Project no.:
241382

Project acronym

ATEsT

Project title:

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

Instrument: Coordination and Support Action
Thematic priority: ENERGY.2009.9.1.1
European Energy Infrastructure Networks and Systems Transition Planning
Start date of project: 01 October 2009
Duration: 30 months

D.6.1
Suggestions for tools and methodologies development to support SetPlan implementation

May 2012

Organisation name of WP Coordinator for this deliverable:
VTT

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Acknowledgements

This project was funded by the European Commission under the 7th Framework Program (Grant Agreement No. 241382). The authors would like to acknowledge many colleagues within the ATEsT project team for providing useful inputs and comments during the process leading to this report. In particular, we are grateful to the project coordinator George Giannakidis and Christos Nakos (CRES), Rodica Sandu and Sophia Simoes (JRC), Koen Schoots and Joost van Stralen (ECN), Oscar Amerighi, Maria Cristina Tommasino and Umberto Ciorba (ENEA), Nazmiye Ozkan and Elisabetta Mocca (PSI), Ralf Kuder and Markus Blesl (IER), Helena Cabal and Yolanda Lechon (CIEMAT), and Drazen Jaksic (EIHP), for their inputs and comments.

The authors are responsible for all remaining errors and omissions.

Contents

1. Introduction

To achieve the transition of Europe to a low carbon future, the Strategic Energy Technology Plan (SET-Plan) has been launched, focusing on strengthening and giving coherence to the overall effort in Europe in the direction of new energy technologies development and deployment. For the effective transition of a sustainable low carbon energy society the use of technoeconomic and socioeconomic tools and methodologies is necessary to support policy making, and on the other hand, to support both investor's and consumer's decision making. Models and tools are also needed to evaluate the effectiveness of energy, climate, and innovation policies. Not only ex-ante but also ex-post analysis is required to ensure that the direction and speed of the development is right and high enough. The EU's transision to a low carbon future is a great challenge, which requires paradigm change by developing and implementing clean energy systems as well as restructuring the way we live, move and work. Analysing and modelling of this multilevel change requires modifications to exsisting tools and methodologies and also the development of new ones to consider and analyse both technoeconomic and socioeconomic changes required.

The objective of the final working package of the ATEsT project (WP6) was to:

1. to create a framework for tools necessary to plan and develop future energy systems and policies.
2. to develop a roadmap for tools and methodologies development necessary to model the evolution of the European low carbon energy systems.

The analysis and especially the gaps identified in the earlier WPs of the ATEsT project were used as a starting point of the WP6 work. In addition, a survey of existing policy making process in energy and climate policies at the EU and its Member State's level were contributed by inquiries of the ATEsT's partners and by literature survey. The idea of the survey was to gather state of the art information of the exsisting policymaking process as well as to find out which models and/or tools are used to support decision making process, if any. The analysis clearly revealed the differences in national traditions in policy making, which was helpful in creating the ATEsT framework and roadmap for tools and methodologies development.

Chapter 2 of this report summarizes the use of models and tools to support decision-making in energy and climate policies in the EU and its MSs and more detailed description is given in the Appendix A1 and A2. Chapter 3, describes the ATEsT framework and its theoretical background. In Chapter 4, identification of gaps in the tools and methodology development is presented based on the WP1-WP5 results as well as based on the ATEsT framework. Chapter 5 describes the overall roadmap process and formulates concrete actions needed to develop advanced tools and methodologies. Finally, Chapter 6 summarises the main conclusions of the WP6 and presents some recommendations.

2. Use of models and tools to support decision-making on energy and climate policy in the EU and its Member States

In WP6, the starting point the analysis was to conduct a survey of today's policy making process in energy and climate related issues. All the project partners gave an overview of their own country's policy making process and especially reported, which models and tools have been used to support national decision making. In addition, the JRC gave an overview of the use of models and tools within the European Commission. The case study countries included Netherlands, Greece, Spain, Italy, Germany and Finland. In addition, Sweden and Austria were included in the summary as there was good information available for those countires. Below, a summary of the overviews given.

2.1 Overview of the use of models within the European Commission

Various models and tools are used within the European Commission at different levels of the energy and climate related policy-making process:

i. for internal use to strengthen the knowledge in particular fields at EU level,

ii. and for external support, such as initiative proposals to the Council and the Parliament.

As a support to Energy and Climate Policy for instance, the Joint Research Center (JRC) provides techno-economic assessments and modeling activities, which are meant to assist the conception, implementation and monitoring of EU policies. Within JRC institutes, modeling capacities are developed with a specific role in developing and operating tools, mathematical models and methodologies that simulate the evolution of the energy technologies within research topics of particular relevance to European policies. As an example, the POLES partial equilibrium model of the energy sector has been used for the quantitative assessment combined with a spreadsheet model for technology learning

Based on this experience, the outputs give general guidance to the Commission services for assessing potential impacts of different policy options, and make further the object of external evaluations and public consultations.

Relevant examples on the use of specific models and tools are the Impact Assessment activities which evaluate the potential economic, social and environmental consequences of new policies prepared by the European Commission for decision-makers. Impact Assessments (IA) are based on integrated approaches for estimating the potential costs and benefits of a policy proposal. To that, the relevant expertise within the Commission is gathered across policy areas for a multidisciplinary view with inputs from experts and stakeholders. The process is transparent and published online.

Main steps for preparing an important policy initiative are as follows.

1. Firstly, the Commission conducts the Impact Assessment from launching the roadmap of IAs, setting up a steering group, and expertise collection to the final draft with preliminary results.
2. An Independent Board is established and together with a High Level Group of National Experts on Better Regulation gives feedback on the IA methodology and results. The external evaluation of stakeholders as well as of the public opinion gives inputs regarding the problem definition and the application of the subsidiary principle. This contributes to draw specific guidelines on impacts, results and potential options for the follow-up of the new policy.
3. Finally, the IA document is submitted to European Parliament and the Council which set amendments. The inter-institutional approach could also be based on the cooperation with the Committee of Regions for the local and regional aspects, in particular for evaluating respect of the subsidiarity and proportionality principles.

The IAs are considered the starting point in the legislative process, but they might be conducted also for non-legislative initiatives such as white papers or guidelines. However, IAs are not conducted for all policies, but only for the most important future policies with strong potential impacts. For instance, the 2012 annual roadmap of IA planning gives an overview of fields and issues which could further make the object of IAs: nuclear safety, renewable energy strategy, energy efficiency, carbon capture and storage, internal energy market, energy technology, and smart cities.

A description of how models have been used to quantitatively assess the impacts of the SET-Plan on the European power sector can be found in Appendix A1.

2.2 Use of models in the case-study EU Member States

In order to study the use of energy models to support energy- and climate-related policy and decision-making within different EU Member States, a few countries were chosen as case-studies. These case-study countries included Spain, Netherlands, Greece, Italy, Germany, Finland, Sweden and Austria. In the following, examples of the models and approaches used in these countries are given. More detailed description, including information on energy and climate-related policy-making processes within these countries, can be found in Appendix A2.

Table 1. Models used in the case-study countries.

Model	**Countries that have used the techno-economic and/or socio-economic modelling to support decision-making**
Med-Pro	Spain
DIME	Germany
PANTA-RHEI	Germany
TIMES	Germany, Greece, Italy, Finland
MARKAL	Sweden, Italy, UK, Greece
NEWAGE	Germany
CEEM	Germany
GEMS	Germany
BALMOREL	Austria
LEAP	Austria
MINNI	Italy
ERNSTL	Austria
VATTAGE	Finland
DELL	UK
E2M2	Germany
WASP	Greece
REMix	Germany
COST+	Greece
ENPEP	Greece
E3.at	Austria
SimEE	Germany
DIMPSA	UK

There seems to be a wide range of models used within these countries (Table 1). The most commonly used models are the MARKAL and the TIMES models. There are national / regional versions of MARKAL for Sweden (in fact, that model includes other Nordic countires as well), Italy, Greece and the UK. TIMES model, which is an evolved version of MARKAL, has been used in Germany, Greece, Finland and Italy. Apart from these two models, there are several different models in use within the studied countries. As can be seen in Table 1, none of the other models mentioned were used by two or more of the case-studied countries. Usually, these models and their databases are created on country level and used by a single organisation or even by the same person from year to year.

In Germany the contents of the energy plan are founded on model based scenario analyses. Examples of the models include the European electricity market model DIME and the economic input-output model PANTA-RHEI, which have both been used in Germany along other quantitative models to produce model-based scenario analyses (*Energieszenarien*) for the German energy plan. A similar approach is used in the UK, where the Department of Energy and Climate Change (DECC) and the Climate Change Committee (CCC) have employed several different models to assess energy and climate policies. In addition to MARKAL-UK and its variants (MARKAL MACRO and MARKAL Elastic Demand), DECC Energy and Emission model and DIMPSA (Distributional Impacts Model for Policy and Strategy Analysis) have been used. UK has also created its own TIMES model.

In Italy on the other hand, modelling has mainly relied on TIMES-Italy and on MARKAL-Italy. In addition, the model MINNI has been used to support international negotiations on different air pollutants. MINNI is a national-scale modelling system used to simulate the dispersion and chemical transformation of the main air pollutants. It has been developed in collaboration with ENEA, IIASA and Arianet Ltd.

In Finland the energy system model TIMES Finland and more recently VTT's Nordic TIMES model have been used to support the preparation of the most recent National Energy and Climate Strategy. Also, the general equilibrium model VATTAGE and the VTT Electricity Market Model (VTT EMM) have been used to support decision making in national policies.

In the Netherlands, the design and evaluation of energy policies mainly rely on the Reference Projection, which uses the Netherlands Energy Outlook Modelling System of the Energy Research Centre of the Netherlands (ECN). The Reference Projection is a joint publication of the ECN and the Environment Assessment Agency (PBL). The system contains gas/power market models, and economic sector model, final energy demand models, energy supply models and models on energy-related emissions. For modelling transport and non-CO_2 greenhouse gases, models of the PBL are used.

