessment of:
        - Identify win-win situations (cooperation beneficial both to EU and to other parties)
        - Monitor benefits of international cooperation on R&D
        - Need for global centres of excellence (existence and fields of activity)
        - Main research interests in and outside EU (mapping technology, international governmental investments in programs for deployment, identify and avoid unidirectional transfer of knowledge)
        - Effectiveness of past international cooperation initiatives
    - Elaborate analysis of:
        - Evaluation of benefits of cooperation initiatives for both sides (EU and outside EU)
- *International cooperation on technology deployment*

    - Elaborate analysis of:
        - Effects of spill-over between different regions of the world and sectors
        - Deployment of technologies and the relative costs outside Europe (i.e., integrate IEA projections in SETIS)

4.4.1 Specifications covered

The specifications covered and the list of models that address a given specification as their primary focus of analysis is provided below.

- *General specifications*
    - Potentials of JI and CDM (for making targets outside the EU): **E3MG; GEM-E3; GEMINI-E3; PACE; AIM; MERGE; GTAP-E; ABARE-GTEM; DICE; ENV-Linkages; GEM-CCGT; MINI-CAM; REMIND-R; RICE; WIAGEM.**
- *International cooperation on R&D*
    - Evaluation of benefits of cooperation initiatives for both sides (EU and outside EU): **E3ME; E3MG; RICE.**
- *International cooperation on technology deployment*
    - Effects of spill-over between different regions of the world and sectors: **WITCH; AIM; NEMESIS.**
    - Deployment of technologies and the relative costs outside Europe (i.e., integrate IEA projections in SETIS): **AIM; REMIND-R.**

4.4.2 Specifications not covered

The specifications under International Cooperation that are not properly/sufficiently covered by the models identified in the analysis are the following ones.

- *International cooperation on R&D*
    - Identify win-win situations (cooperation beneficial both to EU and to other parties): **Horizon Scan; iKnow.**
    - Monitor benefits of international cooperation on R&D: **/.**
    - Need for global centres of excellence (existence and fields of activity): **Horizon Scan; iKnow.**
    - Main research interests in and outside EU (mapping technology, international governmental investments in programs for deployment, identify and avoid unidirectional transfer of knowledge): **Horizon Scan; iKnow.**
    - Effectiveness of past international cooperation initiatives: **/.**

Although global macro-economic models with a description of some energy and environmental sectors or commodities (E3ME, E3MG, RICE) are useful to evaluate the benefits of international cooperation initiatives, most of the specifications under the heading International Cooperation on R&D are difficult to analyze by relying on quantitative models. On the contrary, some of the specifications can be investigated by means of qualitative tools such as HorizonScan and iKnow. This might be related to the intrinsically uncertain nature of R&D activities and to the difficulty in finding appropriate ways to measure the effectiveness of international cooperation initiatives.

5. Feature analysis

Identified models, even when they primarily focus on a given specification, can often provide an unsatisfactory coverage of the specification itself at a given level of detail. In these cases, the partial coverage of the specification strictly depends on the model's features (due to, for example, inadequate level of geographical or time coverage, behavioral aspects not considered, and so on). This section puts forward the main deficiencies of the models (with respect to the list of specifications) from a features perspective. The discussion below will be based on the specifications that are covered as a primary focus by the models.

5.1 Strategic Planning

Overview

The primary focus of several energy models is traditionally related to most of Strategic Planning specifications. Results of the analysis confirm that the specifications included in this section are covered by a variety of models that can be roughly divided as follows:

- "Technology rich" bottom-up or hybrid models that cover the entire energy system (e.g. POLES, PRIMES, TIAM, TIMES, EFDA-TIMES, ETP model, GMM, MESSAGE, WEM). For these models, an inverse relationship between spatial detail (very poor) and technology detail (very rich) can generally be noticed.
- "Technology rich" bottom-up models for specific sectors of the energy system (e.g., bottom-up models of the electricity sector such as COMPETES, EMELIE, BALMOREL, WILMAR, or of the transport sector, such as TEMPO).

As an alternative, Top down models with sub-modules containing a description of the most relevant technologies can be used as a second best option even if they are not primarily focused on Strategic planning specifications (e.g., E3ME, E3MG).

Explicit technology description is a key feature in order to include as a model input all the relevant data concerning technology performance. All relevant dimensions of technology performance and physical barriers are almost entirely covered by technology rich models. The same applies for all issues that require a systemic approach (compatibilities, resilience of the energy system, impact on security of supply, indicators).[8] A trade-off between systemic approach and spatial detail/resolution is worth emphasizing as well as a prevalence of sectoral (electric system mainly) models for specific project analyses.

When the analyses focus on issues related to macroeconomic effects (competitiveness considerations, and impact on economic growth) the panorama of useful models moves towards top-down and hybrid (where a top-down component is dominant) models with an international dimension (e.g. GEM-E3, GEMED, GEMINI-E3, IMACLIM, MDM-E3, NEWAGE, PACE).

[8] It must be stressed that only a part of the issue of security of supply is typically covered in terms of, e.g., impact of fossil fuel import/shortage on the energy system. At the same time, the meaning of security of supply itself changes depending on the geographical perspective (e.g., transmission bottlenecks, intermittent sources and grid operation for a region, reliance on energy imports for a country). In addition, the economics of security of supply seems to be still at its infancy. One interesting project for security of supply evaluation is REACCESS (Risk of Energy Availability: Common Corridors for Europe Supply Security – 2008-2011), a project financed by the 7th Framework Programme (FP7) of the European Commission. The main goal is to build tools suitable for EU27 energy import scenario analyses, able to take into account at the same time the technical, economical and environmental aspects of the main energy corridors, for all energy commodities and infrastructures. It is based on the integration among the PET (to be recalibrated and refined after NEEDS and RES2020 output), the TIAM (TIMES Integrated Assessment Model) describing the whole world with 16 regions and the RECOR (REACCESS Corridor Model) developed for this project to describe the complexity of corridors infrastructures. The representation of risk within large scale models is the principal methodological challenge of this project.

Models used in Strategic planning cannot account for behavioral aspects (Social acceptance)[9] and economy description at branch level (or even more disaggregated); in addition it is possible to select some lack of required features in each of the following sub-sections.

Technology performance and development potential
The specifications "*Potential for cost reduction as a function of time/technical improvements through RD&D/deployment/learning effects*" and "*Overall efficiency gain and efficiency gain per tech/per kWh*" are not covered at local level and scarcely covered at regional level.

Policy indicators
Models ready to analyze the specification "*Total investment required to reach cost competitiveness*" do not explicitly model *uncertainty of R&D* effects as well as on *R&D effects on performance and costs*;
Geographical coverage at country and local level is not provided.

Models for "*Risk assessment ("change of plans", system failure, lock-in situations)*" do not explicitly model End Use technologies and R&D effects; the latter is an unessential feature given the limited time –frame considered.

Finally, the specifications that follows cannot be analyzed at local level:

- CO2 reduction per technology;
- Impact of global economic crisis on the energy system;
- LCA analyses ;
- Impact on water, particulates, soil, etc.
- Competitiveness considerations for regional industry.

5.2 Technology Deployment and Transition Planning

Overview
Spatial Planning of technology deployment requires models with a high geographical detail at the local level. Some sector models (e.g., MoreHys, IER model for Power plants and transmission expansion and other disaggregated grid models) provide information on technology and infrastructure development with a high territorial detail. The capacity and the integration of existing infrastructures are well assessed by the above mentioned models as well. What is missed is a systemic approach that analyses competition between different energy carriers and new infrastructures location and development (CGEN is an exception because take into account natural gas and electricity generation complementarities).
The modeling portfolio with respect to the SET-Plan technologies is also biased towards the electric system. Expansion required for electric grids or the impact of the penetration of wind power and other RES, are assessed by several models. On the other hand we register a scarce coverage for CCS infrastructures (see also par. 3.3) and for biomass.

Moving to a wider geographical coverage enlarges the portfolio of available models including also some hybrid I-A models (Mini-Cam, GRAPE, AIM, DICE; RICE, NEMS[10]) that can provide analyses at country or global level and specifications concerning land use, territorial integration, and availability of natural resources.

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[9] The SOCIO-MARKAL (SOMARKAL) study by Cubizolle et al. (2010) aims at proposing a new MARKAL framework that would take into account consumers technological improvements and behavioural changes to minimize carbon dioxide emissions and encouraging a rational use of energy. As opposed to the MARKAL framework based on technical and economic considerations, the SOCIO-MARKAL model integrates technological, economic and behavioural contributions to the environment.

[10] IMACLIM, NEMS, IMAGE, MESSAGE are not primarily focused on Spatial Planning but can also provide useful information. In MESSAGE, for instance, land use is represented by a limit on bio-energy and sink potentials, based on scenario definition (e.g., degree of urbanisation) and outputs from land-use (forestry and agricultural sector) models.

Qualitative tools may be useful in analyzing issues like synergies between technology, industry, social and policy changes and public-private agent behaviors and partnerships in the Deployment Pathways of technologies. Effects on employment, sectoral changes and supply chain logistics can be evaluated by means of top-down models or hybrid models that include an input-output representation of the economic system.
A good number of models and tools with different approaches (bottom-up, top-down, hybrid Integrated Assessment) and at different levels (sector, energy system, economy) cover two issues related to the acceptance and perception of a technology: energy prices (for different groups) and distributional issues. However, attention must be paid in interpreting these results. In most cases, the possibility of having, e.g., different electricity prices for different sectors of the economy, does not relate directly to the way a given sector accepts and/or perceive a technology. Similarly, distributional issues (such as the impact of energy policies on households' income versus firms' profits) may be analyzed by these models without explicitly addressing equity considerations.

Qualitative tools (e.g. ESTEEM, SocioTechnical Scenarios, Changing Behaviour, Horizon scanning, IEE - Behave/PRECEDE-PROCEED Planning Model, Climate Bonus) can also play a role in analyzing some specific issues related to future evolution or acceptance of technologies.

As for the specifications grouped under the heading "Acceptance/perception of a technology", a number of them are not covered by the models and tools under consideration: i.e., risk perception of investing in a technology (related to technology maturity); landscape preservation[11]; safety issues. On the other hand, public acceptance (awareness and understanding of technology use and implications), public participation and governance as well as sustainability issues (management of local supply chain) are investigated at different levels by relying on qualitative or semi-quantitative tools (e.g., ESTEEM, STSc, Climate Bonus, etc.). A very limited number (two or in some cases just one) of alternative models deal with specific issues: reliability of a technology as energy source (GET, DNE21+); land-use intensity (GRAPE, MINI-CAM); siting issues (MoreHys); health impacts (DICE, RICE).

Market design issues (market and organisational barriers, level playing field for all market participants within and among MS) are investigated in a qualitative way by socio-technical scenarios and in a semi-quantitative manner by energy behaviour tools. At the same time, only a very limited number of hybrid Integrated Assessment models (COMPETES, POWERS) provide a quantitative analysis of these issues.

After this general overview, for each section lack of model's relevant features are identified.

Spatial Planning
Models used in this section cannot deal with *Social acceptance* and with *uncertainty of R&D* effects as well as on *R&D effects on performance and costs*. In addition:
- *Land use* is not considered by models that account for infrastructure expansion;
- *Availability of natural resources* and *Territorial integration* are not assessed at regional or local level

Deployment pathways
Quantitative models used in this section cannot deal with *Social acceptance*.

Market design and organizational changes
Quantitative models used in this section do not take into account *Innovation and R&D effects*.

[11] Issues like these are sometimes included in very elementary ways, e.g., by reducing the potential of a given technology in such a way that the number of protected areas increases. This, however, is usually done for resources that require a large amount of land-area (bio-energy) and even in this case mostly by taking into account areas that are natural reserves.

5.3 Innovation and R&D

Overview

R&D activities present an intrinsically high degree of uncertainty. For instance, concerning the relationship between public and private R&D funding devoted to a particular technology or sector and the effective return - in terms of innovative technologies and/or products – of such investments. Such an uncertainty makes it difficult to quantify by means of a model the effectiveness of R&D spending and to make forecasts about the sectors or technologies that deserve particular attention (hence, funding) by public and private decision-makers. In spite of that, the models identified in the analysis are able to cover some of the issues identified above. In particular, concerning the R&D topic:

- Horizon scanning methodologies are based on a foresight process that aims to chart trends, weak signals, opportunities and threats from a long-term perspective; in particular, events and developments potentially shaping or shaking the future of science, technology and innovation (STI) in the European Research Area (ERA). This methodology can prepare for "surprises" and repetitive scanning allows to check whether charted developments really do take place or weaken. In this sense, this methodology turns out to be relevant to identify the risks involved in research activities, but only partially the risk of a technology breaking through.
- A very limited number of hybrid Integrated Assessment or econometric models are able to account for the effects of both R&D spending and public-private R&D funding in achieving EU policy goals. Many models, however, can analyse the consequences of learning resulting from R&D investments as long as learning parameters are an exogenous input to the model.

Innovation issues have by definition an international dimension. They require an analysis of market developments at a global level, and a comparison of sectoral and regional trade flows. Global top-down or hybrid models (such as, e.g., POLES, REMIND-R, E3MG, etc.) help in understanding this dimension but, despite the massive use of global economic models in energy policy debate, only few of them can be useful to identify sectors and technologies exposed to international competition and to define strengths and weaknesses of EU and national industries.

A summary of the most relevant issues related to feature analysis of this section are reported below.

General specifications

Lack of *Land use* assessment as well as behavioral aspects in evaluating "*Long-term economic perspectives of technologies*".

R&D

Models used to evaluate "*Effects of R&D spending (patenting, deployment)*" and "*Effects of public-private R&D partnerships, effectiveness of stimulating cooperation, timing of inizialization of R&D support*" focus mainly on supply side technologies providing a scarce coverage of End-use technologies, resources and infrastructures. In addition a description of the economic system does not cover a branches detail level while the geographical coverage is not possible a regional level. *Social acceptance* aspects cannot be analyzed by models that focus on the two specifications reported above.

Innovation

Models that focus on the specifications included in the Innovation section do not take into consideration *behavioral aspects* (in particular problems of *social acceptance*). The specifications of this sections aims at evaluating competitiveness issues related to new technologies but the models often provide analyses at a more aggregated level (sector instead of branches or technologies).

5.4 International Cooperation

Overview

Issues about "International cooperation on R&D" are hardly dealt with by identified models. In particular, only horizon scanning methodologies have been developed and are able to account for issues like the identification of win-win situations, the existence and fields of activity of global centres of excellence, the main research interests in and outside EU as well as the effectiveness of past international cooperation initiatives. On the other hand, a few Integrated Assessment econometric models (e.g., E3ME, E3MG, RICE) are able to perform an evaluation of costs and benefits of R&D collaboration for both EU and non-EU countries. Concerning 'International cooperation on technology deployment', a good number of multi-country and global models with different analytical approaches developed both in Europe and by extra-EU research institutions (e.g., PACE, AIM, MERGE, GTAP-E, ABARE-GTEM) cover as their primary focus the potentials of JI and CDM and technology market developments at the world level.[12] In addition, socio-technical scenarios can be used as a complementary tool for qualitative assessment of the potentials of JI and CDM as well as of the effects of turning partial to perfect spill-over.

General specifications
Lack of project and regional dimensions as well as behavioral aspects in assessing "*Potentials of JI and CDM*";

International cooperation in technology deployment
Lack of macroeconomic models with a Branches detail for the following specifications:

- Effects of spill-over between different regions of the world and sectors
- Deployment of technologies and the relative costs outside Europe
- Evaluation of benefits of cooperation initiatives for both sides (EU and outside EU)

Lack of country level detail for "Evaluation of benefits of cooperation initiatives for both sides (EU and outside EU)".

[12] Most energy systems models (e.g. MESSAGE, TIAM) can be interpreted to do the same. If a global emission price is given, the activities that are economically viable with that price are done, no matter the geographic location. It would also be easy to constrain in the model the share of reductions in the developed world that can be done through projects in the developing world. Since these models are global, they also show the development and diffusion of the technologies on the global, as well as regional, levels.

6. How to use the results

The objective of this section is to illustrate the way policymakers and other stakeholders can use the results from primary focus assessment and feature analysis of identified models and tools.

First, models suitability to address the list of specifications is evaluated based on their primary focus. The matrices for primary focus assessment collected in Appendix C show which models cover a given specification. The use of these matrices is straightforward: policymakers and stakeholders interested in providing an answer to a given issue can find, by scrolling down the column, models whose primary focus of analysis is the specification reported in the column's headline.

Second, the matrices for feature analysis collected in Appendix D provide additional information on the level of detail a given specification can be addressed by different models. In these matrices, models are identified by numbers from 1 to 85 (the correspondence between numbers and model names can be found in the model list in Appendix B). Numbers are used to identify the models covering the specification reported in the headline and the features characterizing the model.