The preparation of the national renewable energy action plans (NREAPs) has been supported by modelling in most of the studied countries. However, modelling of feed-in tariffs, green certificates, and other renewable energy supports is challenging with energy system and market models, which means that in many cases analysis of different support systems is more or less indicative. Sweden has used their MARKAL-Nordic model in the preparation of its NREAP. Other models that have been used in the studied countries, include REMIX and SimEE in Germany and the e3.at model in Austria. Of the case-study countries, only for Spain threre are no exact reference on which models, if any, are being used to support energy-related policy-making. The only model, for which reference was found, was the MED Pro model that has been used to estimate CO_2 emissions.

3. ATEsT Framework for supporting SET-Plan implementation

The first objective of the ATEsT WP6 was to develop a framework covering significant methods and tools that are relevant to plan and develop future infrastructures and policies within EU. The second objective of the WP6 was the roadmap development for tools and methodologies development, which is discussed in the Chapter 6. The developed ATEsT framework is used to aggregate the results of the models and tools evaluation that was carried out in WP2 and in the policy analysis shown in the Chapter 2 above, and to identify the future development needs of the models and methodologies.

To cover the entire field of ATEsT project, we needed to consider the following aspects when constructing the framework:

1. The SET-Plan is based on a core idea that the entire energy system and society need to transform to become sustainable. The challenge of climate change calls for an effective low-carbon policy and efficient energy technologies. This has far-reaching implications on the sourcing, production, transportation and use of energy. These aspects led us to the **theory of transition management and its applications to energy sector** as the first constituent of the framework.
2. As the objective of the ATEsT project is to support the development of future infrastructures and policy making, the framework should also cover governance aspects. An interesting direction for the framework development was the discussion on **reflexive governance**, which has been developed in the context of sustainable development (Voß et.al. 2006).

The above mentioned background theories, transition management and reflexive governance are discussed briefly in the following. The ATEsT framework is presented after that.

3.1 Theoretical background of the framework

The sustainable energy structure in the climate change context is possible only through introduction and use of sustainable energy innovations, for example, such as renewable energy technology production innovations, energy saving innovations, behavioural changes in energy consumption, etc. More novel innovations require greater change in all system functions. This means that the whole societal system has to open up in order to find out the barriers and drivers of the innovative system change; decision makers in all levels, in households, companies, schools, universities, ministries, parliament and other levels, should be involved.

Transition Management refers to an attempt to redirect the existing dynamics of technological change and the entire techno-economic and societal system. Transition management intends to clarify the content and challenges of systemic change and societal embedding of new innovations. The Netherlands is among forerunners in developing, applying and implementing transition management approach (see e.g. Geels 2005, Geels and Kemp 2007, Geels and Schot 2007). In transition management approach the technological system, such as energy system, is best understood as being composed of both physical technologies -in the form of components, combined systems and infrastructure, and social technologies (institutions) – in the form of culture, social patterns, constrains and mechanisms of behaviour such as social norms, routines, legislation, standards and economic incentive mechanisms.

A dominating essence of a complex technological system is path dependence, which refers to that directions for future development foreclosed or inhibited by directions in past development. Most innovations are built on past discoveries and needs to adapt to pre-existing conditions for successful diffusion. The path-dependent and irreversible nature of techno-institutional co-evolution makes transitions difficult to achieve; the prevailing system acts as a barrier to the creation of a new system.

Beside the fact that physical existing technological solutions direct or stabilize the development of the system, technology developers often neglect the other fact that the stakeholders would not adopt and adapt to new innovations without resistance. The understanding of the dynamics of social acceptance of new technologies is of crucial importance. The intrinsic resistance of complex systems is highly dominating the development and systemic change.

The transition in path-dependent system is a complex multidimensional societal change process, dealing with the co-evolution of technological, industrial, policy and social changes. A Multi-Level Perspective (MLP) model has been developed first in the Netherlands (Geels 2005), in order to describe this complex process. The framework has also been developed and applied in UK (Foxon et. al. 2010); in this ATEsT framework development we especially refer into this UK application.

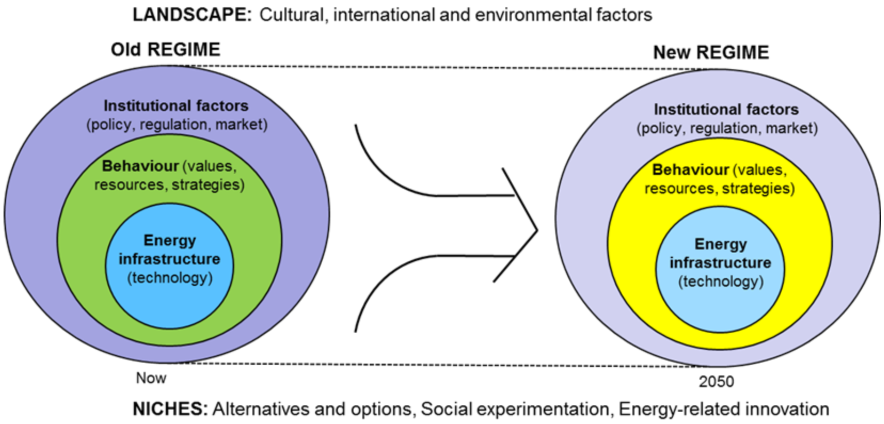

Figure 1 Multi Level Perspective model (see Foxon et. al. 2010).

Three levels of change are abstracted in the MLP model: landscape, regime and niche (see Figure 1). Landscape, forms an exogenous macro level environment that influences developments in niches and regimes. International factors, e.g. economic, and cultural or environmental factors compose the landscape level. The socio-technical landscape tends to change only very slow, for example, demographic changes, macro-economics, and cultural change are slow, possibly over generation changes.

Regime refers to the existing structures and actions of the system, like nuclear or coal fired power, or district heat. The specific form of the regime is dynamically stable and not prescribed by external constraints but mainly shaped and maintained through the mutual adaptation and co-evolution of its actors and elements. Path dependent planning and innovations based on existing solutions direct the almost stable system. Hence, the prevailing system acts as a barrier to the creation of a new system. For example, the technical life times of nuclear power plants are up to sixty years, and existing buildings may still appear over several generation changes, which means that today's decisions would have an long term impact and might act as a barrier for new and clean energy investments.

Niches, in turn, form the level where radical novelties emerge. Niches are local innovative solutions, experiments. Niches may, for instance, take the form of small-market niches, where selection criteria are different from the existing regime. Survival of such niches may be supported by public subsidies and act as incubators for new technologies or practices. Niches provide opportunities for learning and incubation of alternative solutions that may gradually become strong enough to challenge the existing regime or adopt and transform the regime towards new directions.

The system transition is possible, if the change processes in all these different levels are parallel, thus, the socio-technical change is a result of the interaction and synergy of all the different levels. One single change cannot change the whole system, but a system innovation is needed.

In the ATEsT framework we will use the depiction of the regime level of the multi level perspective in order to see all the different and relevant aspects asked to be taken into account in decision making processes. Transition management approach gives also understanding of the transition process itself, which is needed in achieving the change; namely describing how the regime level is changed.

Another constituent of the ATEsT framework is its relation to governance. Governance can be understood as a mode of social coordination. The standard Guidance on social responsibility (ISO 26000) defines governance as the system by which an organization makes and implements decisions in pursuit of its objectives. Central to the concept of governance is that it involves not only formal governance mechanisms based on defined structures and processes, but also informal mechanisms that emerge in connection with organizations culture and values.

Governance structures organise negotiation processes, determine objectives, influence motivations, set standards, perform allocation functions, monitor compliance, impose penalties, initiate and/or reduce conflict, and resolve disputes among actors. The notion of governance fits in with complex systems approaches, as it understands that power is distributed among actors, and the effective exercise of power is through a network of interconnected actors (Kemp et.al. 2005). Therefore, it is important to note that governance also involves conflicting interests and struggle for dominance (Voß & Kemp 2006).

Even if governance deals with informal mechanisms and interaction, it contains also normative aspects. A notion of “good governance” entails an idea of certain kind of governance which guarantees effective, equitable and sustainable mode of operation. For example, **the European Commission (European Commission 2001) defines the principles of good governance, which are openness, participation, accountability, effectiveness and coherence**. These principles should also be considered in future energy and climate policy making to increase common understanding, ensure public and private acceptance and thereby effective implementation.

Besides normative determination, governance can be evaluated based on its outcomes. A starting point for this evaluation is a view that modern societies grow in cycles of producing problems and solutions to these problems that produce new problems (see Figure 2). To break this cycle, alternative methods and processes of problem handling are needed. These alternative processes should be more open, experimental and learning oriented. Reflexive governance is a conception which aims to address this challenge. It refers to modes of governance that pay attention to system-wide effects of particular development processes and try to limit negative long-term effects in the pursuit of goals.

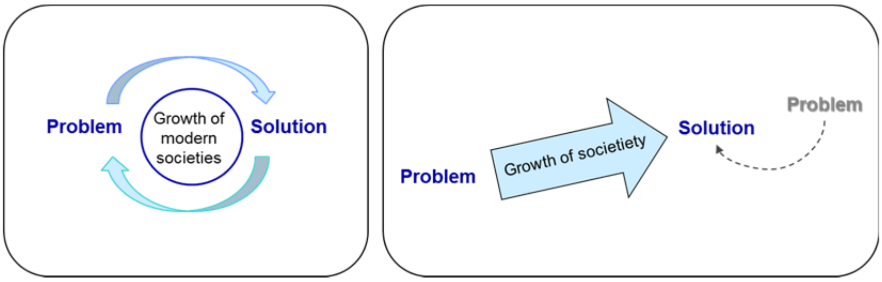

Figure 2 The cycle of governance (left). Reflexive governance attempts to break the cycle of continuous problems and solutions by reflecting the possible problems caused by the solution.

Systemic transitions and the pursuit of goals require system analysis, goal definition and strategy implementation to achieve the goals. Voß and Kemp (2006) argue that sustainable development has specific features that make these activities difficult, and from these difficulties they have derived strategy requirements for reflexive governance. The complexity of sustainable development requires *integrated transdisciplinary knowledge production*, *adaptivity of strategies and institutions*, and *anticipation of the long-term systemic effects of action strategies*. One way to meet these requirements is modelling, as it can be used to anticipate the long-term effects and risks of action strategies. However, the requirement of systemic approach makes demands on the profoundness of modelling; and especially in the case of socio-technological systems, it is important to apply transdisciplinary approaches. The country studies shown in the Chapter 2 and in the Appendix revealed that national decision making may be supported with one or two energy system and/or macro-economic models. As a result, socio-technological systems are usually poorly covered in policy analysis.

In relation to goal formulation, reflexive governance requires *iterative participatory approaches*. Sustainable goals involve risk assessment and tradeoffs of values that cannot be decided scientifically, but through social discourse or political decisions. Therefore, goals need to be revised regularly to adapt them to changing values and perception of problems. The last requirement of reflexive governance is *interactive strategy development*. This is necessary, because the collective transformation strategy is composed of diverse actions of relevant stakeholders. These stakeholders, and their know-how and resources, need to be integrated in the strategy development to assure their support for strategy implementation.

The principles of reflexive governance act as a reference point for the ATEsT framework development. Especially, the division of governance process into system analysis, goal formulation and strategy implementation is applied into the framework, which is presented in the next subsection.

3.2 ATEsT Framework

Figure 5 illustrates the ATEsT framework. The depiction of the regime level of the system is put in the governance context covering the phases of Goal formulation, System analysis and Strategy implementation. The regime level consists of institutional factors, behavioural aspects and energy infrastructure. This is the system description.

In the Goal formulation phase, the targets of the transition process are defined. The System analysis phase constructs the actions needed, and the Strategy implementation phase conducts into actual transformations. The whole process is continuous cycle referring to each other's. In the transformation process, the system (*regime level*) is changed in this adaptive governance cycle; based on the decisions made in the process.

In the ATEsT context the focus is put on the models and tools used to take into account different aspects of the regime level/the system in the different phases of the governance cycle in the transition of the low carbon society.

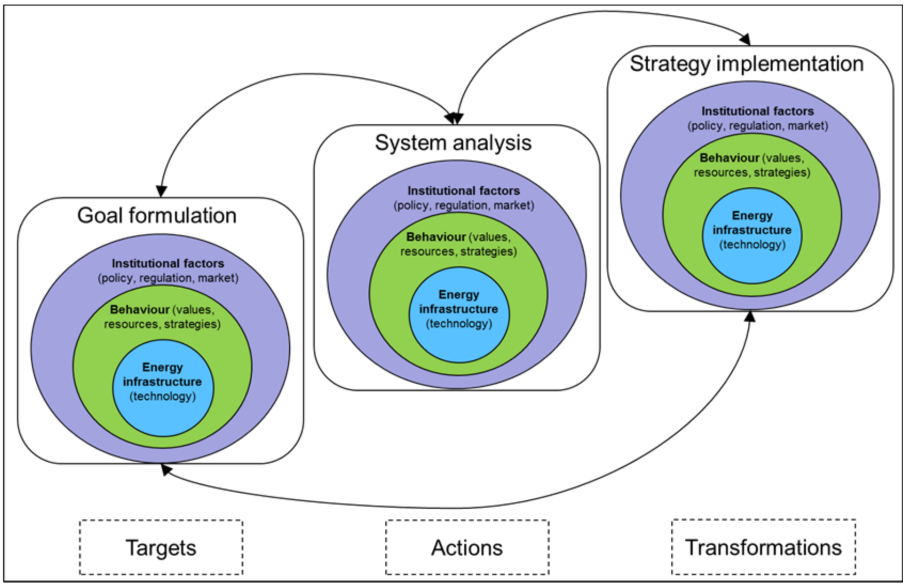

Figure 3 Illustration of the ATEsT framework.

For the purposes of the ATEsT project, it is useful to present the framework in a table format (see Table 1). This table can be used to present the models and tools that were evaluated in the WP2 of the project in the country studies. A color coding is added so that it is easy to recognize the gaps in models and methodologies development. Green color means that the area is well covered with several tools or models, yellow refers to moderate coverage with some deficiencies, orange to coverage with serious deficiencies, and red refers to areas that are not covered at all.

Table 1 ATEsT framework in a table format.

	Energy infrastructure	**Behaviour**	**Institutional factors**	
			R&D policy	Sector
Goal formulation				
System analysis				
Strategy implementation				

Well covered with several tools — No tools

In the following chapter the results of ATEsT WP2 and country studies are analysed using the framework presented above.

4. Identification of gaps in the tools and methodology development

In this section, we present the results of the analysis identifying the gaps in tools and methodology development. The first section summarizes the gaps identified in the earlier workpackages of the ATEsT project (WP2-WP5), including a brief discussion of the methodology applied in the project. The second section presents the findings of the analysis applying the ATEsT framework that was presented in the previous chapter. However, it should be noted that the findings are not necessarily complete as there may be some models or tools available, which were not identified during the ATEsT project, and which might partly cover the identified gaps.

4.1 Specific gaps identified in WP2-WP5

An inventory of existing energy system models and tools was done in ATEsT WP2 (Amerighi et al. 2010). In particular, it was examined how well the models and tools covered the specifications listed in WP1 (Schoots & Bunzeck, 2010). The detailed assessment - with the help of two matrices specifically constructed for the purpose – gave an overview of aspects covered by the existing models and tools and also pointed out areas where further development is needed. The conclusions reported by ATEsT WP2 include the following notions on coverage and development needs (see Amerighi et al, 2010 for a more detailed account):

Issues related to ‘Strategic Planning’

Major part of the ‘strategic planning’ specifications are well addressed (a long list of models having this as primary focus of analysis). This holds for “General specifications” concerning the resilience of the energy system against different sources of shocks, as well as for specifications related to “Technology performance and development potential”. Specifications under the heading “Policy indicators” (except for LCA analyses) are well covered too. On the other hand, there seems to be lack of models designed to investigate the possible “Bottlenecks to technology deployment” (only one of the assessed models directly addresses this type of problems). Although there exist models that take somehow into account constraints to technology penetration and diffusion, a more accurate coverage of this specification would be needed. This also implies deeper analysis of production chains for technologies under consideration.

Issues related to 'Technology Deployment and Transition Planning'

Most of the 'technology deployment and transition planning' specifications are appropriately covered by different types of models. 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. There also seems to be a lack of systemic approaches at the local level and a poor interrelation between technical and behavioural issues. Further research and development is thus needed to tackle the policy questions that address the above-mentioned areas with new types of models and tools. The same holds for some other specifications – for instance "Timing" specifications - that are not covered by the models identified in WP2, or are covered just by means of qualitative tools. Similarly, some "Acceptance/perception of a technology" specifications are not satisfactorily addressed by existing models (lack of appropriate level spatial and sector detail and specificity of issues were identified as a reason behind).

Issues related to 'Innovation and R&D'

Most of the specifications related to "innovation" specifications are well covered. On the other hand, "R&D" issues are still a challenge for modellers and scientific community. For instance, "risks involved in research activities" can be assessed only with the help of qualitative methods. Moreover, there is a lack of useful models designed to deal with technology specific R&D targets and monitoring of the effect of funding mechanisms in bringing emerging technologies to the market. The issue of R&D spending needed for becoming/staying competitive with non-EU countries cannot be addressed by existing models either (intrinsic uncertainties related to R&D makes forecasting difficult). Addressing R&D specifications with modelling tools is noted as a challenge more generally too (data availability, methodological restrictions, feedback loops and spill over are mentioned as reasons behind).

Issues related to International Cooperation

Some general specifications on "potentials of JI and CDM" are appropriately covered by existing models. On the other hand, issues related to "international cooperation on technology deployment" are covered only by a few models, which might indicate a need for further model and tool development. The most evident deficiencies lie, however, 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 under this topic can be investigated only by means of qualitative tools (intrinsic uncertainty in R&D activities and the difficulty in finding appropriate ways to measure the effectiveness of international cooperation initiatives are mentioned as reasons behind). Complementary modelling work is, however, suggested to tackle the questions related to these specifications more accurately.

The complex issue of selecting the most appropriate toolbox for answering policy questions related to the implementation of the SET-Plan, was addressed in ATEsT WP3 (see Giannakidis & Nakos, 2011). The aim was to give guidelines for choosing best available sets of models and tools for specific policy questions that need to be answered. The guided procedure based on project partners' subjective model ranking and subjective assessment of the importance of specifications for the selected policy questions. The process was organised so that each model and tool was independently evaluated by two project partners and consensus was sought after comparing the rankings and assessments. Top ten combinations and the frequency of appearance of each model in the top 200 combinations were reported as results of the process, assuming that this gives an indication of models suitable for answering the policy questions considered. The combination of models was limited to 6 as combining a higher number of models would probably be too complicated in practice. The ways in which the proposed models and tools can or should be combined was, however, not considered in the procedure. Possible and preferred ways of combining models and tools was illustrated in WP5 in one example, but more deep assessment remains thus a task of further research.

The objective of ATEsT WP4 was, in turn, to analyse and evaluate the data and/or qualitative information that are currently in use in different models and tools (Kuder & Blesl, 2011). Needs for additional data and information were also pointed out for the purposes of improving the performance of existing models and tools and to guide their further development, as well as development of new models and tools. The dependence of proper models and tools of policy questions considered is underlined, pointing out that each model and tool type employs also different ways of generating the required information. Availability of high-quality and relevant information are seen as key issues for future development of models and tools. The need for detailed data (i.e. higher time and geographical resolutions), data consistency and comparability of databases among countries, regions and sectors are seen to be key issues for model development. On the other hand, depth of information and context-specific understanding may be even more important when changes in behaviour are strived for (this issue relates especially to the use and development of qualitative tools).

Kuder and Blesl (2011) define different model families for which data assessment was conducted (see Table 2). The model family/type determines the data which are used. In the report, both existing data and additional data needs are analysed in detail by model family. Table 3 and Table 4 below summarize the main findings.