A practical example can be helpful in understanding how to use the matrix for feature analysis. The stakeholder interested in analyzing the specification "Resilience of the energy system against shocks of power system failures and extreme weather events" will scroll down the second column of the matrix for feature analysis of Strategic Planning specifications. Not surprisingly, this issue is one of the primary focuses of analysis for a great amount of models (nearly 30). This ample coverage is shown by the list in the cell corresponding to the intersection of the row "Primary Focus" and the second column of the matrix (this cell summarizes results of the matrix for primary focus assessment of Strategic Planning specifications).

When a model with a very short time frame is needed in order to perform the analysis, the cell at the intersection of the row "Intra-day to year" with the second column of the matrix identifies a subset of models (9 models) with the desired characterization. The same procedure can be applied in order to identify appropriate models when, for example, a specific geographical coverage or system coverage is desired.

The matrix is also useful to identify features that are not covered for each specification. The stakeholder interested in analyzing the specification "Supply chain logistics" for a given technology will find that only the model 76 (SGM) considers it as its primary focus. Nevertheless, if the stakeholder is interested in evaluating this specification from a regional perspective, he/she will not find any model able to deal with this level of geographical coverage because model 76 is a multi-country model. This example can also be helpful in drawing some conclusions on the degree of approximation of the analysis and on the needs for further modeling efforts by the research community. Model 76 is a top-down model without any explicit description of the technologies used in the energy system (cells corresponding to the "Technology detail" set of rows are empty). In addition, the description of the supply chain logistics would be very rough because the economic system is described at sector instead of branch level. Therefore, the stakeholder would identify the economic sector corresponding to the technology he/she is interested in and have only an approximate assessment of the corresponding supply chain needs.

7. Conclusions

This report contributes to the identification and characterization of existing models and tools that can cover the specifications set out by ATEsT WP1. To this end, a list of models and tools was identified based on literature review and experts' suggestions. Then, an open call was made with the support of the JRC to collect information from model developers through a questionnaire. To complete the inventory, additional information on identified models were collected based on literature references and web search. Following this information collection step, models were characterized based on their ability to respond to required specifications and on their main features.

The "ideal" model type and requirements that a model should satisfy to deal with specific SET-Plan issues were presented in an ideal model matrix toolbox and examples on how to couple models to provide an answer to given specifications was provided. Based on the assessment of identified models and tools, matrices for model evaluation were filled to show the degree of coverage for the different specifications. Two sets of matrices were used:

- matrices for primary focus assessment showing the models that cover a given specification as their primary focus of analysis and models that can be potentially useful in answering a specification (second best options);
- matrices for feature analysis showing the level of detail (technological, geographical, temporal, sector, etc.) at which models whose primary focus is to analyze a specification cover it.

These matrices give an overview of the main critical energy system modelling aspects that need to be further or better developed.

The key findings on the specifications that are covered and on those that need further modelling efforts by the scientific community can be summarized as follows.

Strategic Planning
A long list of models addresses most of the specifications under Strategic Planning as their primary focus of analysis. This is true both for "General specifications" concerning the resilience of the energy system against different sources of shocks and for specifications related to "Technology performance and development potential". Similarly, all the specifications under the heading "Policy indicators" (except for LCA analyses) are well covered by different types of identified models.

The most critical deficiency lies on the scarcity of models designed to investigate the possible "Bottlenecks to technology deployment". In fact, only one model (focused on hydrogen) aims at directly analyzing this type of problems. Although there exist models that take somehow into account constraints to technology penetration and diffusion (e.g., Markal-type Bottom-up models), a more accurate coverage of this specification would require at least a deep analysis of the production chain for the technology under consideration.

Technology Deployment and Transition planning
Most of the specifications are appropriately covered by different types of models. For instance, "Capacity expansion (infrastructure)" and "Grid-connection capacity" represent the primary focus of some disaggregated models focused on infrastructure expansion and used by national TSOs and DSOs for electricity grid planning. Many models with different analytical approaches are useful to investigate specifications such as "SET-Plan sectoral targets", whereas "Links between the energy system and the economy" are better analyzed by macro-economic models. The latter, together with energy behaviour and other qualitative tools, are also helpful to cope with "Market design and organisational changes" and a few "Acceptance/perception of a technology" specifications.

The specifications that are not properly/sufficiently covered by the models identified relate to issues like "Territorial integration" and "Migration flows" or "Supply chain logistics" that require a high level of spatial and sector detail. In general, it is evident a lack of systemic approaches at the local level and a poor interrelation between technical and behavioural issues. This will require further research and modelling efforts by the scientific community.

The same is true for other specifications that are not covered at all by identified models or that are covered just by means of qualitative tools such as the "Timing" specifications. Similarly, some "Acceptance/perception of a technology" specifications are not satisfactorily addressed by identified models mainly because of the lack of the appropriate level of spatial and sector detail that would be needed to cover them. Moreover, the specificity of some of these issues would need dedicated sub-modules to be addressed properly.

Innovation and R&D

A good number of models covers most of the specifications related to "Innovation". On the other hand, "R&D" issues represent one of the most challenging tasks for modellers and for the scientific community. Qualitative methodologies represent the only appropriate tool to analyze the "Risks involved in research activities" from a long-term perspective. Moreover, there is a lack of useful models specifically designed to deal with technology specific R&D targets and monitoring of funding mechanisms or able to quantify the necessary amount of R&D spending needed to become or to stay competitive with non-EU countries. This is mainly due to the fact that R&D is an intrinsically uncertain activity – and this makes it difficult to provide forecasts for specific technology needs – and existing models are mostly based on historical data and trends on R&D funding.

In general, addressing R&D specifications from a modelling viewpoint is challenging because of several issues:

- data availability (e.g., need of global data, private data lacking, feedback between private R&D investments and sales, lack of global market model for technology production overtime);
- methodology (e.g., the learning curves is one possible approach, but it is necessary to account not only for the effect of deployment and R&D, but also for bottleneck issues);
- modelling coupling as feedback loops and spill-over.

International Cooperation

General specifications on the "Potentials of JI and CDM" are appropriately covered by different types of models. Issues related to "International cooperation on technology deployment" are covered only by a few models, hence a deeper analysis might be needed in this sense. The most evident deficiencies, however, lie in the coverage of "International Cooperation on R&D" specifications. Although global macro-economic models with a description of some energy and environmental sectors or commodities can be useful to evaluate the benefits of international cooperation initiatives, most of the specifications can be investigated only by means of qualitative tools. This might be related to the intrinsically uncertain nature of R&D activities and to the difficulty in finding appropriate ways to measure the effectiveness of international cooperation initiatives.

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Glossary

ATEsT: Analysing Transition Planning and Systemic Energy Planning Tools for the implementation of the Energy Technology Information System
CCS: Carbon Capture and Storage
CDM: Clean Development Mechanism
CSLF: Carbon Sequestration Leadership Forum
EERA: European Energy Research Alliance
EII: European Industrial Initiatives
ETS: European Trading Scheme
EU: European Union
GDP: Gross Domestic Product
IEA: International Energy Agency
IPCC: Intergovernmental Panel on Climate Change
IPHE: International Partnership for the Hydrogen Economy
IRENA: International Renewable Energy Agency
ITER: International Thermonuclear Experimental Reactor
JI: Joint Implementation
KPI: Key Performance Indicators
LCA: Life Cycle Analysis
O&M: Operation and Maintenance
OECD: Organisation for Economic Co-operation and Development
PV: Photovoltaic
R&D: Research and Development
R, D&D: Research, Development and Demonstration
RES: Renewable Energy Sources
SETIS: SET-Plan Information System
SET-Plan: Strategic Energy Technology Plan
SET-Plan Steering Group: European Community Steering Group on Strategic Energy Technologies
STI: Science, Technology and Innovation
STSc: Socio Technical Scenarios
Tool: methodology that needs to be applied in software as well as software-supported systematic frameworks and procedures that are capable of handling e.g. qualitative data in appropriate ways.
Transition planning: Analyse and recognize the evolution of the energy system reaching the target point, focusing on the technology mix of the entire energy chain, including analysis of the social impact, policy drivers and sustainability.
TPES: Total Primary Energy Supply
TSO: Transmission System Operator
DSO: Distribution System Operator

Analysing Transition Planning and Systemic Energy Planning Tools for the implementation of the Energy Technology Information System

ENERGY MODELS CLASSIFICATION FORM

A. IDENTIFICATION

A1. Name/Extended name

A2. Developed by

A3. Used by

A4. Funded by

A5. Year of implementation

A6. Latest update

A7. References for model description

B. EVALUATION CAPABILITIES AND MAIN APPLICATIONS

B1. Model focus

B2. Model output

B3. Capability to model environmental and energy policies

- □ Market-oriented policies
- □ Non-price policies
- □ Other (specify)

Brief description/comments/explanations:

B4. Capability to model economic and social effects

- □ Impact of change in the environment/energy sector on the economic system
- □ Tax revenue recycling and double dividend issue
- □ Direct and indirect demand effects

- ☐ No-regret potential
- ☐ Impact of policy-induced innovation on country's or regional competitiveness
- ☐ Distributional issues
- ☐ Externalities, societal and healthcare/mortality costs
- ☐ Other (specify)

Brief description/comments/explanations:

B5. Capability to model uncertainty and to assess risk

Uncertainty:	☐ deterministic model	☐ stochastic model	☐ other (specify)
Risk:	☐ explicit	☐ implicit	☐ other (specify)

Brief description/comments/explanations:

B6. References for model use/applications

C. SPECIFIC CAPABILITY TO MODEL AND EVALUATE SET PLAN NEEDS AND PRIORITIES

C1. Strategic planning

C2. Deployment and transition planning

C3. Innovation and R&D

C4. International cooperation

C5. Barriers to SET-Plan implementation

D. MODEL SCOPE

D1. Geographical scope

- ☐ Global
- ☐ Country
- ☐ Region
- ☐ Local
- ☐ Project-related
- ☐ Other (specify)

Brief description/comments/explanations:

D2. Time horizon and transition path

- ☐ Less than 5 years
- ☐ From 5 to 10 years
- ☐ From 10 to 50 years
- ☐ More than 50 years
- ☐ Other (specify)

Brief description/comments/explanations:

D3. System boundaries and detail

D4. Energy commodities detail

☐ ≤ 5 ☐ between 6 and 10 ☐ between 11 and 50 ☐ between 51 and 100 ☐ ≥ 101

Brief description/comments/explanations:

D5. Emission species considered

- ☐ Only CO_2
- ☐ Some gases (specify)
- ☐ All GHG included in the Kyoto Protocol
- ☐ Other (specify)

Brief description/comments/explanations:

D6. Other commodities

D7. Technology detail

☐ ≤ 5 ☐ between 6 and 50 ☐ between 51 and 200 ☐ between 201 and 500 ☐ ≥ 501

Brief description/comments/explanations:

D8. Solution detail

E. <u>THEORETICAL BACKGROUND AND STRUCTURE</u>

E1. Analytical approach

- ☐ Top Down
- ☐ Bottom Up
- ☐ Integrated Assessment
- ☐ Other (specify)

Brief description/comments/explanations:

E2. Model type

E3. Degree of endogenization

E4. Technological progress characterization

Technology learning: ☐ no ☐ yes (☐ endogenous ☐ exogenous)

Brief description/comments/explanations:

E5. Dynamics characterization

☐ Static ☐ Dynamic ☐ Other (specify)

☐ Myopic ☐ Perfect foresight ☐ Other (specify)

☐ Putty-clay capital allocation ☐ Putty-putty ☐ Other (specify)

Brief description/comments/explanations:

E6. Internal and external linkages

E7. Graphical representation

F. <u>ACCESS</u>

F1. Platform required

☐ Windows ☐ Linux ☐ Mac ☐ Other (specify)

F2. Interface required

☐ Veda ☐ RUNGTAP ☐ Other (specify)

F3. Coding/Programming language

☐ GAMS ☐ MPS GE ☐ GEMPACK ☐ Other (specify)

F4. Source code, model and costs

☐ Open ☐ Restricted ☐ Closed ☐ Other (specify)

F5. Skills and training required

☐ User-friendly ☐ Trained users ☐ Experts ☐ Other (specify)

Brief description/comments/explanations:

F6. Main characteristics of the model database

G. ADDITIONAL NOTES AND COMMENTS

Classification form filled by

Name:

Affiliation:

Email/contact details:

Compilation date:

ATEsT

Analysing Transition Planning and Systemic Energy Planning Tools for the implementation of the Energy Technology Information System

GUIDELINES FOR ENERGY MODELS CLASSIFICATION FORM

<u>Introduction</u>

The "tools" that will be evaluated in the framework of ATEsT are methodologies for the analysis of energy policies and mathematical models that can be used in order to simulate the development of the energy system and/or analyse the transition planning in the energy system. We generically use the terms "tool" or "model" to refer to a methodology that needs a software application.

The options we illustrate below have to be considered as suggestions and examples useful to compile the classification form. Whenever needed, more than one option can be chosen and specifications/explanations can be added to your answers. If you consider some questions as being not relevant, feel free to skip them.

A. <u>IDENTIFICATION</u>

A1. Name/Extended name: name of the model/tool used.

A2. Developed by: group (consortium, institute, university, private company, agency, etc.) that first developed the model/tool.

A3. Used by: groups (consortium, institute, university, private company, agency, etc.) that are currently using the model/tool.

A4. Funded by: entity (national government, international institutions, universities, agencies, private companies) that funded the development of the model/tool.

A5. Year of implementation.

A6. Latest update.

A7. References for model description: most relevant articles, websites, or other sources, that describe the model/tool structure and functioning.

B. <u>EVALUATION CAPABILITIES AND MAIN APPLICATIONS</u>

B1. Model focus: describe in a synthetic way the purpose of the model.

B2. Model output: main results of the model, e.g. technology mix and costs of the whole energy system, prices of energy commodities, amount of emissions, investments related to energy technologies, etc.

B3. Capability to model environmental and energy policies

Indicate whether the model is able to address the following categories of policies and provide a brief description of how this is achieved:

- Market-oriented (i.e., price-induced, <u>for a given technology set</u>) policies (e.g. taxes and subsidies, emission charges, tradable emission permits, etc.).
- Non-price policies:

- Technology oriented and R&D (i.e., affecting the technology set) policies (e.g. norms and standards, research, innovation and demonstration programmes, etc.).
- Voluntary policies (e.g. eco-labelling and voluntary agreements).
- Accompanying measures (e.g. public awareness, information distribution, education, etc.).

B4. Capability to model economic and social effects

Indicate whether the model is able to capture the following economic and social effects and provide a brief description of how this is achieved:

- Impact of change in the environment/energy sector on the economic system (based on e.g. percentage GDP change, creation/loss of jobs, trade volumes, etc).
- Tax revenue recycling and double dividend issue.
- Direct and indirect demand effects.
- No-regret potential (negative cost options).
- Impact of policy-induced innovation (introduction of new technologies, first-mover advantage) on country's or regional competitiveness (measured by, e.g., country's terms of trade).
- Distributional issues (inter-generational and intra-generational equity).
- Externalities, societal and healthcare/mortality costs.
- Other (specify).

B.5 Capability to model uncertainty and to assess risk

Indicate whether the model is able to:

- Account for the uncertainty related to technology development (e.g. the relationship between RD&D expenditures and technology cost and technical performance).
- Assess and/or quantify (explicitly or implicitly) the risk of failures in the development of energy technologies and the resulting impact on the energy system.

Provide also a brief description of how this is achieved.

B6. References for Model Use/Applications

Most relevant articles, websites, or other sources, describing the model/tool use and applications. Brief description of case studies (region, technologies considered, problems identified) undertaken using the model/tool.

C. SPECIFIC CAPABILITY TO MODEL AND EVALUATE SET PLAN NEEDS AND PRIORITIES

C1. Strategic planning

Can the model take into account the following relevant information?

- Technology performance and development potential (investment and O&M costs, environmental performance, technical performance, SET-Plan Key Performance Indicators).
- Expected cost reduction (potential for cost reduction as a function of time and/or of deployment, potential for technical improvements, total investments required from public and private funds to reach cost parity with traditional technologies, ultimate cost level at which learning and scale economies do not take place anymore).

- Technology deployment (maximum potential of a given technology and the time horizon of the pathway, regional specificities, endogenous market shares).

Is the model useful to evaluate the following impacts/indicators?

- Impact of technology deployment on the energy system structure and on EU security of supply.
- Policy indicators (main SET Plan sectoral targets, CO_2 reduction per technology, share of RES on TPES or on electricity supply, overall efficiency gain, efficiency gain per technology or per kWh, biofuels targets).
- Shifting technology options (different scenarios that exclude specific technology options and use different kind of implementation stimuli).