Table 2. Data characteristics by model family (Kuder & Blesl 2011)

Model Family	Data characteristics
Energy System	• Detailed data for energy supply and demand sectors
Macroeconomic	• Highly aggregated macroeconomic information
Sector Level	• Detailed data on one specific issue/ sector
Disaggregated	• Detailed data on a specific part of the energy system
Energy Behaviour	• Mainly context-specific qualitative and semi-qualitative

Table 3. Weak points by model family (Kuder & Blesl 2011)

Model Family	Weak points of existing data
Energy System	• Difficult to get data in the same quality for all regions • Different accounting methods in different regions and inconsistencies • Differentiation between conversion and industrial sector • Interpretation of values for specific consumption • Price of access to data • Forecast data (no detailed years given) about technological parameters
Macroeconomic	• Cost for data (GTAP database) • Low frequency and significant time lags •Limited availability of data on specific taxes, subsidies and transfers part. in the energy environment area. • Poor representation of technologies and preferences in substitution elasticities
Sector Level	• Missing updates for some sectors of the reference data
Disaggregated	• Difficult to get all necessary data about existing power plants due to confidential reasons • Data for renewables have to be more frequently updated and must refer to the actual technologies • Due to the use of very detailed and specific data, the model can't be easily adopted for another country
Energy Behaviour	• Data quality strongly depends on involved stakeholders and their commitments and therewith the quality varies by context • Data from different contexts usually not comparable • Some up-to-date information may be confidential or not publicly available

Table 4. Additional data requirements by model family (Kuder & Blesl 2011)

Model Family	Additional data requirements
Energy System	• Data about the stock of technologies which are currently in use • Costs data for new technologies • Data about buildings like number of floors, age structure or reconstruction information • Load curve data for different commodities and sectors • Trade-flows of semi-finished goods and specific energy consumption to produce the goods to compare semi-sector energy consumption across Europe. • Data on recycling potentials • Transport data • Information about behaviour in end-use sectors • Data on useful energy (e.g. process heat, cooling, compressed air in the industrial sector).
Macroeconomic	• Worldwide consistent national Social-Accounting-Matrices with direct connection to Physical-Input-Output-Tables • Data on useful energy production in households, data on durable goods. • Inclusion of durable goods in National Accounts • More profound behavioural and technology information
Sector Level	• Reference values for the single sectors to evaluate efficiency measures have to be updated • Adding data for new technologies and measures
Disaggregated	• Information about the thermal vs. electric generating performance of thermal plants • Forecasting of load duration curves and demand evolution • Data for increasing RES integration and electricity storage (amount of reserve requirements) • Geographically varied, household specific electricity demand load curves. • Information about demand-price relationships and public acceptability
Energy Behaviour	• New and context-specific information sources are needed for specific energy projects • Establish a “case library” (project documentation) to learn from previous projects • Carbon footprint data: life cycle assessment of specific products/services at brand level. • In a new process always the relevant various stakeholders and their experiences, interests and expectations have to be considered

In WP5 a proposed linking scheme was presented showing possible interactions between models that focus on different parts of the energy system and use different methodologies (it was not possible to perform an actual linking exercise, since an extension of some of the models is necessary to cover the whole of the EU). Efforts were concentrated in new types of linking (for instance CGE or MGM models were not included because this type of work has been already performed successfully in the past). It was also noted that efforts of hard linking more than two models are in practice rare due to issues related to the time and spatial resolution of the models and their ownership. The authors also suggest that including other types of models in the linking procedure, should be examined as well (agent based models or models that focus on reproducing behaviours of agents in the energy system under the principles of the game theory are mentioned as examples), although linking would then become even more demanding. The option should be thus be thoroughly investigated in future research. A main conclusions of the analysis of WP4 and WP5 is that a common database is necessary, to ensure a consistent input to all models.

4.1.1 Discussion on the impacts of research methodology

In ATEsT WP2-WP5 the models and tools – and the combinations of models and tools - were primarily assessed to demonstrate some useful procedures and methodologies for their proper selection and appropriate combination. The emphasis of this demonstration was in analytic models and tools that contribute to selected predefined policy questions that were linked to predefined specifications by the project team. In reality, there exist an unlimited number of relevant policy questions, among them also questions that focus on the ways in which key-actors' behavior, attitudes and acceptance can be influenced (limited attention has so far been paid to this type of contribution). It is thus good to keep in mind that new types of policy questions – linked to other types of specifications - may emerge. This emphasizes the need for further work in figuring out reasonable and useful ways of combining models and tools.

The case reports of a number of EU countries (see Appendix A2) and experience of the partners from other projects also shows that each country has its own "traditions" and models for evaluating policy questions, and it is quite challenging to move to another type of models and approaches. This should be taken into account when deciding about the modelling approaches for each country. It should also be kept in mind that the model rankings and assessments in ATEsT WP2-WP4 refer to the state of the models in September 2010. An update of the situation is needed to guarantee that most recent developments are taken into account.

4.2 Gaps revealed by the ATEsT framework

The ATEsT framework presented in the Chapter 3 has been used to identify the gaps in tools and methodologies used today to support decision making. The results of WP2 were used to identify the gaps in modelling especially. In addition, methodologies, tools and other evaluation frameworks not listed in the WP2 report have been added based on the information received from the project partners. In

Table 5 and Table 6 the results of the evaluation are shown. The colors used in different cells are explained in the chapter 3.2 but it should be noted, that there might be some models and tools developed, which could partly cover the gaps (i.e. see the cells with orange and red colours especially) but which were not identified in the ATEsT project.

Table 5. Existing models, tools and methodologies.

	Energy infrastucture	**Behaviour**	**Institutional factors**	
			R&D policy	Sector
Goal formulation	Energy System Models, Macroeconomic Models	Energy Behaviour Tools, Public Awareness and Accepability Tools	Steering groups, Expert groups, Funding organisations	Sector level models
System analysis	Energy System Models Sector Level Models Disaggregated Models	Impacts modelling for policy and strategic analysis	Learning curves*	
Strategy implemantation	Macroeconomic Models	Energy behaviour tools	Technology and industrial platforms, Research alliances, Networks	Energy behaviour tools, Institutional changes e.g. in market design

*Learning curves are not models but they may be implemented in the energy system and other integrated assessment models

Table 6. Examples of models, tools and methodologies used to today.

	Energy infrastructure	Behaviour	Institutional factors	
			R&D policy	Sector
Goal formulation	TIMES, MARKAL, POLES, PRIMES / GTAP-E, GEM-E3	Energy Behaviour Tools, Public Awareness and Accepability Tools	SET Plan Steering Group	Sector level models
System analysis	TIMES, MARKAL, POLES, PRIMES / GASMOD, OILMOD/ BALMOREL, WILMAR	Distibutional Impacts Model for Policy and Strategic Analysis	Implementation of Two Factor Learning curves*	
Strategy implamantation	GTAP-E, GEM-E3	ClimateBonus, MECHanisms, Acceptability?	Technology platforms, Industry Initiatives, EU Programs EERA	ESTEEM, Institutional changes?

*Learning curves are not models but they may be implemented in the energy system and other integrated assessment models

It is clearly seen that most of the existing tools and methodologies are focused on quantitatively analysing the development of energy infrastructures on different levels, i.e. during goal formulation, system analysis and strategy implementation. There is a very good selection of bottom-up energy system and top-down macroeconomic models, but also energy market and infrastructure models are used today to support decision making. On the other hand, tools and methods focused on analysing the behaviour of consumers and investors are moderately or relatively poorly covered, but the area that includes the most serious deficiencies in existing tools and methodologies is the analysis of institutional factors.

Modelling and analysis of the impacts of R&D polcies was identified as a major gap in exsisting analysis methodologies to support SET-Plan implementation. For example, learning curves are not a systems analysis model as such but learning curves my be implemented in these models. The two-factor learning curves at least account for some impact of R&D policy, but they still not cover the institutional factors around (market) development of new technologies. In addition, learning curves only cover costs of a technology that is already deployed, not the effectiveness of R&D policies in supporting the development of e.g. radical innovations and bringing new technologies to the market, i.e the institutional factors around innovation. For example, the implementation of two factor learning curves to analyse the impacts of R&D on technology development and investments would require technology specific data, which might not be publicly available or does not exist because of very early stage of development.

On the other hand, several tools exist to inform consumers of their carbon footprint but there does not exist any common database for the carbon footprints of different products, and the calculators are often built by companies or organisations to support their own interests. However, could also conclude that the implementation of the SET-Plan has been facilitated by several frameworks, programs, networks, and other mechanisms, which is an unique situation in the EU's innovation system. As an example, we could mention EERA (European Energy Research Alliance), Technology Platforms, and Industrial Initiatives, which key objective is to accelerate the development and implementation of new technologies. Under the Joint Programmes of EERA, public research centres and universities are collaborating while Technology Platforms and Industrial Initiatives put together European industries.

5. Roadmaps for tools and methods development

Another objective of the ATEsT project was to develop a a roadmap for tools development necessary to model the evolution of the European low carbon energy systems. Results of the roadmap developing work are presented in this chapter

5.1 ATEsT roadmap process

Roadmapping is a method which outlines the future of a field of technology (Georghiuou et. al 2008). In the ATEsT project, and most often in also other roadmap processes, the technique is applied through a combination of group- and desk-work. The process requires inputs from people with deep knowledge about the focus area. The core idea is to formulate future actions (step by step path) in order to attain the wanted future (vision).

The ATEsT Roadmap work was carried out in five different phases:

1. Preparation of a roadmap template.
2. Generation of roadmap content in internal workshops by each ATEsT partners.
3. Prioritization of roadmap content in a video conference by all ATEsT partners.
4. Composition of the roadmaps by VTT project group.
5. Commenting and edition of the roadmaps in a workshop organized in ATEsT final conference.

The process started with the selection and preparation of a roadmap template, based on the roadmap template developed and used in previous roadmap processes at VTT (see Figure 4). This template is a visualisation of roadmap including megatrends and drivers, challenges and policies, technologies, systems and consumer behaviour (market trends), model and tools development (solutions), and actions in a time span of 10 years ahead. The idea of such a visual roadmap is to ensure that all the important different aspects are taken into account in the scrutiny.

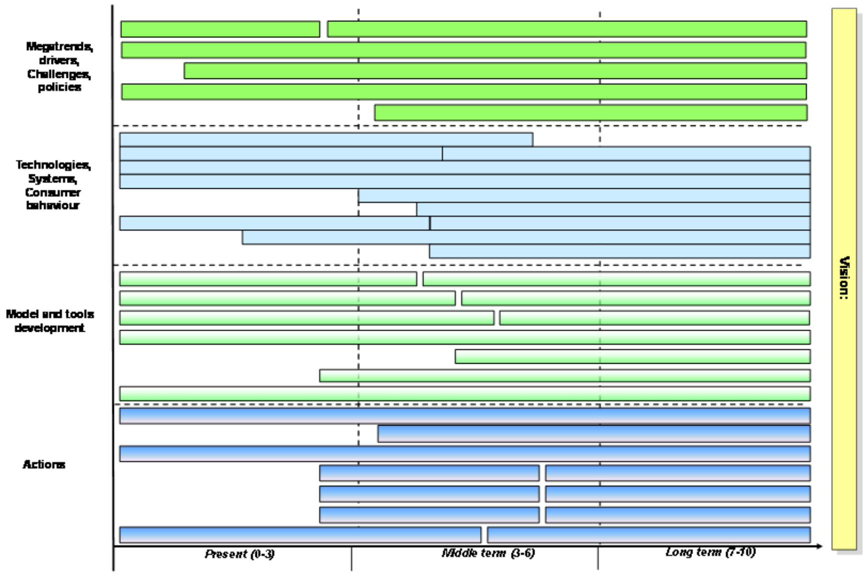

Figure 4 The roadmap template used in ATEsT project.

The vision statement is a crucial part of a roadmap as it defines the goal for the activities described in the process. For the ATEsT roadmap the vision was derived from the project plan and it was edited during the working process. The final formulation of the vision statement is as follows:

- **Advanced models and methodologies to support decision making related to SET-Plan implementation**

The roadmap template used in the ATEsT project has four different layers. The top layer describes the drivers and challenges at the global and EU level. The next layer emphasizes the technological development, infrastructures and the behaviour of consumers and investors affecting the models and methodologies development. The third layer shows the expectations of the model development. The last layer of the roadmap addresses the actions needed in order to achieve the vision taking into account the development that were identified in the upper layers of the roadmap.

The content for the roadmaps was generated in internal workshops by the project partners. The work was based on a formal exercise, which is shown in Appendix B. VTT project team collected the answers and they were further processed in a video conference between ATEsT partners. The task of the video conference was to prioritize the content of the roadmaps, meaning the trends, technologies, model development activities and actions that were generated by the project partners earlier. The results of the video conference were then used as a starting point for the composition of the visual roadmaps, which was done by the VTT project group. At this point, it was evident that there were so much content generated in the process that it was not possible to include everything in a single roadmap. Therefore, the content was divided into two separate roadmaps that address the development from a) **technoeconomic** and b) **socioeconomic** viewpoints. The content of these two roadmaps is discussed in detail in the following subsections.

The final step of the roadmap process was to finalise the visual roadmaps together with the participants of the final ATEsT workshop in Brussels in 26 March 2012. Comments and suggestions for the final edition of the roadmaps were collected with a short questionnaire which is in Appendix B.

5.2 Technoeconomic roadmap

Figure 5 shows the Technoeconomic roadmap. The content of the roadmap is discussed in detail in the following subsections.

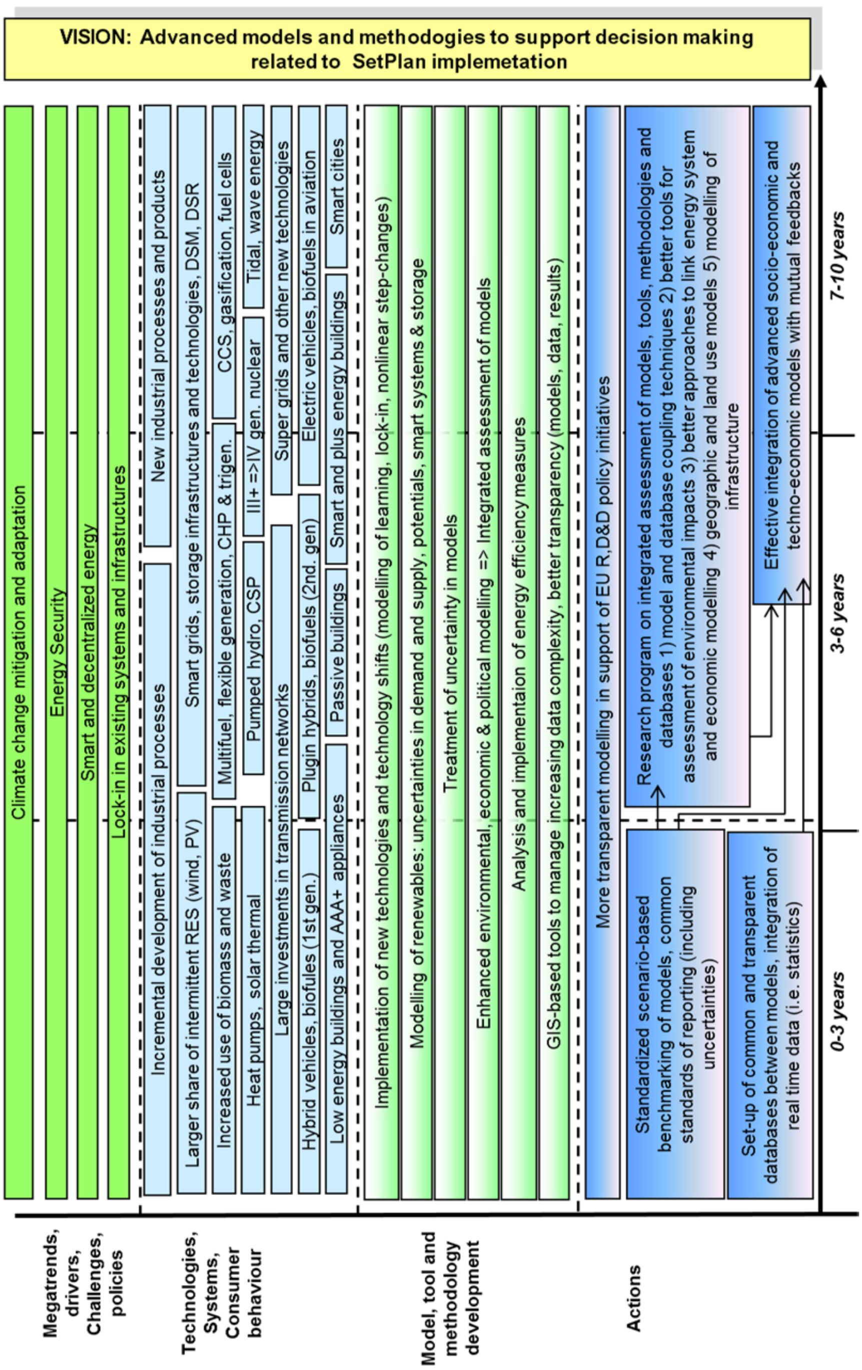

Figure 5 The technoeconomic roadmap.

5.2.1 Megatrends, drivers and challenges

In the techno-economic roadmap, four major mega drivers and challenges were identified, which would have a great impact on low carbon future energy systems. These include climate change mitigation and adaptation, development and implementation of smart and decentralized energy, energy security, and lock-in existing systems and infrastructures. The lock-in challenge was initially put under the second level, i.e. under the technologies and systems level, but in the final roadmap, it was considered more as a driver than a technology challenge. Figure 6 and Figure 7 show the composition of the trends in the technoeconomic roadmap for the three major drivers.

The drivers labeled under the climate change mitigation and adaptation include future policies and thereby increasing emission allowance prices, changes in the resource availability due to either mitigation or climate change (i.e. water, nutrients, land area), and greenhouse gas emissions due to land use changes and deforestation. Also, the overall megatrend to increase energy efficiency is shown in this context even though it might occur under the other major drivers as well.

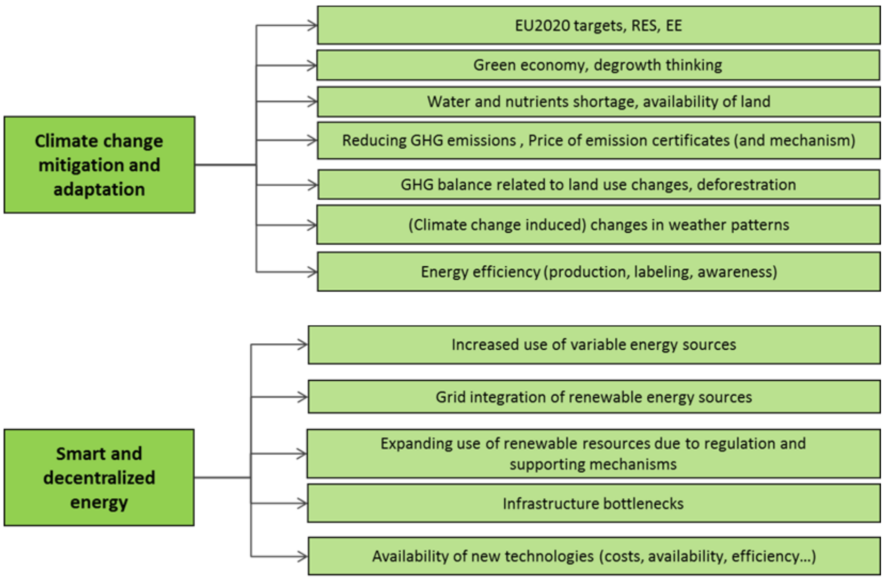

Figure 6 Composition of trends concerning climate change and smart energy systems.