C2. Deployment and transition planning

Capability to model the transition of the energy system towards the SET Plan main objectives (for example, European Industrial Initiatives on wind, solar, nuclear fission, bioenergy, smart grids, etc.) and to evaluate the resulting impact. Two main issues may be of interest:

- Spatial planning and deployment pathways:
    - Geographical and temporal planning of technology deployment.
    - Choice and utilization of demonstration projects.
    - Evolution of grids (e.g. trans-national electricity interconnections, grid dynamics, etc.) and transport networks.
    - Logistics and supply chain requirements.
    - Environmental aspects (based on, e.g., LCA methodology), resource potential and other uses.
    - Territorial considerations.
- Impact analysis of the transition process:
    - System reliability, security of supply (also related to policy issues outside EU).
    - Sectoral changes.
    - Employment that can result from the deployment of low-carbon technologies from a supply chain perspective and with a regional approach.

C3. Innovation and R&D

Capability to:

- Analyse long term economic perspectives and industrial opportunities of technologies.
- Investigate strengths and weaknesses of EU and national industries.
- Evaluate whether a technology deployment is also environmentally and not just economically driven.
- Monitor the allocation of and evaluate trade-offs between public and private R&D funding.
- Measure the effects of R&D spending (patents, deployment, ex-post monitoring of effectiveness in reaching technology-specific targets).

C4. International cooperation

Capability to evaluate how international cooperation mechanisms may help the energy system transition towards the SET-Plan objectives. The reinforcement of international cooperation aims at supporting the decision-making process related to investments in, e.g., commercial-scale demonstration projects. This should provide guidance on how these projects can be used as seeds for further deployment.

The main issues that may be of interest are:

- Potentials of Joint Implementation and Clean Development Mechanism. Can EU make its targets elsewhere? Which technologies are required in an international cooperation framework?
- Benefits of international cooperation initiatives like IPHE, CSLF. Effect of turning partial spill-over to perfect spill-over (e.g. by exchanging knowledge on local learning aspects of energy technologies like installation, utilization, etc.).
- Development and deployment of technologies and the relative costs outside Europe (i.e. integrate IEA projections in SETIS), e.g. for exploring possibilities of free-riding.
- Role of knowledge sharing platforms, taking into account the different legal frameworks for knowledge protection (e.g. intellectual property rights issues). Striking a balance between international cooperation and patents/innovation protection.
- Monitoring of market and technical developments of energy technologies at the world level.
- Evaluation of costs and benefits for both sides (EU and outside EU).

C5. Barriers to SET-Plan Implementation

It is crucial to perform a bottleneck analysis concerning infrastructure developments, resource potential/availability/quality/etc. that are/will be required for the deployment of a given technology.

This Section investigates the capability to model and analyze different forms of barriers to the implementation of the SET-Plan objectives.

- Physical barriers (e.g. resource potential of a geographical area to provide wind or solar power; limited and inappropriate transport network).
- Technical barriers and technology complementarities (interdependency between different technologies: e.g. supporting wind turbines installation not successful in the absence of investments in electric grid development).
- Market and social barriers to technology deployment (market design and organizational changes required; behavioural change; people's perceptions on technologies; social acceptance of technologies).

D. MODEL SCOPE

D1. Geographical scope

Identify the geographical scope of the model/tool, specifying whether (and in case how) trade is considered:

- Global.
- Country.
- Region (it may refer to a group of countries or a group of regions within a country).
- Local.
- Project-related.

D2. Time horizon and transition path

Indicate the time horizon (short, medium, long) of the model using the following characterization:

- Less than 5 years.
- From 5 to 10 years.
- From 10 to 50 years.
- More than 50 years.

Indicate also the time-step (hourly, daily, monthly, yearly, 5 years, etc.) used in the analysis.

Finally, specify whether the transition path (i.e., an entire set of results for intermediate periods) is described or only initial and final situations are provided. This information is aimed at understanding if the model/tool can be useful for transition planning, defined as: "Analyze and recognize the evolution of the energy system reaching the target point, focusing on the technology mix of the entire energy chain, including analysis of the social impact, policy drivers and sustainability" (ATEsT kickoff meeting, Athens 12th – 13th October 2009).

D3. System boundaries and detail

Energy sectors and energy demand sectors (e.g. industry, households, government, etc.) included in the model/tool.

D4. Energy commodities detail

Energy carriers considered in the model/tool (please indicate units). E.g. primary energy carriers (coal, gas, oil, natural gas, etc.); secondary energy carriers (solid, liquid gas, electricity, petroleum products, etc.).

D5. Emission species considered

Indicate whether the model/tool considers GHG and/or other pollutants in the analysis and specify which ones:

- Only carbon dioxide (CO_2).
- Some gases (specify which ones: CO_2, NOx, SOx, etc.).
- All GHG included in the Kyoto Protocol.
- Others (specify: e.g. water pollutants, particles, black and organic carbon, etc.).

D6. Other commodities

Materials, wastes, non-energy commodities.

D7. Technology detail

- Technology representation:
    - Black box (production function with n production factors and elasticities of substitution between factors).
    - Technology cards/sheets with explicit data on costs, efficiencies, etc.
    - Other (specify).
- Technology competition representation:
    - Technologies are not described in detail, but aggregated proxies are used for converting primary energy to final end-use commodity.
    - Conversion technologies are described in detail, leading to competition between not only primary energy carriers, but also conversion technologies for which these commodities can be used as inputs.
    - Other (specify).

D8. Solution detail

Specify how many regions are involved in the solution algorithm (i.e. there is only a global region or the global coverage is given by n regions; the national model is composed by sub-regional models).
Specify the number of time slices involved in the model solution.

E. THEORETICAL BACKGROUND AND STRUCTURE

E1. Analytical approach

- Top-Down models are economic, general equilibrium or aggregated models; they aim at giving a comprehensive picture of the functioning of an economic system, including the relationship between energy markets and the rest of the economy, based on the behaviour of representative and rational economic agents maximizing an objective function. The economic theory underlining the model structure can differ between models. They are usually divided into two categories:
  - Macro-econometric models, oriented towards short to medium term analysis with the focus on the dynamics of adjustment (so called Keynesian or effective Demand models).
  - General equilibrium models oriented towards long term analysis.
- Bottom-Up models usually focus on the energy sector and use highly disaggregated data to describe energy end-uses and technological options in detail, but the macroeconomic background remains exogenous.
- Integrated Assessment models that include sectors beyond the energy/economy sector in their description. They usually cover mostly the entire economy but some only the energy system (e.g. TIAM) and for the entire World, they consider a very long term horizon (100 to 300 years). They may include impact on the environment (e.g. temperature increase for climate change); the feedback on the economy through damage function (when macroeconomic). Because of their very long term horizon and world coverage, they are rather simplified regarding economics mechanisms, sectoral and technical disaggregation, and regional disaggregation.

E2. Model type

If useful, please refer to the following commonly used categories:

- Economic/not economic models (where economic models include prices as model variables or result).

And/or:

- Economic Partial equilibrium models/ Economic General equilibrium models/ not economic equilibrium models/ multicriteria analysis (used for including other criteria than just economic efficiency).

And/or:

- Forecasting/Backcasting/Scenario analysis (exploring purposes).

And/or:

- Optimisation/simulation.
  - Optimisation: the model is specified by more variables than equations; in order to solve it, it is necessary to minimise/maximise explicitly an objective function (profits, costs, welfare, consumer and producer surplus) under a number of constraints using different

mathematical approaches (Linear programming, Non-linear programming, Mixed-integer programming, Dynamic programming).

- Simulation: the model is specified as a set of equations with an equal number of variables and solved by solving a system of equations directly or with a iterative procedure. The solution algorithm does not imply that there is no optimisation behaviour behind simulations models through the equations specifications. For instance, energy demand equation in energy simulation model derived from the maximisation of a welfare function under budget constraint; or many general equilibrium models are written as a set of equations equal to the number of variables but the solution corresponds to the maximisation of a welfare function under budget constraint.

E3. Degree of endogenization

- Endogenous variables computed by the model/tool (e.g. prices, quantities, energy supply, energy demand, technological change, GDP change).
- Data provided as an exogenous input to the model/tool (external assumptions about population or economic growth, energy demand and supply, price and income elasticity of energy demand, existing tax system and tax recycling, cost and lifetime of technologies, etc.).
- Sensitivity analysis and exogenous shocks evaluation:
  - Assessment of the resilience of the energy system to exogenous shocks and of its ability to recover from them (economic and financial crisis, energy prices, supply of primary energy sources, etc.).
  - Inclusion of decision parameters for actions in case of deviation from expected targets.

E4. Technological progress characterization

Indicate how technological change is represented:

- Energy input per unit of production decreases over time following the Autonomous Energy Efficiency Improvement (AEEI) that is an exogenous parameter of the model.
- Different technologies with lower costs or higher efficiencies enter the market in different years.
- Learning curves link cost reduction for certain technologies to the installed capacity (by using an exogenous learning ratio).
- Other (specify).

<u>Remark:</u> we can differentiate between technological progress that is time dependent (the first two cases above) and technological progress that is endogenously determined by the system evolution. Even in the latter case, anyway, an exogenous estimate of technological evolution (the learning ratio) has to be provided to the model.

It is useful for the SET Plan needs to investigate whether there exists any model/tool aimed at providing an estimate of progress ratio or of future cost reduction.

E5. Dynamics characterization

- Static/Dynamic.
- Myopic/perfect foresight.
- Capital allocation: putty-clay/ putty-putty.

E6. Internal and external linkages

Indicate whether (and in case how) the model/tool integrates a macroeconomic model with a partial equilibrium model covering the energy system:

- Hard-linking (full integration of detailed macroeconomic and energy models or of simplified description of one system and detailed description of the other).
- Soft-linking (output of macro model used as input for the energy model or vice versa).
- Soft or hard link to forestry, agricultural and land use models.
- No linking.

E7. Graphical representation

If available, insert (copy and paste) a graphical overview of the model/tool structure (e.g. blocks diagram).

F. ACCESS

F1. Platform required

Platform required in order to run the model/tool (e.g. Windows, Linux, Mac, etc.).

F2. Interface required

Interface/software required in order to run the model/tool (e.g. Veda, RUNGTAP, etc.).

F3. Coding/Programming language

E.g. GAMS (General Algebraic Modelling System); MPS GE (mathematical programming system for general equilibrium analysis); GEMPACK - General Equilibrium Modelling PACKage; etc.

F4. Source code, model and costs: Open/Restricted/Closed

Is the source code and model/tool readily available or access is somehow restricted? If access is restricted, specify how. If possible specify cost of licenses for software and/or for dedicated databases.

F5. Skills and training required

- Does the model/tool require any special skill set?
- Is the model/tool user-friendly?
- Can it be used by trained users?
- Can it be used only by the group of experts that developed it?

If training is required in order to use the model for a typical application, specify whether standard courses are available or not. If standard courses are not available, provide an estimate of the number of months of informal training/experience required in order to be able to use the model/tool.

F6. Main characteristics of the model database

Type of exogenous data required by the model (qualitative, quantitative, monetary, physical units).

Are dedicated databases used and shared between institutions?

Which are the most relevant sources of the data used in the model (IEA, World Bank, Eurostat, experts estimate, etc.)?

Is it possible to add information to the model database?

G. ADDITIONAL NOTES AND COMMENTS

Feel free to provide comments and/or any additional information.

Appendix B Models list

Model Number	Model Name	Developed by (Institution, literature or web references)
1	**BALMOREL**	Elkaraft System, Denmark
2	**BEST**	Comillas Pontifical University, Spain
3	**COALMOD (COALMOD-World)**	DIW, Germany
4	**COMPETES**	ECN, the Netherlands, Johs Hopkins University
5	**E2M2s**	IER, Stuttgart University, Germany
6	**E3ME**	Cambridge Econometrics, UK
7	**E3MG**	Cambridge Centre for Climate Change Mitigation Research (4CMR), Cambridge Econometrics, UK
8	**EMELIE**	DIW, Germany
9	**EMM**	VTT, Finland
10	**ESTEEM**	CREATE ACCEPTANCE Project team,EU/DG Energy/FP7 Contract; websites: http://www.createacceptance.net; http://www.esteem-tool.eu
11	**GASMOD**	DIW, Germany
12	**GEM-E3**	University of Athens, Greece
13	**GEMED**	Comillas Pontifical University, Spain
14	**GEMINI-E3**	CEA-IDIE, France
15	**GET**	Physical Resource Theory, Chalmers University of Technology, Göteborg, Sweden
16	**GRAPE**	Institute of Applied Energy (IAE), Japan
17	**Model for Power Plant and Transmission Expansion**	IER, Stuttgart University, Germany
18	**IMACLIM**	CIRED, France
19	**IMAGE-TIMER**	RIVM, Netherland Environmental Assessment Agency, PBL, the Netherlands
20	**Wilmar Planning Tool** (mainly consisting of Joint Market Model (JMM) and Scenario Tree Tool)	IER, Stuttgart University, Germany; Risø DTU, Denmark
21	**LEAP**	Stockholm Environment Institute - US Center
22	**MDM-E3**	Cambridge Econometrics, UK
23	**"Long-term energy demand model" consisting in three sub-models: MURE-Residential, ISIndustry, TEP-Tertiary.**	Fraunhofer Institute for Systems and Innovation Research (FhG ISI), Germany
24	**NEWAGE**	IER, Stuttgart University, Germany
25	**OILMOD**	DIW, Germany
26	**POLES**	IEPE, France
27	**POWERS**	ECN, the Netherlands
28	**PRIMES**	University of Athens, Greece
29	**RESolve-E** (formerly known as ADMIRE-REBUS)	ECN, the Netherlands

30	**RESolve-T**	ECN, the Netherlands
31	**ROM**	Comillas Pontifical University, Spain
32	**TEMPO**	ECN, the Netherlands
33	**TIAM-World**	IEA -ETSAP, Energy Technology Systems Analysis Programme
34	**TIMES PanEU**	Developed from the NEEDS-PEM model
	TIMES Nordic	VTT, Finland
	TIMES FI	VTT, TEKES, Finland
35	**WILMAR**	IER, Stuttgart University, Germany; Risø DTU, Denmark; VTT, Finland
36	**WITCH**	FEEM, Italy
37	**STSc** **SocioTechnical Scenarios**	"Transition paths towards a sustainable electricity system: An exploration using sociotechnical scenarios", Boelie Elzen and Peter Hofman, University of Twente: Dept. STeHPS and CSTM Enschede, October 2007
38	**Changing Behaviour**	http://www.energychange.info/
39	**Horizon Scan**	http://www.horizonscan.nl/
40	**iKnow**	http://wiwe.iknowfutures.eu/
41	**IEE - Behave / PRECEDE-PROCEED Planning Model**	www.energy-behave.net
42	**GoReNEST framework**	http://www.vtt.fi/inf/pdf/tiedotteet/2009/T2505.pdf
43	**Climate Bonus / Carbon footprinting, monitoring, feedback & rewards**	http://extranet.vatt.fi/climatebonus
44	**GMM**	Paul Scherrer Institute, Switzerland
45	**PACE**	ZEW, Germany
46	**ADAGE**	RTI, USA
47	**AIM**	NIES, Kyoto University, Japan
48	**IGEM**	Harvard University, Texas University, USA
49	**MERGE**	EPRI, USA
50	**MESSAGE**	International Institute for Applied Systems Analysis (IIASA), Austria
51	**GTAP-E**	Purdue University, USA
52	**UKENVI**	University of Strathclyde, UK
53	**MoreHys**	Fraunhofer Institute for Systems and Innovation Research (FhG ISI), Germany
54	**ABARE-GTEM**	ABARE, Australia
55	**AMIGA**	EPA, USA
56	**COMBAT**	CICERO, University Oslo, Norway
57	**DICE**	Yale University, USA
58	**DNE21+**	RITE, Japan
59	**EDGE**	Copenhagen economics ApS, Denmark

60	**EFDA-TIMES**	EFDA, Germany
61	**EnergyPLAN**	Aalborg University, Denmark
62	**ENPEP-BALANCE**	CEEESA- Environmental Systems Analysis Tools, Argonne National Laboratory USA, IAEA
63	**ENV-Linkages**	OECD
64	**EPPA**	MIT, USA
65	**ETP model**	IEA
66	**FUND**	University of Hamburg, Germany
67	**GEM-CCGT**	ZEW, Germany
68	**INVERT**	EGG, University of Technology, Vienna
69	**IPAC**	ERI, China
70	**MINI-CAM**	Pacific Northwest National Laboratory (PNNL), Univ. Maryland, USA
71	**MIRAGE**	CEPII, France
72	**NEMESIS**	Centrale Recherche S.A., lab. ERASME, France
73	**NEMS**	EIA, DOE, USA
74	**REMIND-R**	Postdam Institute for Climate Impact Research (PIK), Germany
75	**RICE**	Yale University, USA
76	**SGM**	Joing Global Change Research Institute JGCL, PNNL - Pacific Northwest National Laboratory, USA
77	**WEM**	IEA
78	**WIAGEM**	SPEED, Oldenburg University, Germany
79	**SAMLAST**	Sintef, Norway
80	**REMARK**	ERSE, Italy
81	**ESPAUT**	ERSE, Italy
82	**MTSIM**	ERSE, Italy
83	**WASP**	IAEA
84	**CGEN**	Cardiff University, Wales, UK
85	**GreenNET-Europe model**	Vienna University of Technology, Austria