The composition of smart and decentralized energy is more technology oriented. In fact, also this was labelled under the technology level in the first phase but changed to as a mega driver in the final roadmap. The composition of the energy security includes both long term energy security aspects and short term aspects concerning the security of supply. Resource availability and fuel prices, increasing share of variable energy production, and phasing out of nuclear were considered important in this context, as an example.

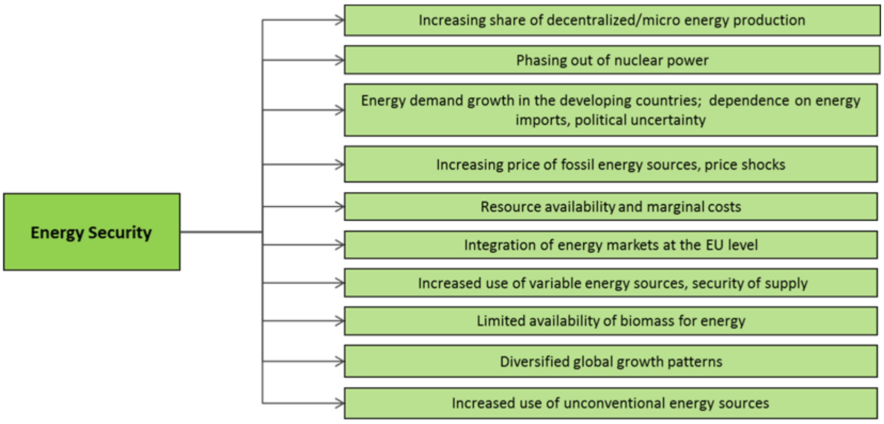

Figure 7 Composition of trend concerning energy security.

5.2.2 Technologies, systems and consumer behaviour

The transition to low carbon energy system requires the development and implementation of new technologies for the whole energy chain. The technoeconomic roadmap shows examples of needed changes in energy technologies and systems, which should be considered in the future analysis and modelling. Increased use of variable and distributed renewable energy production (e.g. wind, solar) would require implementation of smart grids, energy storages, demand side management (DSM) as well as demand supply management (DSR). In addition to increased renewable energy production, the energy generation plants should be more flexible utilising different low grade fuels and producing combined heat, power and maybe cooling energy as well. In the longer term, new technologies, like gasification, fuel cells, new nuclear, ocean energy, etc. would penetrate in the markets. Cost effective mitigation would also require carbon capture and storage (CCS) investments in fossil fuel generation, large bioenergy plants, and in industrial processes.

Transition to low carbon energy systems would also require radical changes in energy infrastructures and in all energy end use sectors. Integration of electricity markets, ageing of old infrastructures, and effective integration of renewable electricity would require large infrastructure investments, which should be taken into account in modelling of future energy systems. Also, implementation of new technologies, like super grids, could enable electricity transmission with large distances.

New technologies and systems would also be needed in all the energy end use sectors. In industrial processes an incremental development in energy and resource efficiencies as well as emission reduction would be required. In the longer term, transition to new industrial processes and production of new products should be considered also. New energy efficient technologies and new fuels should be implemented in transportation and housing, like electric vehicles and plus energy buildings. A vision for the future is to move to not only smart grids but also towards smart energy buildings, smart transportation, and even smart cities. The challenge is, how to model these new smart systems.

5.2.3 Model, tool and methodology development

Because the transition of low carbon energy systems would require implementation of wide mix of new technologies and systems, and also renewal of the whole energy system, several new challenges should be considered in tomorrow's modelling and analysis. Based on roadmap exercises and teleconference carried out by ATEsT project partners, six major development needs were identified:

- Modelling of the implementation of new technologies and technology shifts, especially modelling of technology learning, lock-in in old and possible new systems, and non-linear step-changes.
- Modelling of renewables to include uncertainties in demand and supply, smart systems, and storage. Also assessments of technical potentials of renewable energy sources are a challenge.
- Overall treatment of uncertainty in models as energy and climate change mitigation cannot be considered a "single issues" any longer but a larger system issue. In the modelling the uncertainties in the development of technologies, infrastructures, economies, policies, societies and democraphies should be included. Also, availability and price of energy resources, food, water and minerals as well as aspects related to biodiversity issues and terrestrial ecosystems increase the uncertainty in many respects.
- Integrated assessment of models to enhance environmental, economic and political modelling (see also the above bullet), which was considered very important even though there have been several attempts to either soft- of hard-link different models, where the latter refers to full integration of the models. In the final workshop, it was raised that the added value of model integration should be carefully considered, as usually requires a lot of time (both creating and running the models) and thereby money.
- Analysis and implementation of energy efficiency measures. In the existing models and tools, energy efficiency might be relatively poorly modelled and there are also bottle necks in analysing methodologies. Energy efficiency should be assessed across the whole energy chain with a numerous options. On the other hand, optimisation models

foresee very optimistic energy efficiency improvements compared to the real world.

- GIS-based tools to manage increasing data complexity. Also better transparency of models, data, and modelling results would be needed.

5.2.4 Actions

The issues presented above were finally formulated as concrete actions. Two short term (0-3 years) and two longer term (>3 years) actions were suggested as the most important ones. In addition, increasing the transparency in supporting of the EU RD&D policy initiatives was suggested as an overall action related to all the other actions as well. In the ATEsT final workshop it was recommended to start with improving the tools, methodologies, and data by:

1. Standardized scenario-based benchmarking of models, common standards of reporting (including uncertainties).
2. Set-up of common and transparent databases between models, integration of real time data (i.e. statistics).

After the benchmarking of models, it was recommended to set up a larger research program related to integrated assessment of models (IAM), tools, etc., which could include several important objectives:

3. Research program on integrated assessment of models, tools, methodologies, and databases:
    a. model and database coupling techniques
    b. better tools for assessment of environmental impacts
    c. better approaches to link energy system and economic modelling
    d. geographic and land use models
    e. modelling of infrastructures

The final step, where the results of all the above projects and/or programs would be:

4. Effective integration of advanced socio-economic and techno-economic models with mutual feedbacks.

5.3 Socio-economic roadmap

Figure 8 Shows the Socioeconomic roadmap. The content of the roadmap is discussed in detail in the following subsections.

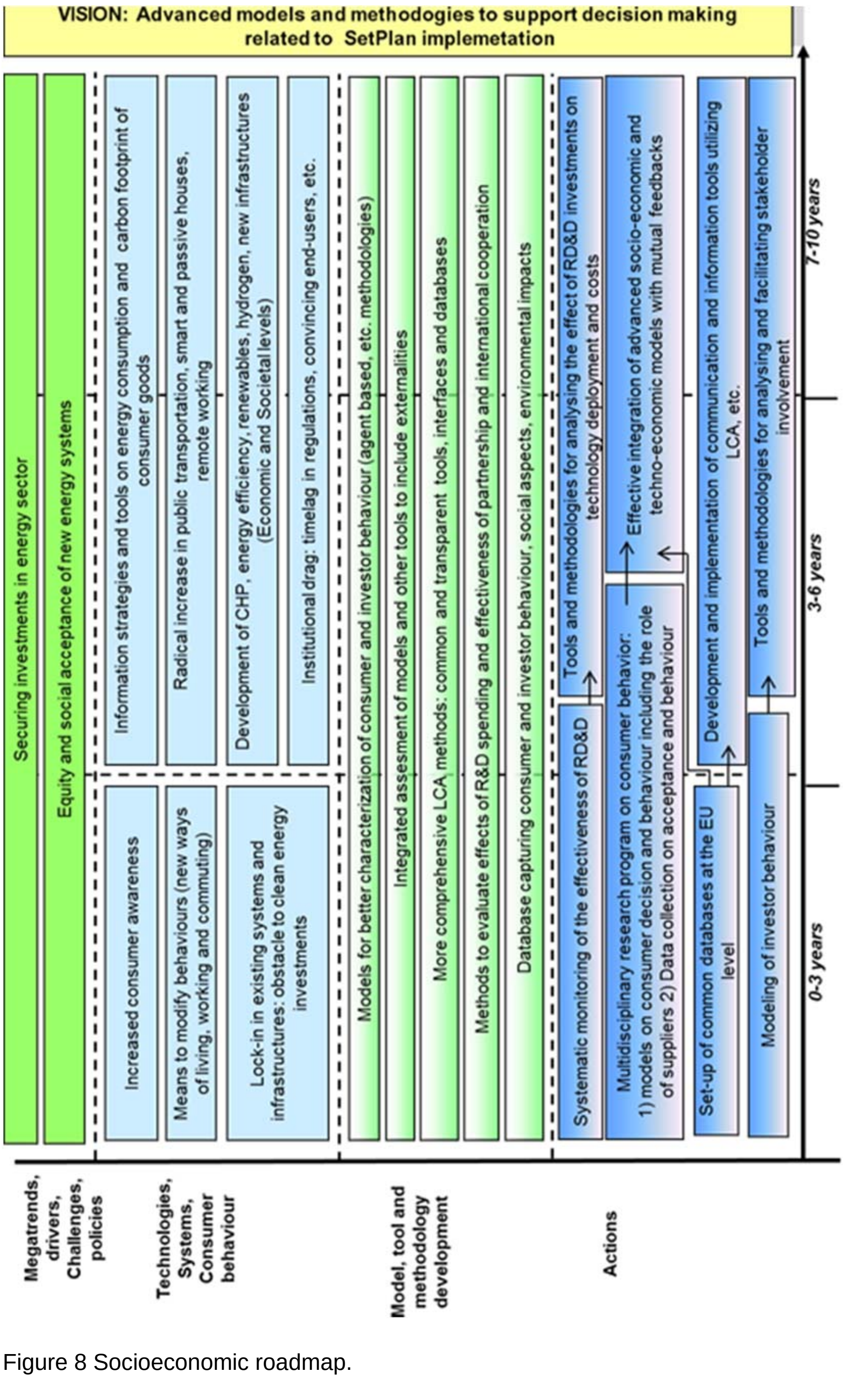

Figure 8 Socioeconomic roadmap.

5.3.1 Megatrends, drivers and challenges

Figure 9 shows the composition of trends and drivers in the socioeconomic roadmap. Two major perspectives, i.e. securing investments in energy sector as well as equity and social acceptance of different energy technologies, were seen the strongest drivers in the socio-economic development. The debt crisis in the euro area is challenging. At the same time electricity infrastructure is largely ageing in the Europe; expensive reconstruction is demanded. On the other hand, energy markets are rapidly integrated at the EU level, whilst at the same time privatization and deregulation are battling with the national interests related to industries and grids. The affordability of reasonable energy price to everybody in the world causes also economic challenges.

In addition as well as the fact that the availability of new reasonable technologies is not a fixed; results of the R&D investments in energy technologies are not guaranteed. The acceptance and embedding of new innovations/technologies into the society may cause unforeseeable surprises. It is also important to keep in mind that acceptance and behaviour do not always go hand in hand, but cultural and country specific aspects, and also timing drive the actions, e.g. although acceptance is high, in economic crisis no-one will invest in electric cars or hydrogen technology etc.

Very strong drivers consist also around environmental question, which drive the development towards renewable energy sources and technology. Besides the SET-Plan implementation, also the carbon certificate mechanism drives the system into this direction. This development creates challenges to the grid integration and infrastructure bottlenecks, e.g. efficient wind power utilisation. Increasing trend phasing out of nuclear power is connected to the increased environmental awareness and safety questions hence low carbon efforts on the other hand favour nuclear power. Phasing out of nuclear power increases the stress of renewable resource and technology availability, if the usage of fossil fuels really is decreased. The amount and depth of conflicts between the usage of renewable energy sources and ecosystem services are about to grow.

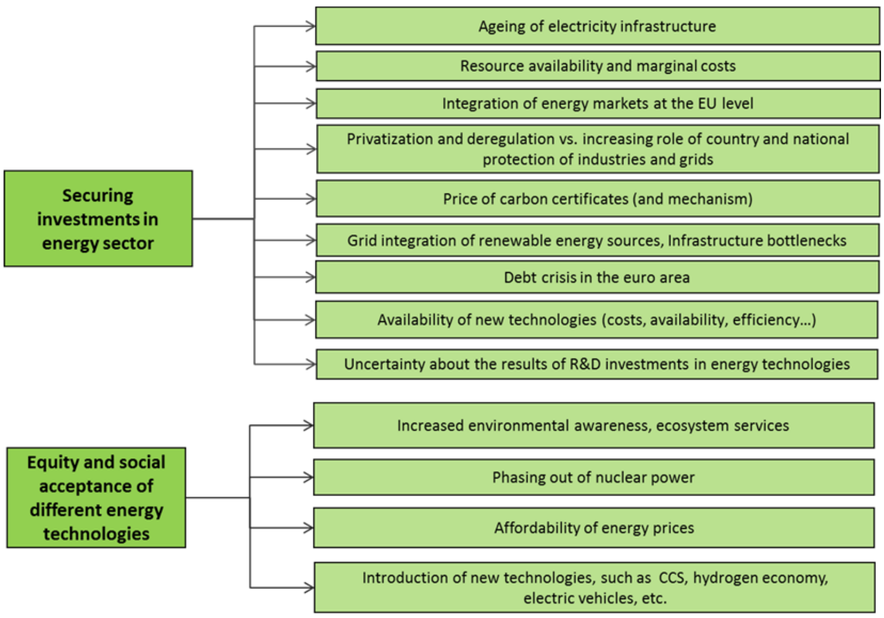

Figure 9 Composition of the trends and drivers in the socioeconomic roadmap.

5.3.2 Technologies, systems and consumer behaviour

In the modern information society people are increasingly aware of different things; for instance environmental awareness or safety issues direct consumers' behaviour. Hence, information strategies and tools on also energy consumption and carbon footprint are increasingly asked. People want to have technologies and systems intend to tell them facts about their energy consumption or carbon footprint, and also societies in general demand this knowledge in various kinds of activities, e.g. energy consumption of houses.

New ways of living, working and commuting, for instance avoiding of personal vehicles because of various reasons, is about to increase radically public transport. Remote working, on the other hand, changes the housing habits, e.g. people can more easily live in the country side. Smart and passive houses, smart grids etc. will make energy efficient behaviour easier and at the same time change radically the behaviour of people.

Existing technological systems (*regime*) construct often lock-in into the system which creates obstacles to the system development, e.g. obstacles to clean energy investments. That is why for instance CHP, energy efficiency, renewables, hydrogen and other technologies cannot develop either in technological nor in economic and societal levels. Often there exists an institutional drag which means that regulations do not follow the rapid development, hence society is not ready for new innovations. Also, consumers' attitudes and believes do not follow the rapid development; consumers are not convinced in the capabilities of the new innovations and technologies, they do not believe in new technologies and hesitate to use them.

5.3.3 Model, tool and methodology development

This level of the roadmap introduces the potential solutions for the chances shown above. In order to reveal more effective the consumer behaviour and its meaning to the energy system and the SET-Plan, models for better characterization of consumer and investor behaviour (agent based, etc. methodologies) are needed. In this context also databases capturing consumer and investor behaviour are seen important. Databases will help also in capturing the knowledge in social aspects and environmental impacts. In addition more comprehensive LCA methods including common and transparent tools, interfaces and databases are welcome.

This roadmap process emphasises also the relevance of integrated assessment of models and other tools in order to include externalities. Tools and methodologies focused on analysing the effectiveness of RD&D policies and institutional factors are nearby missing. On the other hand, energy system modelling barely takes these issues into account. Therefore methods to evaluate effects of R&D spending and effectiveness of policies, partnerships and international cooperation are momentous.

5.3.4 Actions

Referring to the issues and stories above, in order to gain development in decision making in implementing the EU Set-plan by modelling and tools, according to this roadmap process, actions needed are as follows:

- monitor systematically the effectiveness of RD&D policies (include both ex-ante & ex-post analysis)
- highlight the major issues, which have a direct impact on SET-Plan implementation
- create tools to analyse the R&D spending and innovation systems, consumer behaviour & market agents
- implement the tools and methodologies for stakeholder involvement
- integrate the outputs of socioeconomic actions in decision-making via techno-economic models, via feedback between techno-economic and socioeconomic models, or directly in the policymaking process via some other way

The most important emphasised action line is the development of tools to investigate the effects of RD&D policies by systematic modelling, and systematic monitoring of the effectiveness of RD&D policies in commercialising new and emerging technologies. Actions in this direction should focus on helping to understand the direct impact of the SET-Plan, the EU RD&D programmes, and cost benefits of the technologies to be implemented & deployed.

Another important issue is the integration of socioeconomic and techno-economic models and methodologies. The roadmap process emphasises the significance of consumer and investor behaviour models, which enable integration of social aspects into the modelling and decision making processes. The prime modelling technique to address these issues is agent based modelling, where behavioural issues can be represented in a more strict scientific/mathematical way.

To support policy makers in designing effective policies to embed innovations, technologies and behaviour of decision makers (i.e. consumers, investors, etc.) in society, we need to better understand the institutional factors (i.e. policy, markets, regulation) and consumer acceptance. There is also a need to better understand the impacts on affordability for consumers, the financing of new infrastructures (like hydrogen) and the users of this infrastructure. Policy and regulation can work together in this process.

The third base line in actions suggested in this roadmap process is the implementation of communication and information tools utilizing LCA analysis. This action includes the set-up of common databases of the EU level in order to enhance the effective information exchange.

6. Conclusions and recommendations

The final outcome of the ATEsT project was a framework and roadmaps for tools, models and methodologies necessary to plan and develop future energy systems and policies. The transition to low carbon energy systems requires a paradigm change. Therefore, the formulation and analysis of effective policies and strategies to carry out the transition requires multilevel and multidisciplinary perspectives. The analysis made within ATEsT WP2-WP4 clearly revealed that the existing models and tools and their databases do not cover the multilevel perspective (MLP) of the transition process. In the MLP approach, the assessments consider three levels: *energy infrastructures (i.e. energy systems and technologies), behaviour (i.e. consumer's and investor's chooses), and institutional factors (i.e. policy, regulation, and markets).* These three levels form a regime level of the specified system. On the other hand, the depiction of the regime level of the system is put in the governance context covering the phases of *Goal formulation, System analysis and Strategy implementation.* The formulation the of the ATEsT framework was based on the above theories. The framework was presented as a matrix to identify the gaps in existing tools, models, and methodologies. The major findings may be summarized as follows:

- Tools and methodologies focused on analysing the effectiveness of RD&D policies, consumer and/or investor behaviour and institutional factors are nearby missing. On the other hand, energy system modelling barely takes these issues into account.
- Increasing complexity of tomorrow's energy system requires more complex models and/or integration of several models/tools
- The transparency in supporting of the EU RD&D policy initiatives could be increased.

The WP6 also contributed an survey of today's policy making in the energy and climate issues within the EU and its Member States. This revealed, that policy analysis usually included some background studies assessed with energy system and/macroeconomic models. Whereas, behaviour and institutional aspects were barely considered in the policy making.

Based on the gaps identified usisng the ATEsT framework, a techno-economic and a socio-economic roadmap was developed. The roadmaps suggested actions needed to achieve the vision of advanced models and methodologies to support decision making related to the Set-plan implementation.

According to the techno-economic roadmap, a special emphasis should be put on the following issues:

- Standardized scenario-based benchmarking of models, common standards of reporting (including uncertainties) should be realized as an early action.
- Setting-up of common and transparent databases between models and integration of real time data (i.e. statistics) would be recommend as a short term action as well.
- Research program on integrated assessment of models, tools, methodologies, and databases, which should include:
    - model and database coupling techniques
    - better tools for assessment of environmental impacts
    - better approaches to link energy system and economic modelling
    - geographic and land use models
    - modelling of infrastructures

Actions recommended from the point of view of socio-economic roadmap are as follows:

- monitor systematically the effectiveness of RD&D policies (include both ex-ante & ex-post analysis);
- highlight the big issues, which have the direct impact on SetPlan implementation;
- create tools to analyse the R&D spending, consumer behaviour & market agents;
- implement the tools and methodologies for stakeholder involvement.