Appendix C Models evaluation matrices: primary focus assessment

Strategic Planning		Specifications					
		GENERAL SPECIFICATIONS		TECHNOLOGY PERFORMANCE AND DEVELOPMENT POTENTIAL			
Models (number and name)		Resilience of the energy system against shocks of energy prices and supply of primary energy sources	Resilience of the energy system against shocks of power system failures and extreme weather events	SET-Plan Key Performance Indicators	Investment, O&M costs, technical and environmental performance	Potential for cost reduction as a function of time/technical improvements through RD&D/deployment/learning effects	Overall efficiency gain and efficiency gain per tech/per kWh
1	BALMOREL			PF	PF	PF	PF
2	BEST						PF
3	COALMOD (COALMOD-World)						
4	COMPETES						
5	E2M2s				PF		PF
6	E3ME						
7	E3MG						
8	EMELIE				PF	PF	PF
9	EMM	PF	PF		PF	PF	PF
10	ESTEEM						
11	GASMOD						
12	GEM-E3						
13	GEMED						
14	GEMINI-E3						
15	GET				PF	PF	PF
16	GRAPE						
17	Model for Power Plant and Transmission Expansion	PF	PF	PF	PF	PF	
18	IMACLIM						
19	IMAGE-TIMER						
20	**Wilmar Planning Tool** (mainly consisting of Joint Market Model (JMM) and Scenario Tree Tool)	PF	PF		PF		PF
21	LEAP	PF	PF	PF	PF	PF	PF
22	MDM-E3						
23	"Long-term energy demand model" consisting in three sub models: MURE-Residential, ISIndustry, TEP-Tertiary.	PF	PF	PF	PF	PF	PF
24	NEWAGE						
25	OILMOD						
26	POLES	PF		PF	PF	PF	PF
27	POWERS						PF
28	PRIMES	PF		PF	PF	PF	PF
29	**RESolve-E** (formerly known as ADMIRE-REBUS)				PF	PF	PF
30	RESolve-T			PF	PF	PF	
31	ROM		PF				
32	TEMPO			PF	PF	PF	PF
33	TIAM-World	PF	PF	PF	PF	PF	PF
34	TIMES PanEU	PF	PF	PF	PF	PF	PF
35	WILMAR	PF	PF		PF		PF
36	WITCH						
37	STSc SocioTechnical Scenario						
38	Changing Behavior						
39	Horizon Scan						
40	iKnow						
41	IEE - Behave/PRECEDE-PROCEED Planning Model						
42	GoReNEST framework						
43	Climate Bonus/Carbon footprinting, monitoring, feedback & rewards						

Strategic Planning

Models (number and name)		Specifications: GENERAL SPECIFICATIONS – Resilience of the energy system against shocks of energy prices and supply of primary energy sources	Specifications: GENERAL SPECIFICATIONS – Resilience of the energy system against shocks of power system failures and extreme weather events	Specifications: TECHNOLOGY PERFORMANCE AND DEVELOPMENT POTENTIAL – SET-Plan Key Performance Indicators	Investment, O&M costs, technical and environmental performance	Potential for cost reduction as a function of time/technical improvements through RD&D/deployment/learning effects	Overall efficiency gain and efficiency gain per tech/per kWh
44	GMM	PF	PF	PF	PF	PF	PF
45	PACE				PF	PF	PF
46	ADAGE				PF		PF
47	AIM	PF	PF		PF		PF
48	IGEM						
49	MERGE						
50	MESSAGE	PF	PF	PF	PF	PF	PF
51	GTAP-E						
52	UKENVI						PF
53	MoreHys				PF		
54	ABARE-GTEM						
55	AMIGA						PF
56	COMBAT						
57	DICE	PF	PF				
58	DNE21+	PF		PF		PF	
59	EDGE						
60	EFDA-TIMES	PF	PF	PF	PF	PF	PF
61	EnergyPLAN						PF
62	ENPEP-BALANCE	PF	PF	PF			
63	ENV-Linkages						
64	EPPA						
65	ETP model	PF	PF	PF	PF	PF	PF
66	FUND						
67	GEM-CCGT						
68	INVERT				PF		PF
69	IPAC	PF	PF	PF	PF	PF	PF
70	MINI-CAM				PF	PF	PF
71	MIRAGE						
72	NEMESIS						
73	NEMS	PF	PF		PF	PF	PF
74	REMIND-R						PF
75	RICE	PF	PF				
76	SGM						
77	WEM	PF	PF	PF	PF	PF	PF
78	WIAGEM						
79	SAMLAST	PF	PF				
80	REMARK	PF	PF				
81	ESPAUT	PF	PF				
82	MTSIM	PF	PF				
83	WASP	PF	PF				
84	CGEN	PF	PF				
85	GreenNET-Europe model	PF	PF				

Strategic Planning

Models (number and name)		Specifications: TECHNOLOGY DEPLOYMENT — Technical barriers and technology complementarities (impact on the energy system structure; interdependency between different technologies: e.g. wind turbines and electric grid development)	Maximum potential of a given technology and the time horizon of the pathway, regional specificities	Bottlenecks to technology deployment (industry not ready to follow
1	BALMOREL	PF	PF	
2	BEST		PF	
3	COALMOD (COALMOD-World)			
4	COMPETES			
5	E2M2s		PF	
6	E3ME			
7	E3MG			
8	EMELIE	PF	PF	
9	EMM		PF	
10	ESTEEM			
11	GASMOD			
12	GEM-E3			
13	GEMED			
14	GEMINI-E3			
15	GET			
16	GRAPE	PF		
17	Model for Power Plant and Transmission Expansion	PF	PF	
18	IMACLIM			
19	IMAGE-TIMER			
20	**Wilmar Planning Tool** (mainly consisting of Joint Market Model (JMM) and Scenario Tree Tool)	PF	PF	
21	LEAP	PF	PF	
22	MDM-E3			
23	"Long-term energy demand model" consisting in three sub models: MURE-Residential, ISIndustry, TEP-Tertiary.	PF	PF	
24	NEWAGE			
25	OILMOD			
26	POLES		PF	
27	POWERS			
28	PRIMES	PF	PF	
29	**RESolve-E** (formerly known as ADMIRE-REBUS)		PF	
30	RESolve-T		PF	
31	ROM			
32	TEMPO			
33	TIAM-World	PF	PF	
34	TIMES PanEU	PF	PF	
35	WILMAR	PF	PF	
36	WITCH			
37	STSc SocioTechnical Scenario			
38	Changing Behavior			
39	Horizon Scan			
40	iKnow			
41	IEE - Behave/PRECEDE-PROCEED Planning Model			
42	GoReNEST framework			
43	Climate Bonus/Carbon footprinting, monitoring, feedback & rewards			

Strategic Planning		Specifications		
		TECHNOLOGY DEPLOYMENT		
Models (number and name)		Technical barriers and technology complementarities (impact on the energy system structure; interdependency between different technologies: e.g. wind turbines and electric grid development)	Maximum potential of a given technology and the time horizon of the pathway, regional specificities	Bottlenecks to technology deployment (industry not ready to follow
44	GMM	PF	PF	
45	PACE		PF	
46	ADAGE		PF	
47	AIM	PF	PF	
48	IGEM			
49	MERGE			
50	MESSAGE	PF	PF	
51	GTAP-E			
52	UKENVI			
53	MoreHys		PF	PF
54	ABARE-GTEM			
55	AMIGA			
56	COMBAT			
57	DICE			
58	DNE21+		PF	
59	EDGE			
60	EFDA-TIMES	PF	PF	
61	EnergyPLAN	PF	PF	
62	ENPEP-BALANCE	PF	PF	
63	ENV-Linkages			
64	EPPA			
65	ETP model	PF	PF	
66	FUND			
67	GEM-CCGT			
68	INVERT			
69	IPAC	PF	PF	
70	MINI-CAM	PF	PF	
71	MIRAGE			
72	NEMESIS			
73	NEMS	PF	PF	
74	REMIND-R		PF	
75	RICE			
76	SGM			
77	WEM	PF	PF	
78	WIAGEM			
79	SAMLAST	PF		
80	REMARK	PF		
81	ESPAUT	PF		
82	MTSIM	PF		
83	WASP	PF		
84	CGEN	PF		
85	GreenNET-Europe model	PF		

Strategic Planning

		Specifications										
		POLICY INDICATORS										
Models (number and name)		Impact of different stimuli (feed in, quotas, fiscal measures etc.) on technology deployment/cost	Impact of different stimuli (feed in, quotas, fiscal measures etc.) on share of RES in TPES	Total investment required to reach cost competitiveness	Risk assessment ("change of plans", system failure, lock-in situations)	CO2 reduction per technology	Security of supply	Impact of global economic crisis on the energy system (input)	Impact on economic growth, development and employment (output)	LCA analyses	Impact on water, particulates, soil, etc.	Competitiveness considerations for regional industry
1	**BALMOREL**											
2	**BEST**		PF		PF							
3	**COALMOD (COALMOD-World)**											
4	**COMPETES**											
5	**E2M2s**		PF		PF	PF						
6	**E3ME**							PF	PF			PF
7	**E3MG**							PF	PF			PF
8	**EMELIE**		PF	PF	PF	PF						
9	**EMM**				PF	PF						
10	**ESTEEM**											
11	**GASMOD**											
12	**GEM-E3**							PF	PF			PF
13	**GEMED**							PF	PF			PF
14	**GEMINI-E3**							PF	PF			PF
15	**GET**					PF						
16	**GRAPE**									PF	PF	PF
17	**Model for Power Plant and Transmission Expansion**											
18	**IMACLIM**	PF	PF						PF			
19	**IMAGE-TIMER**											
20	**Wilmar Planning Tool** (mainly consisting of Joint Market Model (JMM) and Scenario Tree Tool)					PF						
21	**LEAP**	PF	PF	PF		PF		PF				
22	**MDM-E3**		PF						PF			
23	**"Long-term energy demand model" consisting in three sub models: MURE-Residential, ISIndustry, TEP-Tertiary.**	PF	PF	PF		PF		PF				
24	**NEWAGE**		PF						PF			
25	**OILMOD**											
26	**POLES**	PF	PF			PF	PF	PF				
27	**POWERS**											
28	**PRIMES**	PF	PF			PF	PF					
29	**RESolve-E** (formerly known as ADMIRE-REBUS)		PF									
30	**RESolve-T**					PF	PF					
31	**ROM**											
32	**TEMPO**					PF						
33	**TIAM-World**	PF	PF	PF		PF		PF				
34	**TIMES PanEU**	PF	PF	PF		PF		PF				
35	**WILMAR**				PF	PF						
36	**WITCH**											
37	**STSc SocioTechnical Scenario**											
38	**Changing Behavior**											
39	**Horizon Scan**											
40	**iKnow**											
41	**IEE - Behave/PRECEDE-PROCEED Planning Model**											
42	**GoReNEST framework**											
43	**Climate Bonus/Carbon footprinting, monitoring, feedback & rewards**											

Strategic Planning

Models (number and name)		Specifications – POLICY INDICATORS: Impact of different stimuli (feed in, quotas, fiscal measures etc.) on technology deployment/cost	Impact of different stimuli (feed in, quotas, fiscal measures etc.) on share of RES in TPES	Total investment required to reach cost competitiveness	Risk assessment ("change of plans", system failure, lock-in situations)	CO2 reduction per technology	Security of supply	Impact of global economic crisis on the energy system (input)	Impact on economic growth, development and employment (output)	LCA analyses	Impact on water, particulates, soil, etc.	Competitiveness considerations for regional industry
44	GMM	PF	PF	PF		PF		PF				
45	PACE	PF	PF						PF			PF
46	ADAGE	PF	PF				PF		PF			PF
47	AIM	PF	PF			PF	PF	PF	PF		PF	PF
48	IGEM								PF			
49	MERGE											
50	MESSAGE	PF	PF	PF		PF		PF				
51	GTAP-E							PF	PF			PF
52	UKENVI							PF	PF			PF
53	MoreHys											
54	ABARE-GTEM							PF	PF			PF
55	AMIGA	PF						PF	PF			PF
56	COMBAT							PF	PF			
57	DICE						PF	PF	PF		PF	
58	DNE21+											
59	EDGE							PF	PF			PF
60	EFDA-TIMES	PF	PF	PF		PF		PF				
61	EnergyPLAN		PF			PF						
62	ENPEP-BALANCE		PF	PF		PF	PF					
63	ENV-Linkages							PF	PF			PF
64	EPPA						PF		PF			
65	ETP model	PF	PF	PF		PF		PF				
66	FUND											
67	GEM-CCGT							PF	PF			PF
68	INVERT	PF	PF			PF						
69	IPAC	PF	PF			PF	PF	PF	PF			
70	MINI-CAM	PF	PF			PF	PF	PF			PF	
71	MIRAGE											
72	NEMESIS	PF	PF									
73	NEMS	PF	PF			PF	PF	PF	PF			
74	REMIND-R	PF	PF			PF			PF			
75	RICE						PF	PF	PF		PF	
76	SGM		PF						PF			
77	WEM	PF	PF	PF		PF	PF	PF				
78	WIAGEM							PF	PF			PF
79	SAMLAST				PF		PF					
80	REMARK				PF		PF					
81	ESPAUT				PF		PF					
82	MTSIM				PF		PF					
83	WASP				PF		PF					
84	CGEN				PF		PF					
85	GreenNET-Europe model		PF		PF		PF					

Transition Planning

No.	Models (number and name)	Physical barriers (e.g. resource potential of a geographical area to provide wind or solar power; limited and inappropriate transport network)	Capacity expansion (infrastructure)	Grid-connection capacity	Cost effective technology deployment	Availability of natural resources	Territorial integration	Migration flows	Effects on labor demand	Land use and population density
		Specifications								
		SPATIAL PLANNING								
1	**BALMOREL**	PF		PF						
2	**BEST**									
3	**COALMOD (COALMOD-World)**									
4	**COMPETES**									
5	**E2M2s**	PF								
6	**E3ME**								PF	
7	**E3MG**								PF	
8	**EMELIE**	PF								
9	**EMM**	PF				PF				
10	**ESTEEM**									
11	**GASMOD**									
12	**GEM-E3**									
13	**GEMED**									
14	**GEMINI-E3**									
15	**GET**									
16	**GRAPE**									PF
17	**Model for Power Plant and Transmission Expansion**	PF	PF							
18	**IMACLIM**								PF	
19	**IMAGE-TIMER**									
20	**Wilmar Planning Tool** (mainly consisting of Joint Market Model (JMM) and Scenario Tree Tool)									
21	**LEAP**	PF								
22	**MDM-E3**									
23	**"Long-term energy demand model" consisting in three sub models: MURE-Residential, ISIndustry, TEP-Tertiary.**	PF								
24	**NEWAGE**									
25	**OILMOD**									
26	**POLES**									
27	**POWERS**									
28	**PRIMES**									
29	**RESolve-E** (formerly known as ADMIRE-REBUS)									
30	**RESolve-T**									
31	**ROM**									
32	**TEMPO**									
33	**TIAM-World**	PF								
34	**TIMES PanEU**	PF								
35	**WILMAR**	PF								
36	**WITCH**									
37	**STSc SocioTechnical Scenario**		PF	PF						
38	**Changing Behavior**									
39	**Horizon Scan**									
40	**iKnow**									
41	**IEE - Behave/PRECEDE-PROCEED Planning Model**									
42	**GoReNEST framework**									
43	**Climate Bonus/Carbon footprinting, monitoring, feedback & rewards**									

Transition Planning

		Specifications								
		SPATIAL PLANNING								
Models (number and name)		Physical barriers (e.g. resource potential of a geographical area to provide wind or solar power; limited and inappropriate transport network)	Capacity expansion (infrastructure)	Grid-connection capacity	Cost effective technology deployment	Availability of natural resources	Territorial integration	Migration flows	Effects on labor demand	Land use and population density
44	**GMM**	PF								
45	**PACE**									
46	**ADAGE**								PF	
47	**AIM**	PF				PF	PF		PF	PF
48	**IGEM**									
49	**MERGE**									
50	**MESSAGE**	PF								
51	**GTAP-E**									
52	**UKENVI**									
53	**MoreHys**	PF	PF	PF	PF					
54	**ABARE-GTEM**									
55	**AMIGA**									
56	**COMBAT**									
57	**DICE**					PF				
58	**DNE21+**				PF					
59	**EDGE**									
60	**EFDA-TIMES**	PF								
61	**EnergyPLAN**	PF								
62	**ENPEP-BALANCE**	PF								
63	**ENV-Linkages**									
64	**EPPA**									
65	**ETP model**	PF								
66	**FUND**									
67	**GEM-CCGT**									
68	**INVERT**				PF					
69	**IPAC**	PF								
70	**MINI-CAM**	PF		PF	PF	PF	PF			PF
71	**MIRAGE**									
72	**NEMESIS**								PF	
73	**NEMS**	PF			PF	PF				
74	**REMIND-R**	PF								
75	**RICE**					PF				
76	**SGM**									
77	**WEM**	PF								
78	**WIAGEM**									
79	**SAMLAST**	PF	PF	PF						
80	**REMARK**	PF	PF	PF						
81	**ESPAUT**	PF	PF	PF						
82	**MTSIM**	PF	PF	PF						
83	**WASP**	PF	PF	PF						
84	**CGEN**	PF	PF	PF						
85	**GreenNET-Europe model**	PF	PF	PF						

Transition Planning

	Models (number and name)	Specifications DEPLOYMENT PATHWAYS						
		SET-Plan sectoral targets	Evolution of grid and transport networks	Supply chain logistics (interaction between local demand and global supply, time dependence, impact of changes in the energy	Links between the energy system and the economy (changes in demand, sectoral changes)	Synergies between tech, ind, social and policy changes	Public-private agent behaviors and partnerships	Effects of 1st demonstration projects in Europe and scenarios to close gaps between demonstration and
1	**BALMOREL**	PF						
2	**BEST**				PF			
3	**COALMOD (COALMOD-World)**							
4	**COMPETES**							
5	**E2M2s**	PF			PF			
6	**E3ME**				PF			
7	**E3MG**				PF			
8	**EMELIE**				PF			
9	**EMM**							
10	**ESTEEM**							
11	**GASMOD**							
12	**GEM-E3**				PF			
13	**GEMED**				PF			
14	**GEMINI-E3**				PF			
15	**GET**							
16	**GRAPE**							
17	**Model for Power Plant and Transmission Expansion**							
18	**IMACLIM**							
19	**IMAGE-TIMER**							
20	**Wilmar Planning Tool** (mainly consisting of Joint Market Model (JMM) and Scenario Tree Tool)	PF						
21	**LEAP**	PF						
22	**MDM-E3**							
23	**"Long-term energy demand model" consisting in three sub models: MURE-Residential, ISIndustry, TEP-Tertiary.**	PF						
24	**NEWAGE**							
25	**OILMOD**							
26	**POLES**							
27	**POWERS**							
28	**PRIMES**	PF						
29	**RESolve-E** (formerly known as ADMIRE-REBUS)							
30	**RESolve-T**	PF						
31	**ROM**							
32	**TEMPO**							
33	**TIAM-World**	PF						
34	**TIMES PanEU**	PF						
35	**WILMAR**	PF						
36	**WITCH**							
37	**STSc SocioTechnical Scenario**		PF			PF	PF	
38	**Changing Behavior**							
39	**Horizon Scan**							
40	**iKnow**							
41	**IEE - Behave/PRECEDE-PROCEED Planning Model**							
42	**GoReNEST framework**					PF	PF	
43	**Climate Bonus/Carbon footprinting, monitoring, feedback & rewards**							

Transition Planning

Models (number and name)		Specifications – DEPLOYMENT PATHWAYS: SET-Plan sectoral targets	Evolution of grid and transport networks	Supply chain logistics (interaction between local demand and global supply, time dependence, impact of changes in the energy	Links between the energy system and the economy (changes in demand, sectoral changes)	Synergies between tech, ind, social and policy changes	Public-private agent behaviors and partnerships	Effects of 1st demonstration projects in Europe and scenarios to close gaps between demonstration and
44	GMM	PF						
45	PACE							
46	ADAGE				PF			
47	AIM	PF			PF			
48	IGEM				PF			
49	MERGE							
50	MESSAGE	PF						
51	GTAP-E				PF			
52	UKENVI				PF			
53	MoreHys							
54	ABARE-GTEM				PF			
55	AMIGA				PF			
56	COMBAT							
57	DICE				PF			
58	DNE21+							
59	EDGE				PF			
60	EFDA-TIMES	PF						
61	EnergyPLAN							
62	ENPEP-BALANCE	PF						
63	ENV-Linkages				PF			
64	EPPA				PF			
65	ETP model	PF						
66	FUND							
67	GEM-CCGT				PF			
68	INVERT							
69	IPAC	PF						
70	MINI-CAM	PF						
71	MIRAGE							
72	NEMESIS				PF			
73	NEMS							
74	REMIND-R							
75	RICE				PF			
76	SGM			PF	PF			
77	WEM	PF						
78	WIAGEM				PF			
79	SAMLAST	PF	PF					
80	REMARK	PF	PF					
81	ESPAUT	PF	PF					
82	MTSIM	PF	PF					
83	WASP	PF	PF					
84	CGEN	PF	PF					
85	GreenNET-Europe model	PF	PF					

Transition Planning

Models (number and name)		Specifications: TIMING – Time lag between investment decision and entering into operation of installations	Specifications: TIMING – Effects of different regulatory frameworks in MS	Specifications: MARKET DESIGN AND ORGANISATIONAL CHANGES – Market barriers (market design and organizational changes required; behavioural	Specifications: MARKET DESIGN AND ORGANISATIONAL CHANGES – Level playing field for all market participants within and among MS
1	**BALMOREL**				
2	**BEST**			PF	
3	**COALMOD (COALMOD-World)**				
4	**COMPETES**				
5	**E2M2s**				
6	**E3ME**			PF	PF
7	**E3MG**			PF	PF
8	**EMELIE**				
9	**EMM**				
10	**ESTEEM**				
11	**GASMOD**				
12	**GEM-E3**				
13	**GEMED**				
14	**GEMINI-E3**				
15	**GET**				
16	**GRAPE**			PF	PF
17	**Model for Power Plant and Transmission Expansion**				
18	**IMACLIM**				
19	**IMAGE-TIMER**				
20	**Wilmar Planning Tool** (mainly consisting of Joint Market Model (JMM) and Scenario Tree Tool)				
21	**LEAP**				
22	**MDM-E3**				
23	**"Long-term energy demand model" consisting in three sub models: MURE-Residential, ISIndustry, TEP-Tertiary.**				
24	**NEWAGE**				
25	**OILMOD**				
26	**POLES**				
27	**POWERS**				
28	**PRIMES**				
29	**RESolve-E** (formerly known as ADMIRE-REBUS)				
30	**RESolve-T**				
31	**ROM**				
32	**TEMPO**				
33	**TIAM-World**				
34	**TIMES PanEU**				
35	**WILMAR**				
36	**WITCH**				
37	**STSc SocioTechnical Scenario**	PF	PF	PF	PF
38	**Changing Behavior**			PF	PF
39	**Horizon Scan**				
40	**iKnow**				
41	**IEE - Behave/PRECEDE-PROCEED Planning Model**				
42	**GoReNEST framework**				
43	**Climate Bonus/Carbon footprinting, monitoring, feedback & rewards**			PF	

Transition Planning		Specifications			
		TIMING		MARKET DESIGN AND ORGANISATIONAL CHANGES	
Models (number and name)		Time lag between investment decision and entering into operation of installations	Effects of different regulatory frameworks in MS	Market barriers (market design and organizational changes required; behavioural	Level playing field for all market participants within and among MS
44	GMM				
45	PACE				
46	ADAGE				
47	AIM				
48	IGEM				
49	MERGE				
50	MESSAGE				
51	GTAP-E				
52	UKENVI				
53	MoreHys				
54	ABARE-GTEM				
55	AMIGA				
56	COMBAT				
57	DICE				
58	DNE21+				
59	EDGE				
60	EFDA-TIMES				
61	EnergyPLAN				
62	ENPEP-BALANCE				
63	ENV-Linkages				
64	EPPA				
65	ETP model				
66	FUND				
67	GEM-CCGT				
68	INVERT				PF
69	IPAC				
70	MINI-CAM				
71	MIRAGE				
72	NEMESIS				
73	NEMS				
74	REMIND-R				
75	RICE				
76	SGM				
77	WEM				
78	WIAGEM				
79	SAMLAST				
80	REMARK				
81	ESPAUT				
82	MTSIM				
83	WASP				
84	CGEN				
85	GreenNET-Europe model				

Transition Planning

	Models (number and name)	Specifications														
		ACCEPTANCE/PERCEPTION OF A TECHNOLOGY														
		Social barriers (people's perceptions on technologies; social acceptance of	Quantification of employment (from supply chain perspective, regional approach	Public acceptance (awareness and understanding of tech use and implications)	Public participation (stakeholders involvement and resistance) and	Perceptions on reliability of a technology as energy	Energy prices (for different groups)	Influence of competing technologies	Risk perception (investments, immaturity of technologies, reputation of operator or initiator, risk	Management of local supply chain (economic efficiency, sustainability, social responsibility, system operation	Land-use intensity	Divergence of views on landscape preservation	Siting issues	Concerns on health impacts	Safety issues and related perception	Distribution of local costs and benefits (fairness, equality)
1	**BALMOREL**															
2	**BEST**						PF									
3	**COALMOD (COALMOD-World)**						PF									
4	**COMPETES**															
5	**E2M2s**						PF									PF
6	**E3ME**		PF				PF									PF
7	**E3MG**		PF				PF									PF
8	**EMELIE**						PF									PF
9	**EMM**															
10	**ESTEEM**	PF		PF	PF					PF						PF
11	**GASMOD**						PF									
12	**GEM-E3**		PF				PF									PF
13	**GEMED**		PF				PF									PF
14	**GEMINI-E3**		PF				PF									PF
15	**GET**					PF										
16	**GRAPE**	PF									PF					
17	**Model for Power Plant and Transmission Expansion**															
18	**IMACLIM**		PF													
19	**IMAGE-TIMER**															
20	**Wilmar Planning Tool** (mainly consisting of Joint Market Model (JMM) and Scenario Tree Tool)															
21	**LEAP**															
22	**MDM-E3**		PF													
23	**"Long-term energy demand model" consisting in three sub models: MURE-Residential, ISIndustry, TEP-Tertiary.**															
24	**NEWAGE**		PF													
25	**OILMOD**						PF									
26	**POLES**															
27	**POWERS**															
28	**PRIMES**															
29	**RESolve-E** (formerly known as ADMIRE-REBUS)															
30	**RESolve-T**															
31	**ROM**															
32	**TEMPO**															
33	**TIAM-World**															
34	**TIMES PanEU**															
35	**WILMAR**															
36	**WITCH**															
37	**STSc SocioTechnical Scenario**			PF	PF			PF		PF						
38	**Changing Behavior**	PF		PF												
39	**Horizon Scan**															
40	**iKnow**															
41	**IEE - Behave/PRECEDE-PROCEED Planning Model**															
42	**GoReNEST framework**				PF											
43	**Climate Bonus/Carbon footprinting, monitoring, feedback & rewards**	PF		PF												

Transition Planning

Models (number and name)		Social barriers (people's perceptions on technologies; social acceptance of	Quantification of employment (from supply chain perspective, regional approach	Public acceptance (awareness and understanding of tech use and implications)	Public participation (stakeholders involvement and resistance) and	Perceptions on reliability of a technology as energy	Energy prices (for different groups)	Influence of competing technologies	Risk perception (investments, immaturity of technologies, reputation of operator or initiator, risk	Management of local supply chain (economic efficiency, sustainability, social responsibility, system operation	Land-use intensity	Divergence of views on landscape preservation	Siting issues	Concerns on health impacts	Safety issues and related perception	Distribution of local costs and benefits (fairness, equality)
		Specifications: ACCEPTANCE/PERCEPTION OF A TECHNOLOGY														
44	GMM															
45	PACE															
46	ADAGE		PF													
47	AIM		PF													
48	IGEM															PF
49	MERGE															
50	MESSAGE															
51	GTAP-E		PF				PF									PF
52	UKENVI		PF				PF									PF
53	MoreHys												PF			
54	ABARE-GTEM		PF				PF									PF
55	AMIGA		PF				PF									PF
56	COMBAT															
57	DICE													PF		PF
58	DNE21+					PF										
59	EDGE		PF													
60	EFDA-TIMES															
61	EnergyPLAN															
62	ENPEP-BALANCE															
63	ENV-Linkages		PF				PF									PF
64	EPPA															
65	ETP model															
66	FUND															
67	GEM-CCGT		PF				PF									PF
68	INVERT															
69	IPAC															
70	MINI-CAM							PF			PF					
71	MIRAGE															
72	NEMESIS		PF													
73	NEMS															
74	REMIND-R															
75	RICE													PF		PF
76	SGM		PF													
77	WEM															
78	WIAGEM		PF				PF									PF
79	SAMLAST															
80	REMARK															
81	ESPAUT															
82	MTSIM															
83	WASP					PF										
84	CGEN															
85	GreenNET-Europe model															

Innovation and R&D

		Specifications											
		GENERAL SPECIFICATIONS		R&D					INNOVATION				
	Models (number and name)	Long-term economic perspectives of technologies	Risks involved in research activities (long-term perspective)	Effects of R&D spending (patenting, deployment)	Effects of public-private R&D partnerships, effectiveness of stimulating cooperation, timing of initialization of R&D support	Technology specific R&D interim and final targets	Decision parameters to modify the ambition level of targets and the time paths	Assessment and monitoring of R&D funding mechanisms (for technological development lagging behind)	Strengths and weaknesses of EU and national industries	Quantify necessary R&D spending on specific technologies in order to cover the gap between EU and RoW	Technologies needed to reach 2020 and beyond targets	Identification of industrial opportunities in the energy sector for EU	Identification of sectors/technologies needing particular attention due to worldwide competition
1	**BALMOREL**												
2	**BEST**												
3	**COALMOD (COALMOD-World)**												
4	**COMPETES**												
5	**E2M2s**												
6	**E3ME**	PF		PF					PF			PF	PF
7	**E3MG**	PF		PF					PF			PF	PF
8	**EMELIE**										PF		
9	**EMM**												
10	**ESTEEM**												
11	**GASMOD**												
12	**GEM-E3**				PF								PF
13	**GEMED**												PF
14	**GEMINI-E3**												PF
15	**GET**										PF		
16	**GRAPE**												
17	**Model for Power Plant and Transmission Expansion**												
18	**IMACLIM**												
19	**IMAGE-TIMER**												
20	**Wilmar Planning Tool** (mainly consisting of Joint Market Model (JMM) and Scenario Tree Tool)												
21	**LEAP**												
22	**MDM-E3**												
23	**"Long-term energy demand model" consisting in three sub models: MURE-Residential, ISIndustry, TEP-Tertiary.**												
24	**NEWAGE**												
25	**OILMOD**												
26	**POLES**										PF		
27	**POWERS**										PF		
28	**PRIMES**										PF		
29	**RESolve-E** (formerly known as ADMIRE-REBUS)												
30	**RESolve-T**												
31	**ROM**												
32	**TEMPO**												
33	**TIAM-World**										PF		
34	**TIMES PanEU**										PF		
35	**WILMAR**												
36	**WITCH**			PF							PF		
37	**STSc SocioTechnical Scenario**												
38	**Changing Behavior**												
39	**Horizon Scan**		PF										
40	**iKnow**		PF										
41	**IEE - Behave / PRECEDE-PROCEED Planning Model**												
42	**GoReNEST framework**												

Innovation and R&D

		Specifications											
		GENERAL SPECIFICATIONS		R&D					INNOVATION				
Models (number and name)		Long-term economic perspectives of technologies	Risks involved in research activities (long-term perspective)	Effects of R&D spending (patenting, deployment)	Effects of public-private R&D partnerships, effectiveness of stimulating cooperation, timing of initialization of R&D support	Technology specific R&D interim and final targets	Decision parameters to modify the ambition level of targets and the time paths	Assessment and monitoring of R&D funding mechanisms (for technological development lagging behind)	Strengths and weaknesses of EU and national industries	Quantify necessary R&D spending on specific technologies in order to cover the gap between EU and RoW	Technologies needed to reach 2020 and beyond targets	Identification of industrial opportunities in the energy sector for EU	Identification of sectors/technologies needing particular attention due to worldwide competition
43	Climate Bonus/Carbon footprinting, monitoring, feedback & rewards												
44	GMM										PF		
45	PACE												
46	ADAGE	PF			PF				PF		PF	PF	PF
47	AIM												
48	IGEM	PF		PF	PF				PF			PF	
49	MERGE			PF	PF								
50	MESSAGE										PF		
51	GTAP-E												PF
52	UKENVI												
53	MoreHys										PF		
54	ABARE-GTEM												PF
55	AMIGA				PF								PF
56	COMBAT												
57	DICE										PF		
58	DNE21+	PF							PF			PF	
59	EDGE												PF
60	EFDA-TIMES										PF		
61	EnergyPLAN												
62	ENPEP-BALANCE												
63	ENV-Linkages												PF
64	EPPA	PF							PF			PF	
65	ETP model										PF		
66	FUND												
67	GEM-CCGT												PF
68	INVERT										PF		
69	IPAC												
70	MINI-CAM										PF		
71	MIRAGE												
72	NEMESIS			PF	PF				PF				PF
73	NEMS												
74	REMIND-R	PF									PF	PF	PF
75	RICE										PF		
76	SGM												
77	WEM												
78	WIAGEM												PF
79	SAMLAST												
80	REMARK												
81	ESPAUT												
82	MTSIM												
83	WASP												
84	CGEN												
85	GreenNET-Europe model												

International cooperation

		Specifications								
		GENERAL SPECIFICATIONS	INTERNATIONAL COOPERATION ON R&D						INTERNATIONAL COOPERATION IN TECHNOLOGY DEPLOYMENT	
Models (number and name)		Potentials of JI and CDM (for making targets outside the EU)	Identify win-win situations (cooperation beneficial both to EU and to other parties)	Monitor benefits of international cooperation on R&D	Need for global centres of excellence (existence and fields of activity)	Main research interests in and outside EU (mapping technology, international governmental investments in programs for deployment, identify and avoid	Effectiveness of past international cooperation initiatives	Evaluation of benefits of cooperation initiatives for both sides (EU and outside EU)	Effects of spill-overs between different regions of the world and sectors	Deployment of technologies and the relative costs outside Europe (i.e integrate IEA projections in SETIS)
1	**BALMOREL**									
2	**BEST**									
3	**COALMOD (COALMOD-World)**									
4	**COMPETES**									
5	**E2M2s**									
6	**E3ME**							PF		
7	**E3MG**	PF						PF		
8	**EMELIE**									
9	**EMM**									
10	**ESTEEM**									
11	**GASMOD**									
12	**GEM-E3**	PF								
13	**GEMED**									
14	**GEMINI-E3**	PF								
15	**GET**									
16	**GRAPE**									
17	**Model for Power Plant and Transmission Expansion**									
18	**IMACLIM**									
19	**IMAGE-TIMER**									
20	**Wilmar Planning Tool** (mainly consisting of Joint Market Model (JMM) and Scenario Tree Tool)									
21	**LEAP**									
22	**MDM-E3**									
23	**"Long-term energy demand model" consisting in three sub-models: MURE-Residential, ISIndustry, TEP-Tertiary.**									
24	**NEWAGE**									
25	**OILMOD**									
26	**POLES**									
27	**POWERS**									
28	**PRIMES**									
29	**RESolve-E** (formerly known as ADMIRE-REBUS)									
30	**RESolve-T**									
31	**ROM**									
32	**TEMPO**									
33	**TIAM-World**									
34	**TIMES PanEU**									
35	**WILMAR**									
36	**WITCH**								PF	
37	**STSc SocioTechnical Scenario**									
38	**Changing Behavior**									
39	**Horizon Scan**		PF		PF	PF				
40	**iKnow**		PF		PF	PF				
41	**IEE - Behave / PRECEDE-PROCEED Planning Model**									
42	**GoReNEST framework**									

International cooperation		Specifications								
		GENERAL SPECIFICATIONS	INTERNATIONAL COOPERATION ON R&D						INTERNATIONAL COOPERATION IN TECHNOLOGY DEPLOYMENT	
Models (number and name)		Potentials of JI and CDM (for making targets outside the EU)	Identify win-win situations (cooperation beneficial both to EU and to other parties)	Monitor benefits of international cooperation on R&D	Need for global centres of excellence (existence and fields of activity)	Main research interests in and outside EU (mapping technology, international governmental investments in programs for deployment, identify and avoid	Effectiveness of past international cooperation initiatives	Evaluation of benefits of cooperation initiatives for both sides (EU and outside EU)	Effects of spill-overs between different regions of the world and sectors	Deployment of technologies and the relative costs outside Europe (i.e integrate IEA projections in SETIS)
43	Climate Bonus/Carbon footprinting, monitoring, feedback & rewards									
44	GMM									
45	PACE	PF								
46	ADAGE									
47	AIM	PF							PF	PF
48	IGEM									
49	MERGE	PF								
50	MESSAGE									
51	GTAP-E	PF								
52	UKENVI									
53	MoreHys									
54	ABARE-GTEM	PF								
55	AMIGA									
56	COMBAT									
57	DICE	PF								
58	DNE21+									
59	EDGE									
60	EFDA-TIMES									
61	EnergyPLAN									
62	ENPEP-BALANCE									
63	ENV-Linkages	PF								
64	EPPA									
65	ETP model									
66	FUND									
67	GEM-CCGT	PF								
68	INVERT									
69	IPAC									
70	MINI-CAM	PF								
71	MIRAGE									
72	NEMESIS								PF	
73	NEMS									
74	REMIND-R	PF								PF
75	RICE	PF						PF		
76	SGM									
77	WEM									
78	WIAGEM	PF								
79	SAMLAST									
80	REMARK									
81	ESPAUT									
82	MTSIM									
83	WASP									
84	CGEN									
85	GreenNET-Europe model									

Appendix D Models evaluation matrices: feature analysis

Strategic Planning		Specifications																			
		GENERAL SPECIFICATIONS		TECHNOLOGY PERFORMANCE AND DEVELOPMENT POTENTIAL				TECHNOLOGY DEPLOYMENT			POLICY INDICATORS										
Model features		Resilience of the energy system against shocks of energy prices and supply of primary energy sources	Resilience of the energy system against shocks of power system failures and extreme weather events	SET-Plan Key Performance Indicators	Investment, O&M costs, technical and environmental performance	Potential for cost reduction as a function of time/technical improvements through RD&D/deployment/learning effects	Overall efficiency gain and efficiency gain per tech/per kWh	Technical barriers and technology complementarities (impact on the energy system structure; interdependency between different technologies: e.g. wind turbines and electric grid development)	Maximum potential of a given technology and the time horizon of the pathway, regional specificities	Bottlenecks to technology deployment (industry not ready to follow the demand)	Impact of different stimuli (feed in, quotas, fiscal measures etc.) on technology deployment/cost	Impact of different stimuli (feed in, quotas, fiscal measures etc.) on share of RES in TPES	Total investment required to reach cost competitiveness	Risk assessment ("change of plans", system failure, lock-in situations)	CO2 reduction per technology	Security of supply for EU	Impact of global economic crisis on the energy system (input)	Impact on economic growth, development and employment (output)	LCA analyses	Impact on water, particulates, soil, etc.	Competitiveness considerations for regional industry
Model primary focus		9,17,20,21,23,26,28,33,34,35,44,47,50,57,58,60,62,65,73,75,77,79,80,81,82,83,84,85,	9,17,20,21,23,31,33,34,35,44,47,50,57,60,62,65,69,73,75,77,79,80,81,82,83,84,85	1,17,21,23,26,28,30,32,33,34,44,50,58,60,62,65,69,77,	1,5,8,9,15,17,20,21,23,26,28,29,30,32,33,34,35,44,45,46,47,50,53,60,65,68,69,70,73,77,	1,8,9,15,17,21,23,26,28,29,30,32,33,34,44,45,50,58,60,65,69,70,73,77,	1,2,5,8,9,15,20,21,23,26,27,28,29,32,33,34,35,44,45,46,47,50,52,55,60,61,65,68,69,70,73,74,77	1,8,16,17,20,21,23,28,33,34,35,44,47,50,60,61,62,65,69,70,73,77,79,80,81,82,83,84,85	1,2,5,8,9,17,20,21,23,26,28,29,30,33,34,35,44,45,46,47,50,53,58,60,61,62,65,69,70,73,74,77	53,	18,21,23,26,28,33,34,44,45,45,46,47,50,55,60,65,68,69,70,72,73,74,77	2,5,8,18,21,22,23,24,26,28,29,33,34,44,45,46,47,50,60,61,62,65,68,69,70,72,73,74,76,77,85	8,21,23,33,34,44,50,60,62,65,77,	2,5,8,9,35,79,80,81,82,83,84,85,	5,8,9,15,20,21,23,26,28,30,32,33,34,35,44,47,50,60,61,62,65,68,69,70,73,74,77	26,28,30,46,47,57,62,64,69,70,73,75,77,79,80,81,82,83,84,85,	6,7,12,13,14,21,23,26,33,34,44,50,51,52,54,55,56,57,59,60,63,65,67,69,70,73,75,77,78,	6,7,12,13,14,18,22,24,45,46,47,48,51,52,54,55,56,57,59,63,64,67,69,73,74,75,76,78,	16,	16,47,57,70,75,	6,7,12,13,14,16,45,46,47,51,52,54,55,59,63,68,78
Technology detail	End Use techs	23,33,44,50,60,65,34,21,28,47,77,73,58,62	33,44,50,60,65,34,21,31,47,77,73,69,23,62	1,33,44,50,60,65,34,21,23,28,77,69,58,32,62	1,33,44,50,60,65,34,21,23,32,28,47,77,73,70,69,15,53,68,9	1,33,44,50,60,65,34,21,28,77,73,70,69,15,58,23	1,32,33,44,50,60,65,34,21,23,28,47,77,73,70,69,15,55,68,	1,33,44,50,60,65,34,21,28,47,77,73,70,69,23,62	1,33,44,50,60,65,34,21,23,28,47,77,73,70,69,53,58,	53,	33,44,50,60,65,34,21,23,28,47,77,73,70,69,55,68	23,33,44,50,60,65,34,21,28,47,77,73,70,69,68,62	33,44,50,60,65,34,21,77,23		32,33,44,50,60,65,34,21,23,28,47,77,73,70,69,15,68,62	28,47,77,73,70,69,62	33,44,50,60,65,34,21,23,77,73,70,69,55,	47,73,69,55,		47,70,	47,55,68
	Supply side techs	9,33,44,50,60,65,34,21,35,20,26,28,17,47,77,73,58,80,81,82,83,84,85,62	9,33,44,50,60,65,34,21,35,20,31,17,47,77,73,69,80,81,82,83,84,85,62	1,33,44,50,60,65,34,21,30,26,28,17,77,69,58,62	1,5,8,33,44,50,60,65,34,21,35,20,29,30,26,28,45,46,17,47,77,73,70,69,15,53,68,	1,33,44,50,60,65,34,21,29,30,26,28,45,17,77,73,70,69,15,58,9,8	1,33,44,50,60,65,34,21,35,20,29,26,27,28,45,46,47,77,74,73,70,69,15,55,68,61,5,2,8	1,16,33,44,50,60,65,34,21,35,20,28,17,47,77,73,70,69,80,81,82,83,84,85,62,61,8,	1,5,9,33,44,50,60,65,34,21,35,20,29,30,26,28,45,46,17,47,77,74,73,70,69,53,58,8,2	53,	18,33,44,50,60,65,34,21,26,28,45,46,47,77,74,72,73,70,69,55,68	5,8,18,33,44,46,50,60,65,34,21,26,28,45,47,77,74,72,73,70,69,68,85,62,61,2,29	33,44,50,60,65,34,21,77,8,	35,5,9,2	5,9,33,44,50,60,65,34,21,35,20,26,28,47,77,74,73,70,69,15,68,62,61,8,	26,28,46,47,77,73,70,69,62	6,7,33,44,50,60,65,34,21,26,77,73,70,69,54,55,	6,7,18,45,46,47,74,73,69,54,55,	16,	16,47,70,	6,7,16,45,46,47,54,55,68
	Resources	33,44,50,60,65,34,21,35,20,26,28,17,47,77,73,75,57,58,	33,44,50,60,65,34,21,35,20,31,17,47,77,73,69,75,57,	1,33,44,50,60,65,34,21,26,28,17,77,69,58,	1,8,33,44,50,60,65,34,21,35,20,26,28,17,47,77,73,70,69,15,53,68	33,44,50,60,65,34,21,26,28,17,77,73,70,69,15,58,8,	1,33,44,50,60,65,34,21,35,20,26,28,47,77,73,70,69,15,68,2,8	1,16,33,44,50,60,65,34,21,35,20,28,17,47,77,73,70,69,8,	1,33,44,50,60,65,34,21,35,20,26,28,17,47,77,73,70,69,53,58,8,2	53,	33,44,50,60,65,34,21,26,28,47,77,73,70,69,68	8,33,44,50,60,65,34,21,26,28,47,77,73,70,69,68,2	33,44,50,60,65,34,21,77,8,	35,8,2	33,44,50,60,65,34,21,26,28,47,77,73,70,69,15,68,11,8,	26,28,47,77,73,70,69,75,57,	6,7,33,44,50,60,65,34,21,26,77,73,70,69,75,57,	6,7,47,73,69,75,57,	16,	16,47,70,75,57,	6,7,16,47,
	Infrastructure	9,33,44,50,60,65,34,21,35,20,17,77,73,79,80,81,82,83,84,85,	9,33,44,50,60,65,34,21,35,20,31,17,77,73,69,79,80,81,82,83,84,85,	1,33,44,50,60,65,34,21,28,17,77,69,	1,5,8,33,44,50,60,65,34,21,35,20,28,17,77,73,70,69,15,53,68,9	33,44,50,60,65,34,21,28,17,77,73,70,69,15,9,8	1,33,44,50,60,65,34,21,35,20,28,77,73,70,69,15,68,5,2,8	1,16,33,44,50,60,65,34,21,35,20,28,17,77,73,70,69,79,80,81,82,83,84,85,	1,5,9,33,44,50,60,65,34,21,35,20,28,17,77,73,70,69,53,2	53,	33,44,50,60,65,34,21,28,77,73,70,69,68	5,8,33,44,50,60,65,34,21,28,77,73,70,69,68,85,2,29	33,44,50,60,65,34,21,77,	35,5,9,79,80,81,82,83,84,85,2	33,44,50,60,65,34,21,35,20,9,28,77,73,70,69,15,68,9	28,77,73,70,69,79,80,81,82,83,84,85,	6,7,33,44,50,60,65,34,21,77,73,70,69,	6,7,73,69,	16,	16,70,	6,7,16,68
Spatial dimension	Micro level	35,20,17,79,80,81,82,83,84,85,	35,20,17,79,80,81,82,83,84,85,	17,	1,35,20,17,53,68,	17,		1,35,20,17,79,80,81,82,83,84,85,	1,35,20,17,53,	53,	68	5,68,85,		35,79,80,81,82,83,84,85,		79,80,81,82,83,84,85,					68
	Region	35,20,17,79,80,81,82,83,84,85,	35,20,17,69,79,80,81,82,83,84,85,	17,69,	1,5,35,20,46,17,69,53,68,	17,69,	46,69,	1,35,20,17,69,79,80,81,82,83,84,85,	1,5,35,20,46,17,69,53,	53,	46,69,68	5,69,68,85,		35,5,79,80,81,82,83,84,85,	69,	46,69,79,80,81,82,83,84,85,	69,	46,69,			46,68
	Country	9,35,20,17,47,73,75,58,79,80,81,82,83,84,85,62	9,35,20,31,17,47,73,69,75,79,80,81,82,83,84,85,62	29,30,17,69,58,32,62	1,5,6,7,8,35,20,29,30,32,46,17,47,73,69,53,68,9	1,29,30,17,73,69,58,9,8,	1,32,35,20,29,27,46,47,73,69,52,55,68,61,5,2,8	1,16,35,20,17,47,73,69,80,81,82,83,84,85,62,61,8,	1,5,9,35,20,29,30,46,17,47,73,69,53,58,8,2	53,	18,46,47,73,69,55,68	5,8,18,47,73,69,68,85,62,61,2,22,46,29		35,5,79,80,81,82,83,84,85,8,9,2	5,32,35,20,47,73,69,68,9,62,61,8,	46,47,73,69,75,79,80,81,82,83,84,85,62,64,	6,7,73,69,51,14,12,13,52,54,55,75,59,63,67,56,78	6,7,18,22,46,47,73,69,51,14,12,13,52,54,55,75,59,64,63,67,48,78	16,	16,47,75,	46,47,51,14,12,13,52,54,55,59,68,63,78
	Multi-country	9,34,21,35,20,28,47,77,75,58,79,80,81,82,84,85,62	9,34,21,35,20,47,77,75,79,80,81,82,84,85,62	1,34,21,29,30,23,28,77,58,62	1,8,34,21,35,20,29,30,23,28,46,47,77,70,9	1,34,21,29,30,28,77,70,58,9,8	1,34,21,35,20,23,28,46,47,77,74,70,61,2,8	1,16,34,21,35,20,28,47,77,70,79,80,81,82,84,85,62,61,8,	1,9,34,21,35,20,29,30,23,28,46,47,77,74,70,58,8,		34,21,23,28,46,47,77,74,72,70,	8,34,21,35,20,28,47,76,77,74,72,70,85,62,61,2,46,	34,21,77,8	35,79,80,81,82,84,85,9,2	34,21,35,20,23,28,47,77,74,70,9,62,61,8,	28,46,47,77,70,75,80,81,82,83,84,85,62,64,79	6,7,34,21,23,77,70,51,14,12,52,54,55,75,59,63,67,56,78	6,7,46,47,76,74,51,14,12,52,54,55,59,64,63,67,78	16,	16,47,70,75,	6,7,16,46,47,51,14,12,54,55,59,63,78
	Global	33,44,50,60,65,26,47,77,75,57,58,	33,47,77,75,57,	33,44,50,60,65,26,77,58,	33,44,50,60,65,26,45,46,47,77,70,15,	33,44,50,60,65,26,45,77,70,15,58,	33,44,50,60,65,26,45,46,47,77,74,70,15,2,8	16,33,44,50,60,65,47,77,70,	7,33,44,50,60,65,26,45,46,47,77,74,70,58,		33,44,50,60,65,26,45,46,47,77,74,70,	33,44,50,60,65,26,24,45,47,76,77,74,70,46	33,44,50,60,65,77,		33,44,50,60,65,26,47,77,74,70,15,	26,46,47,77,70,75,57,64	7,33,44,50,60,65,26,3,77,70,51,14,54,55,75,57,59,63,67,56,78	7,24,45,46,47,76,74,51,14,54,55,75,57,59,64,63,67,78	16,	16,47,70,75,57,	7,16,45,46,47,51,14,54,55,59,63,78
Time frame	Intra-day to year	35,20,79,80,81,82,83,84,85,	35,20,79,80,81,82,83,84,85,		1,5,35,20,		35,20,27,2,8	1,35,20,79,80,81,82,83,84,85,	1,5,35,20,2,8					35,5,79,80,81,82,83,84,85	35,20,5,	79,80,81,82,83,84,85					
	Year to multiple-year periods	23,9,33,44,50,60,65,34,21,26,28,17,47,77,73,75,57,58,79,80,81,82,83,84,85,62	9,23,33,44,50,60,65,34,21,31,17,47,77,73,69,75,57,79,80,81,82,83,84,85,62	1,33,44,50,60,65,34,21,29,30,26,23,28,17,77,69,58,32,62	1,5,8,33,44,50,60,65,34,21,29,30,26,23,32,28,45,46,17,47,77,73,70,69,15,53,68,9	1,33,44,50,60,65,34,21,29,30,26,28,45,17,77,73,70,69,15,58,23,9,8,	1,5,29,32,26,27,23,28,45,46,47,77,73,70,69,15,52,55,68,61,2,8	1,16,33,44,50,60,65,34,21,28,17,47,77,73,70,69,79,80,81,82,83,84,85,23,62,61,8,	1,2,5,33,44,50,60,65,34,21,29,30,26,23,28,45,46,17,47,77,73,70,69,53,58,9,8,	53,	18,33,44,50,60,65,34,21,26,23,28,45,46,47,77,72,73,70,69,55,68	5,8,18,33,44,50,60,65,34,21,26,24,28,45,47,76,77,72,73,70,69,68,23,62,61,2,22,46,29	33,44,50,60,65,34,21,77,23,8,	8,5,15,79,80,81,82,83,84,85,9,2	5,26,23,32,28,47,77,73,70,69,15,68,9,62,61,8,9	26,28,46,47,77,73,70,69,75,57,79,80,81,82,83,84,85,62,64	6,7,33,44,50,60,65,34,21,26,3,23,77,73,70,69,14,12,52,54,55,75,57,59,63,67,56,78	6,7,18,22,24,45,46,47,76,73,69,14,12,52,54,55,75,57,59,64,63,67,48,78	16,	16,47,70,75,57,	6,7,16,45,46,47,14,52,54,55,59,68,63,78
System boundaries	Sector level	9,35,20,17,79,80,81,82,83,84,85,	9,35,20,311,7,79,80,81,82,83,84,85,	1,29,30,17,58,32	1,5,8,35,20,29,30,32,17,53,68,9	1,29,30,17,58,9,8,	1,32,35,20,29,27,68,2,8	1,17,80,81,82,83,84,85,8,	1,5,35,20,29,30,17,53,58,9,8,2	53,		5,8,85,29		35,5,79,80,81,82,83,84,85,8,9,2	5,35,20,32,68,9	79,80,81,82,83,84,85,					68
	Energy system	23,33,44,50,60,65,34,21,26,28,77,73,58,62	33,44,50,60,65,34,21,77,73,69,23,62	33,44,50,60,65,34,21,26,23,28,77,69,58,62	33,44,50,60,65,34,21,26,23,28,77,73,70,69,15,68	33,44,50,60,65,34,21,26,28,77,73,70,69,15,58,23	33,44,50,60,65,34,21,26,23,28,77,73,70,69,15,68,61	33,44,50,60,65,34,21,28,77,73,70,69,23,62,61	33,44,50,60,65,34,21,26,23,28,77,73,70,69,58,		33,44,50,60,65,34,21,26,23,28,77,73,70,69,55,68	33,44,50,60,65,34,21,26,28,77,73,70,69,68,23,62,61	33,44,50,60,65,34,21,77,23		33,44,50,60,65,34,21,26,23,28,77,73,70,69,15,68,62,61,	26,28,77,73,70,69,62	33,44,50,60,65,34,21,26,23,77,73,70,69,	73,69,		70,	
	Entire economy	47,75,57,	47,75,57,		45,46,47,	45,	45,46,47,74,52,55,	47,	45,46,47,74,		18,45,46,47,74,72,	18,24,45,47,76,74,72,46			47,74,	46,47,75,57,64	6,7,51,14,12,13,52,54,55,75,57,63,67,56,78	6,7,18,22,24,45,46,47,76,74,51,14,12,13,52,54,55,75,57,64,63,67,48,78		16,47,75,57,	6,7,16,45,46,47,51,14,12,13,52,54,55,63,78
Innovation and R&D effects	Technology learning	28,47,77,	47,77,69,	33,44,50,60,65,34,21,29,30,26,28,77,69,58,	8,33,44,50,60,65,34,21,29,30,26,28,45,46,47,77,70,69,	1,33,44,50,60,65,34,21,29,30,26,28,45,77,70,69,58,8,	1,33,44,50,60,65,34,21,29,26,28,45,46,47,77,74,70,69,55,	33,44,50,60,65,34,21,28,47,77,70,69,8,	33,44,50,60,65,34,21,29,30,26,28,45,46,47,77,74,70,69,58,8,		33,44,50,60,65,34,21,26,28,45,46,47,77,74,70,69,55,	28,47,46,77,74,70,69,	33,44,50,60,65,34,21,77,	8	33,44,50,60,65,34,21,26,28,47,77,74,70,69,8,	26,28,47,77,70,69,75,57,	77,70,69,	46,47,74,69,		47,70,	45,46,47,55,
	Performance/Cost/Uncertainty				46,		46,		46,		72,46,	72,				46,		46,			46,
Economic system detail	Sectors detail	47,73,	47,73,69,	69,	45,46,47,73,70,69,	73,70,69,	23,45,46,47,74,73,70,69,55,	47,73,70,69,	46,47,74,73,70,69,		46,47,74,72,73,70,69,	47,76,74,72,73,70,69,22,46			23,47,74,73,70,69,	46,47,73,70,69,64	6,7,73,70,69,51,14,12,13,52,54,55,59,63,67,56,78	6,7,18,22,24,45,46,47,76,74,73,69,51,14,12,13,52,54,55,59,64,63,67,48,78		47,70,	6,7,45,46,47,51,14,12,13,52,54,55,59,63,78
	Branches detail																,	18,			
Behavioral aspects	Social acceptance																				
	Other behavioral aspects	73,	73,69,	69,	73,69,	73,69,	28,73,69,	73,69,	73,69,		72,73,69,	72,73,69,			28,73,69,	73,69,	73,69,51,14,12,13,52,54,55,59,	73,69,51,14,12,13,52,54,55,59,			,51,14,12,13,52,54,55,59,
Environmental aspects	Emissions	17,47,77,73,	17,47,77,73,69,	17,77,69,	1,28,45,46,17,47,77,73,70,69,	28,17,77,73,70,69,	46,47,77,74,73,70,69,	17,47,77,73,70,69,	28,46,17,47,77,74,73,70,69,		46,47,77,74,72,73,70,69,	47,76,77,74,72,73,70,69,46	77,		5,32,33,44,50,60,65,34,21,35,20,26,28,47,77,74,73,70,69,15,68	46,47,77,73,70,69,	77,73,70,69,59,78	46,47,76,74,73,69,59,		47,70,	46,47,59,
	Land use	47,	47,69,	69,	47,70,69,	70,69,	47,70,69,	47,70,69,	47,70,69,		47,72,70,69,	47,76,72,70,69,			47,70,69,	47,70,69,	70,69,	47,76,69,		47,70,	47,
Type of operation	Market simulation	9,26,28,47,77,79,80,82,83,85,62	9,31,47,77,79,80,82,83,85,62	18,29,30,26,28,77,70,54,55,83,62	8,29,30,26,28,45,46,47,77,70,9	29,30,26,28,45,77,70,9,32,8,	29,26,27,28,45,46,47,77,74,70,52,55,61,2,8	28,47,77,70,79,80,82,83,85,62,61,8,	29,30,26,28,45,46,47,77,74,70,9,8,2		18,21,26,28,45,46,47,77,74,72,70,55,	8,18,26,24,28,45,47,76,77,74,72,70,85,62,61,2,27,46,29	77,	79, 80,82,83,85,8,2	26,28,47,77,74,70,9,62,61,8,	26,28,46,47,77,70,79,80,82,83,85,62,64	6,7,26,77,70,51,14,12,13,52,54,55,59,63,67,56,78	6,7,18,22,24,45,46,47,76,74,51,14,12,13,52,54,55,59,64,63,67,48,78		47,70,	6,7,45,46,47,51,14,12,13,52,54,55,59,63,78
	System optimisation	23,33,44,50,60,65,34,35,20,17,73,75,57,58,81,84,	23,33,44,50,60,65,34,35,20,17,73,69,75,57,81,84,	1,16,33,44,50,60,65,34,23,17,69,15,58,	1,5,33,44,50,60,65,34,35,20,23,32,17,73,69,15,53,68,	1,33,44,50,60,65,34,17,73,69,15,58,23	1,5,32,33,44,50,60,65,34,35,20,23,73,69,15,68	1,16,33,44,50,60,65,34,35,20,17,73,69,81,84,23	1,5,33,44,50,60,65,34,35,20,23,17,73,69,53,58,	53,	33,44,50,60,65,34,23,73,69,68	5,23,33,44,50,60,65,34,73,69,68	33,44,50,60,65,34,23	35,5,81,84,	5,32,33,44,50,60,65,34,35,20,23,73,69,15,68	73,69,75,57,81,84,	33,44,50,60,65,34,3,23,73,69,75,57,	73,69,75,57,	16,	16,75,57,	16,68
	Qualitative assessment																				

Transition Planning

Model features		Specifications: SPATIAL PLANNING									DEPLOYMENT PATHWAYS							TIMING		MARKET DESIGN AND ORGANISATIONAL CHANGES	
Model features		Physical barriers (e.g. resource potential of a geographical area to provide wind or solar power; limited and inappropriate transport network)	Capacity expansion (infrastructure)	Grid-connection capacity	Cost effective technology deployment	Availability of natural resources	Territorial integration	Migration flows	Effects on labor demand	Land use and population density	SET-Plan sectoral targets	Evolution of grid and transport networks	Supply chain logistics (interaction between local demand and global supply, time dependence, impact of changes in the energy system)	Links between the energy system and the economy (changes in demand, sectoral changes)	Synergies between tech, ind, social and policy changes	Public-private agent behaviors and partnerships	Effects of 1st demonstration projects in Europe and scenarios to close gaps between demonstration and commercialization	Time lag between investment decision and entering	Effects of different regulatory frameworks in MS	Market barriers (market design and organizational changes required; behavioural change)	Level playing field for all market participants within and among MS
Model primary focus		1,5,8,9,17,21,23,33,34,35,44,47,50,53,60,61,62,65,69,70,73,74,75,77,79,80,81,82,83,84,85,	17,37,53,79,80,81,82,83,84,85,	1,37,53,70,79,80,81,82,83,84,85,	53,58,68,70,73,	9,47,57,70,73,75,	47,70,		6,7,18,46,47,72,	16,47,70,	1,5,20,21,23,28,30,33,34,35,44,47,50,60,62,65,69,70,77,79,80,81,82,83,84,85,	37,79,80,81,82,83,84,85,	76,	2,5,6,7,8,12,13,14,46,47,48,51,52,54,55,57,59,63,64,67,72,75,76,78,	37, 42,	37,42		37,	37,	2,6,7,16,37,38,	6,7,16,37, 38,68
Technology detail	End Use techs	33,44,50,60,65,34,21,47,77,73,70,69,53,62	37,53,	70,37,53,	73,70,53,58,68	47,73,70,	47,70		47,	47,70,	1,33,44,50,60,65,34,21,28,47,77,70,69,23,62	37,		47,55,	37, 42,	37,42,		37,	37,	37,38,	37,38,68
	Supply side techs	1,5,33,44,50,60,65,34,21,35,17,47,77,74,73,70,69,53,9,62,8,61,	37,53,17,	1,70,37,53,	73,70,53,58,68,	47,73,70,9	47,70		18,46,47,72,	16,47,70,	1,5,33,44,50,60,65,34,21,35,20,20,28,47,77,70,69,62,	37		6,7,46,47,72,54,55,8,5	37,42,	37,42,		37,	37,	2,6,7,16,37,	6,7,16,37,68
	Resources	1,33,44,50,60,65,34,21,17,47,77,73,70,69,53,8,75	37,53,17	1,70,37,53,	73,70,53,58,68,	47,73,70,75,57,	47,70		47,	16,47,70,	1,33,44,50,60,65,34,21,28,47,77,70,69,	37,		15,47,75,57,8,	37,42,	37,42,		37,	37,	16,37,	6,7,16,37,68
	Infrastructure	1,5,33,44,50,60,65,34,21,35,17,77,73,70,69,53,79,80,81,82,83,84,85,9	37,53,17,79,80,81,82,83,84,85,79,	1,70,37,53,79,80,81,82,83,84,85,	73,70,53,68,	73,70,9	70			16,70,	1,5,33,44,50,60,65,34,21,35,20,28,77,70,69,80,81,82,83,84,85,79,	37,79,80,81,82,83,84,85,		6,7,5	37,42,	37,42,		37,	37,	6,7,16,37,	6,7,16,37,68
Spatial dimension	Micro level	1,17,53,79,80,81,82,83,84,85,	37,53,17,79,80,81,82,83,84,85,79,	1,37,53,79,80,81,82,83,84,85,	53,68,						80,81,82,83,84,85,79,	37,80,81,82,83,84,85,79,			37,	37,		37,	37,	37,38,	37,38,
	Region	1,5,17,69,53,79,80,81,82,83,84,85,	37,53,17,79,80,81,82,83,84,85,79,	1,37,53,79,80,81,82,83,84,85,	53,68,				46,		69,80,81,82,83,84,85,79,	37,80,81,82,83,84,85,79,		46,5	37,	37,		37,	37,	37,	37,68
	Country	1,17,47,73,69,53,79,80,81,82,83,84,85,9,62,8,61,75	37,53,17,79,80,81,82,83,84,85,79,	1,37,53,79,80,81,82,83,84,85,	73,53,58,68,	47,73,75,57,9	47,		6,7,18,46,47,	16,47,	1,5,35,20,47,69,80,81,82,83,84,85,79,62,	37,80,81,82,83,84,85,79,	76,	6,7,46,47,51,14,12,13,52,54,55,75,57,59,8,64,63,5,48,78	37,42,	37,42,		37,	37,	6,7,16,37,	6,7,16,37,68
	Multi-country	1,34,21,35,47,77,74,70,79,80,81,82,84,85,9,62,75	79,80,81,82,84,85,79,	70,79,80,81,82,84,85,	70,58,	47,70,75,57,9	47,70		46,47,72,	47,70,	1,34,21,35,20,28,47,77,70,80,81,82,84,85,79,62,	37,80,81,82,84,85,79,	76,	6,7,46,47,76,72,51,14,12,54,55,75,57,59,8,64,63,5,78	37,42,	37,42,		37,	37,	6,7,16,37,	6,7,16,37,
	Global	33,44,50,60,65,47,77,74,70,75		70,	70,58,	47,70,75,57,	47,70		46,47,	16,47,70,	33,44,50,60,65,47,77,70,		76,	7,46,47,76,51,14,54,55,75,57,59,64,63,78						7,16,	7,16,
Time frame	Intra-day to year	1,5,35,79,80,81,82,83,84,85,	79,80,81,82,83,84,85,79,	1,79,80,81,82,83,84,85,							35,20,79,80,81,82,83,84,85,	80,81,82,83,84,85,79,		5							
	Year to multiple-year periods	1,5,33,44,50,60,65,34,21,17,47,77,73,70,69,53,79,80,81,82,83,84,85,9,62,8,61,75	37,53,79,80,81,82,83,84,85,	1,70,37,53,79,80,81,82,83,84,85,	73,70,53,58,68	47,73,70,75,57,9	47,70		6,7,18,46,47,72,	16,47,70,	28,47,77,70,69,23,79,80,81,82,83,84,85,62,	37,79,80,81,82,83,84,85,	76,	6,7,46,47,76,72,14,12,52,54,55,75,57,59,8,64,63,5,48,78,	37,42,	37,42,		37,	37,	6,7,16,37,38,	6,7,16,37,38,68
System boundaries	Sector level	1,5,35,17,53,79,80,81,82,83,84,85,9,8,	53,17,79,80,81,82,83,84,85,	1,53,79,80,81,82,83,84,85,	53,58,68,	9					1,5,35,20,79,80,81,82,83,84,85,	80,81,82,83,84,85,79,		8,5							68
	Energy system	33,44,50,60,65,34,21,77,73,70,69,62,61	37,	70,37,	73,70,58,68	73,70,	70			70,	33,44,50,60,65,34,21,28,77,70,69,23,62	37,			37,42,	37,42,		37,	37,	37,38,	37,38,68
	Entire economy	47,74,75				47,75,57,	47,		6,7,18,46,47,72,	16,47,	47,		76,	6,7,46,47,76,72,51,14,12,13,52,54,55,75,57,64,63,48,78						6,7,16,	6,7,16,
Innovation and R&D effects	Technology learning	33,44,50,60,65,34,21,47,77,74,70,69,8,75	37,	70,37,	70,58,	47,70,75,57,	47,70		46,47,	47,70,	33,44,50,60,65,34,21,28,47,77,70,69,	37,		46,47,75,57,8,	37,42,	37,42,		37,	37,	37,	37,
	Performance/Cost/Uncertainty								72,46,					72,46,	37,	37,		37,	37,		
Economic system detail	Sectors detail	47,74,73,70,69,		70,	73,70,	47,73,70,	47,70		6,7,18,46,47,72,	47,70,	47,70,69,		76,	6,7,46,47,76,72,51,14,12,13,52,54,55,59,64,63						6,7,38,	6,7,38,
	Branches detail								18,												
Behavioral aspects	Social acceptance											37,			37,42,	37,42,		37,	37,	37,38,	37,38,
	Other behavioral aspects	73,69,			73,	73,			18,6,7,18,72,		28,69,	37,		14,12,54,12,54,55,6,7,72,51,14,12,13,52,54,55,59,	37,42,	37,42,		37,	37,	16,2,16,37,38,	
Environmental aspects	Emissions	17,47,77,74,73,70,69,	17	70,	73,70,58,	47,73,70,	47,70		18,46,47,72,	16,47,70	1,33,44,50,60,65,34,21,28,47,77,70,69,	37,	76,	46,47,76,72,59,	37,42,	37,42,		37,	37,	37,	37,
	Land use	47,70,69,		70,	70,	47,70,	47,70		18,47,72,	16,47,70	47,70,69,	37,	76,	47,76,72,	37,	37,		37,	37,		37,
Type of operation	Market simulation	47,77,74,70,79,80,82,83,85,9,62,8,61	79,80,82,83,85,	79,70,80,82,83,85,	70,	47,70,9	47,70		6,7,18,46,47,72,	47,70,	28,47,77,70,79,80,82,83,85,79,62,	80,82,83,85,79,	76,	6,7,46,47,76,72,51,14,12,13,52,54,55,59,8,64,63,48,78						6,7,	
	System optimisation	1,5,33,44,50,60,65,34,17,73,69,53,81,84,75	53,17,81,84,	1,53,81,84,	73,53,58,68,	73,75,57,				16	1,33,44,50,60,65,34,35,20,69,81,84,23	81,84,		75,57,5						16,	68
	Qualitative assessment		37,	37,								37,			,37,42,	37,42,		37,	37,	37,38,	37,38,

Transition Planning

Model features		Social barriers (people's perceptions on technologies; social acceptance of technologies)	Quantification of employment (from supply chain perspective, regional approach and accounting for impact of the transition)	Public acceptance (awareness and understanding of tech use and implications)	Public participation (stakeholders involvment and resistance) and governance issues	Perceptions on reliability of a technology as energy source	Energy prices (for different groups)	Influence of competing technologies	Risk perception (investments, immaturity of technologies, reputation of operator or	Management of local supply chain (economic efficiency, sustainability, social responsibility, system operation	Land-use intensity	Divergence of views on landscape preservation	Siting issues	Concerns on health impacts	Safety issues and related perception	Distribution of local costs and benefits (fairness, equality)
		Specifications: ACCEPTANCE/PERCEPTION OF A TECHNOLOGY														
Model primary focus		10,16, 38, 43,	6,7,12,13,14,18,22,24,46,47,51,52,54,55,59,63,67,72,76,78	10, 37, 38, 43,	10, 37, 38, 42,	15,58,83,	2,3,5,6,7,8,11,12,13,14,25,51,52,54,55,63,67,78	37,70		10, 37,	16,70,		53,	57,75,		5,6,7,8,10,12,13,14,48,51,52,54,55,57,63,67,75,78,
Technology detail	End Use techs	10,43,	47,55,	10,37,38,43,	10,37,38,42	15,58	55	70,37,		10,37,			53,			10,
	Supply side techs	16,10,	18,46,47,72,54,55,	10,37,	10,37,42	15,58,83,	54,55,5	70,37,		10,37,	16,70,		53,			8,10,54,55,5
	Resources	16,	47,	37,	37,42	15,58	3	70,37,		37,	16,70,		53,	57,75,		8,75,57,
	Infrastructure	16,		37,	37,42	15,83,	5,3	70,37,		37,	16,70,		53,			8,5
Spatial dimension	Micro level	10,43,		10,37,38,43,	10,37,38,	83,		37,		10,37,			53,			10,
	Region	10,43,	22,46,	10,37,43,	10,37,	83,	5	37,		10,37,			53,			10,5
	Country	16,	6,7,18,46,47,51,14,12,13,52,54,55,59,63,78	37,	42	58,83	2,6,7,8,51,14,12,13,52,54,55,5,63,67,78	37,		37,	16,					6,7,8,48,51,14,12,13,52,54,55,5,63,67,78,
	Multi-country	16,	6,7,46,47,76,72,51,14,12,54,55,59,63,78	37,	37,42	58,	6,7,8,11,51,14,12,54,55,63,67,78	70,37,			16,70,					6,7,8,51,14,12,54,55,63,67,78,
	Global	16,	7,24,46,47,76,51,14,54,55,59,63,78		42	15,58	7,25,3,51,14,54,55,63,3,67,78	70,			16,70,					7,51,14,54,55,63,67,78
Time frame	Intra-day to year	43,	0	43,			15,5									5
	Year to multiple-year periods	16,10,	6,7,18,22,24,46,47,76,72,14,12,52,54,55,59,63,78	10,37,38,	10,37,38,	15,58	5,6,7,8,25,3,11,51,14,54,55,5,63,3,67,78	70,37,		10,37,	16,70,			57,75,		5,6,7,8,48,10,51,14,54,55,75,57,63,67,78,
System boundaries	Sector level			,		83,	18,25,3,11,5,3						53,			5
	Energy system			37,38,	37,38,42	15,58		70,37,		37,	70,					
	Entire economy	16,43,	6,7,18,22,24,46,47,76,72,51,14,12,13,52,54,55,63,78	43,			6,7,51,14,12,13,52,54,55,63,67,78				16,			57,75,		6,48,51,14,12,13,52,54,55,75,57,63,67,78
Innovation and R&D effects	Technology learning		46,47,	37,	37,			70,37,		37,	70,			57,75,		75,57,
	Performance/Cost/Uncertainty		72,46,					37,								
Economic system detail	Sectors detail		6,7,18,22,24,46,47,76,72,51,14,12,13,52,54,55,59,63,78				6,7,51,14,12,13,52,54,55,63,67,78	70,			70,					6,7,48,51,14,12,13,52,54,55,63,67,78
	Branches detail	43,	18,													
Behavioral aspects	Social acceptance	16,10,43,		10,37,38,43,	10,37,38,			37,		10,37,	10,					10,
	Other behavioral aspects	10,43,	18,14,12,54,18,12,54,55,6,7,18,72,51,14,12,13,52,54,55,59,	10,37,38,43,	10,37,38,		14,12,54,2,54,55,2,6,7,51,14,12,13,52,54,55,	37,		10,37,						54,55,6,7,8,10,51,14,12,13,52,54,55,
Environmental aspects	Emissions	43,	18,22,46,47,76,72,59,	37,43,	37,	15,58		70,37,		37,	70		53,			
	Land use		18,47,76,72,	37,	37,			70,37,		37,	16,70,					
Type of operation	Market simulation		6,7,18,22,24,46,47,76,72,51,14,12,13,52,54,55,59,63,78			83,	2,6,7,51,14,12,13,52,54,55,63,3,67,78	70,			70,					8,48,51,14,12,13,52,54,55,63,67,78,6
	System optimisation	16,		,		15,58	25,3,11,5				16,		53,	57,75,		75,57,5
	Qualitative assessment	10,43,		10,37,38,43,	10,37,38,42			37,		10,37,						10,

Innovation and R&D

		Specifications											
		GENERAL SPECIFICATIONS		R&D					INNOVATION				
Model features		Long-term economic perspectives of technologies	Risks involved in research activities (long-term perspective)	Effects of R&D spending (patenting, deployment)	Effects of public-private R&D partnerships, effectiveness of stimulating cooperation, timing of inizialization of R&D support	Technology specific R&D interim and final targets	Decision parameters to modify the ambition level of targets and the time paths	Assessment and monitoring of R&D funding mechanisms (for technological development lagging behind)	Strengths and weaknesses of EU and national industries	Quantify necessary R&D spending on specific technologies in order to cover the gap between EU and RoW	Technologies needed to reach 2020 and beyond targets	Identification of industrial opportunities in the energy sector for EU	Identification of sectors/technologies needing particular attention due to worldwide competition
Model primary focus		6,7,46,48,58,64,74,	39, 40,	6, 7,36,48, 49,72,	12,46,48,49,55,72,				6,7,46,48,58,64,72		8,15,26,27,28,33,34,36,44,46,50,53,57,60,65,68,70,74,75	6,7,46,48,58,64,74	6,7,12,13,14,46,51,54,55,59,63,67,72,74,78
Technology detail	End Use techs	58,	39,40,		55,				58,		33,44,50,60,65,34,26,28,70,15,53,68	58,	55,
	Supply side techs	6,7,46,74,58,64,	39,40,	6,7,72,36,	46,72,55,				6,7,46,72,58,64		8,33,44,50,60,65,34,26,27,28,46,74,70,36,15,53,68,	6,7,46,74,58,64,	6,7,46,74,72,54,55,
	Resources	58,	39,40,	6,7,36,					75,58,		8,33,44,50,60,65,34,26,28,70,36,15,53,75,57,68	58,	
	Infrastructure	6,7,	39,40,	6,7,					6,7,		8,33,44,50,60,65,34,26,28,70,15,53,68,	6,7,	6,7,
Spatial dimension	Micro level		39,40,								68,		
	Region	46,	39,40,		46,				46,		46,68,	46,	46,
	Country	6,7,46,58,64	39,40,	6,7,48,	46,48,49,12,55,				6,7,46,58,64,48		8,27,46,53,68,	6,7,46,58,64,48	6,7,46,51,14,12,13,54,55,59,63,78
	Multi-country	6,7,46,74,58,64	39,40,	6,7,72,36,	46,49,72,12,55,				6,7,46,72,58,64,48		8,34,28,46,74,70,36,	6,7,46,74,58,64,	6,7,46,74,72,51,14,12,54,55,59,63,78
	Global	7,46,74,58,64	39,40,	7,36,	46,49,				7,46,58,64,48		33,44,50,60,65,26,46,74,70,36,15,	7,46,74,58,64,	7,46,74,51,14,54,55,59,63,78
Time frame	Intra-day to year		39,40,										
	Year to multiple-year periods	6,7,46,58,64	39,40,	6,7,48,72,36,	46,48,49,72,12,55,				6,7,46,72,75,58,64,48		8,33,44,50,60,65,34,26,27,28,46,70,36,15,53,75,57,68	6,7,46,58,64,48,	6,7,46,72,14,12,55,59,63,78
System boundaries	Sector level	58,	39,40,						58,		8,27,53,68,	58,	
	Energy system	58,	39,40,						58,		33,44,50,60,65,34,26,28,70,15,68	58,	
	Entire economy	6,7,46,74,64,	39,40,	6,7,48,72,36,	46,48,49,72,12,55,				6,7,46,72,75,64,48		46,74,36,75,57,	6,7,46,74,64,48	6,7,46,74,72,51,14,12,13,54,55,63,78
Innovation and R&D effects	Technology learning	46,74,58,	39,40,	6,7,36,	46,55,				46,75,58,		33,44,50,60,65,34,26,28,46,74,70,36,75,57,	46,74,58,	46,74,55,
	Performance/Cost/Uncertainty	46,	39,40,	72,36,36,	72,12,46,				72,46,		36,46,36,	46,	72,46,
Economic system detail	Sectors detail	6,7,46,74,64,		6,7,48,72,	46,48,49,72,12,55,				6,7,46,72,64,48		46,74,70,	6,7,46,74,64,	6,7,46,74,72,51,14,12,13,54,55,59,63,78
	Branches detail												
Behavioral aspects	Social acceptance												
	Other behavioral aspects			72,	72,				72,				72,59,
Environmental aspects	Emissions	46,74,58,		72,36,	46,49,72,12,				46,72,58,		33,44,50,60,65,34,26,27,28,46,74,70,36,53,68	46,74,58,	46,74,72,59,
	Land use			72,	72,				72,		70,36,		72,
Type of operation	Market simulation	6,7,46,74,64,		6,7,48,72,	46,48,49,72,12,55,				6,7,46,72,64,48		8,27,28,46,74,70,	6,7,46,74,64,48	6,7,46,74,72,51,14,12,54,55,59,63,78
	System optimisation	58,		36,					75,58,		33,44,50,60,65,34,26,36,15,53,75,57,68	58,	
	Qualitative assessment		39,40,										

International cooperation		Specifications								
		GENERAL SPECIFICATIONS	INTERNATIONAL COOPERATION ON R&D						INTERNATIONAL COOPERATION IN TECHNOLOGY DEPLOYMENT	
Model features		Potentials of JI and CDM (for making targets outside the EU)	Identify win-win situations (cooperation beneficial both to EU and to other parties)	Monitor benefits of international cooperation on R&D	Need for global centres of excellence (existence and fields of activity)	Main research interests in and outside EU (mapping technology, international governmental investments in programs for	Effectiveness of past international cooperation initiatives	Evaluation of benefits of cooperation initiatives for both sides (EU and outside EU)	Effects of spill-overs between different regions of the world and sectors	Deployment of technologies and the relative costs outside Europe (i.e integrate IEA projections in SETIS)
Model primary focus		7,12,14,45,47,49,51,54,57,63,67,70,74,75,78,	39, 40,		39, 40,	39, 40,		6,7,75,	47,72,	47,74,
Technology detail	End Use techs	47,70,	39,40,		39,40,	39,40,			47,	47,
	Supply side techs	7,45,47,74,70,54,	39,40,		39,40,	39,40,		6,7,	47,72,	47,
	Resources	47,70,75,57,	39,40,		39,40,	39,40,		75,	47,	47,
	Infrastructure	7,70,	39,40,		39,40,	39,40,		6,7,		
Spatial dimension	Micro level									
	Region									
	Country	47,49,63,78							47,	47,
	Multi-country	7,47,49,74,70,51,14,12,54,63,78	39,40,		39,40,	39,40,		6,7,	47,72,	47,74,
	Global	45,47,49,74,70,51,14,54,63,78	39,40,		39,40,	39,40,		7,	47,	47,74,
Time frame	Intra-day to year									
	Year to multiple-year periods	7,45,47,49,70,75,57,63,78	39,40,		39,40,	39,40,		6,7,75,	47,72,	47,
System boundaries	Sector level	7,								
	Energy system	70,								
	Entire economy	45,47,49,74,51,14,12,54,75,57,63,78	39,40,		39,40,	39,40,		6,7,75,	47,72,	47,74,
Innovation and R&D effects	Technology learning	45,47,74,70,75,57,	39,40,		39,40,	39,40,		75,	47,	47,74,
	Performance/Cost/Uncertainty		39,40,		39,40,	39,40,		6,7,	72,	
Economic system detail	Sectors detail	7,45,47,49,74,70,51,14,12,54,63,78						6,7,	47,72,	47,74,
	Branches detail									
Behavioral aspects	Social acceptance									
	Other behavioral aspects								72,	
Environmental aspects	Emissions	7,45,47,49,74,70,							47,72,	47,74,
	Land use	47,70,							47,72,	47,70,
Type of operation	Market simulation	7,45,47,49,74,70,51,14,12,54,63,78						6,7,	47,72,	47,74,
	System optimisation	7,75,57,						75,		
	Qualitative assessment		39,40,		39,40,	39,40,				