In reality, there exist an unlimited number of relevant policy questions, among them also questions that focus on the ways in which key-actors' behavior, attitudes and acceptance can be influenced (limited attention has so far been paid to this type of contribution). It is thus good to keep in mind that new types of policy questions – linked to other types of specifications - may emerge. This emphasizes the need for further work in figuring out reasonable and useful ways of combining models and tools. This was a clear output of both socio-economic and techno-economic roadmaps, which included the same action, i.e.:

- integrate the outputs of socioeconomic actions in decision-making via techno-economic models, via feedback between techno-economic and socioeconomic models, or directly in the policymaking process via some other way.

The SET-Plan implementation and transition to low carbon societies is a great challenge, which would foster EU's growth and development. The creation of new generation of EU's energy system requires also multidisciplinary system thinking and a new generation of analysis tools and methodologies. Transition management and societal change towards low carbon systems call for increased understanding of interplay of societal, economical, technical, and terrestrial factors, public and stakeholder involvement, increased transparency of decision making, as well as new cultures in modelling, analysing, and reporting the results. Complex systems need complex models, but on the other hand, we should also try to simplify our analysis as much as possible to increase the transparency and understanding of the challenges and opportunities.

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WP1: Schoots, K. & Bunzeck, I.G. (2010). Specifications and requirements for the ATEsT toolbox. ATEsT WP1 Specification Report, Deliverable D1.1. The Netherlands: ECN. (http://www.atest-project.eu/pdf/D.1.1_Specification_Report.pdf)

WP2: Amerighi, O., Ciorba, U. & Tommasino, M.C. (2010). Inventory and characterization of existing tools. ATEsT Models Characterization Report. ATEsT WP2 Deliverable D2.1. Italy: ENEA. (http://www.atest-project.eu/pdf/D_2_1_Models_Characterisation_Report.pdf)

WP3: Giannakidis , G. & Nakos, C. (2011). Models/Tools Selection Methodology. ATEsT Deliverable D3.1. Greece: CRES. (http://www.atest-project.eu/pdf/D.3.1.Tools_Selection_Methodology.pdf)

WP3: Models/Tools Ranking using the ATEsT Specifications. Appendix of D3.1(?). Greece: CRES. (www.atest-project.eu/pdf/ATEST_Model_Rankings.pdf)

WP4: Kuder, R. & Blesl, M. Analysis of data requirements for the proposed models. ATEsT Report on Existing Data and Data requirements. ATEsT Deliverable D4.1. Germany: IER. (http://www.atest-project.eu/pdf/D_4_1-Report_Exiting_Data-Data_Requirements.pdf)

WP5: Nakos, C. & Giannakidis, G. (2012). Description of the approach on Linking Models. ATEsT Deliverable D5.1. Greece: CRES. (http://www.atest-project.eu/pdf/Description%20of%20the%20approach%20on%20Linking%20Models.pdf)

Appendix A1

Quantitative Assessment of the Impact of the Strategic Energy Technology Plan of the European Power Sector

Objectives and relevant policy questions

The objective of the assessment was to estimate the effect of increasing RD&D efforts for a set of low carbon power technologies on the development of the European energy sector by 2020 and 2030, in line with the needs identified by the SET-plan. The studied technologies were photovoltaic, concentrated solar power, wind onshore and offshore, biomass conventional electricity and biomass gasification.

Models and tools

The POLES partial equilibrium model of the energy sector was used for the quantitative assessment combined with a spreadsheet model for technology learning in a multi-step iterative approach, as follows:

1. Quantification of the effect of RD&D investment on the economic performance of a given energy technology using the Two-Factor-Learning Curve (TFLC) spreadsheet model. This model quantitatively links the cost evolution of a technology to its cumulative volume of production ('learning-by-doing') and the knowledge stock ('learning-by-researching').
2. The resulting energy technologies investment costs are then used as an input to the POLES model to evaluate the response of the whole energy system, in particular in terms of technology penetration and costs.
3. Finally, the deployed capacities of the energy technologies generated by the POLES model are fed into the TFLC spreadsheet model. Several iterations have been carried to ensure convergence between the two models.

The multi-step iterative approach was used to compare two main scenarios reflecting two different levels of RD&D investments but aiming to achieve the same shares of renewable energies and similar levels of greenhouse gas emissions by 2020: 'reference scenario' which applies the RD&D investments in line with the ones identified by the European Union in the context of the SET-Plan over the period 2010-2020; and the 'Global SET-Plan Scenario' which assumes that RD&D investments are also made by the rest of the world.

The analysis performed within this IA could contribute to address other issues related to low carbon technologies such as framed within the ATEsT project by the following policy questions:

- PQ1 “How to achieve a low cost and low emissions energy mix?”
- PQ4 “Which are the most competitive low carbon technologies in the medium and long term?”

Relevant aspects and outputs to answer the policy question(s)

For all studied scenarios the following outputs such as required in Work Package 5 were obtained:

- Electricity generation by fuel in EU27 (TWh);
- Share of renewable energies by 2020 and 2030 in EU27 (%);
- Change in installed capacities between scenarios in EU27 relative to a reference by 2020 and 2030 (in %);
- Installed renewable energy capacities in EU27 in 2020 and 2030 (GW);
- Deployment of CCS technologies in the EU27 from 2000 to 2030 (GW);
- Discounted (3%) net benefits cumulated from 2010 onwards for EU27 (billion EUR2000);

The comparison of these outputs among scenarios allows contributing to the identification of pathways to PQ1 (how to achieve a low cost and low emissions energy mix), namely by identifying how RD&D investments affect deployment of the studied renewable technologies. Moreover, by comparing the differentiated outputs for each of the studied technologies (photovoltaic, concentrated solar power, wind and biomass) it is possible to assess “Which are the most competitive low carbon technologies in the medium and long term?” (PQ4).

Participants in the assessment

The quantitative assessment was performed by the JRC institutes IPTS and IET, and received inputs and feedbacks from the 'Sherpa' Group of the European Community Steering Group on Strategic Energy Technologies , DG ENER and DG RTD.

The publications resulting from the assessment are public thus ensuring transparency. Moreover, 'Sherpa' Group is composed of both university researchers and high level government representatives from Member States thus adding to the openess of the process.

Appendix A2

Implementation of the EU energy and climate policies in selected EU Member States

In order to study the structures of energy-related policy and decision-making within different EU countries, some countries were chosen as case-studies. These countries included Spain, Netherlands, Greece, Italy, Germany, Finland, Sweden, UK and Austria. In addition, information was gathered on the use of models to support decision-making within these countries.

Energy-related decision-making in the studied countries

In the studied countries, the energy policy is generally based on the principles of security of supply, competitive energy prices and the achievement of the climate policy targets set in the EU for 2020 and anticipated in the long-term.

Finland

In Finland the Ministry of Employment and the Economy (MEE) is responsible for national energy policy and integration of the national preparation and implementation of climate policy. Implementation of Finland's energy policy follows the separately drawn-up energy policy documents, such as the Government's Energy Policy Programme, and the objectives set in governmental negotiations. In addition to international commitments, special programmes like the National Climate and Energy Strategy also underpin the realisation of the country's energy policy.

The National Climate and Energy Strategy and its supplementary programmes determine the energy policy lines to be followed. On the other hand, while drafting the Climate and Energy Strategy, principles underlying energy policy were also taken into account. The latest strategy was accepted by the Government on 6th November 2008 and it covers climate and energy policy measures in great detail up to 2020, and also briefly up to 2050. The strategy report was prepared under the steering of the Government's Ministerial Working Group on Climate and Energy Policy. The preparatory body for the Ministerial Working Group has been the Climate and Energy Policy Network, which comprises of representatives from several ministries, including the Ministry of Employment and the Economy, Ministry of Transport and Communications, Ministry of Agriculture and Forestry, Ministry of Education, Ministry for Foreign Affairs, the Prime Minister's Office, the Ministry of Finance, and the Ministry of the Environment. Research results, and statistical sources at international and national level, were used in strategic planning and the sketching of scenarios. The climate and energy strategy is presently being updated and the aim is for the work to be ready by the end of 2012. In addition to the update, the ministry is also preparing an energy policy roadmap for year 2050. A multidisciplinary research project has been lunched to support Finland 2050 strategies, which is coordinated by the VTT and steered by four ministries. Moreover, the government has set a scientific panel on climate change. The aim of the panel is to advice the government on climate policy and follow-up the progress towards emission reduction targets. It also gives recommendations on actions for emission reduction.

The so-called RES-directive (Directive 2009/28/EC on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC) is presently being implemented in Finland. MEE is preparing a law on the sustainability criteria of biofuels and bio-liquids. The law would give regulations on the sustainability criteria following articles 17-19 of Directive 2009/28/EC. In the preparation of the law, different ministries (including Ministry of Finance, Ministry of the Environment and Ministry of Agriculture and Forestry), Finnish Customs, The Energy Market Authority, Finnish Accreditation Service, oil industry, producers and distributors of fuels, forest industry, agricultural producers, environmental organisations and other interest groups will be consulted. Draft for government proposal is planned to be sent for consultation in 2012.

Austria

In Austria, energy policy is conducted at two levels: at the federal and at the joint federal/state levels (IEA 2008, see table 1). The federal constitution allocates responsibilities to either to the federal or to the state level (Schilcher & Schmidl 2009). Energy policy is prepared and implemented in cooperation with social partner organisations representing important groups of the society (e.g. employees, agriculture and employers). Also dialogue is held with the NGOs and the public.

The primary energy policy making is conducted at the federal level on many different government ministries and institutions (IEA 2008). The Federal Ministry of Economics and Labour is the main government institution responsible for energy issues at the federal level. The Federal Ministry of Agriculture, Forestry, Environment and Water Management attends to environmental protection (including climate change and emissions from combustion) while the Federal Ministry of Transport, Innovation and Technology is responsible for transport policy and energy R&D. Setting of energy taxes is the responsibility of the Federal Ministry of Finance. The E-Control Commission acts as the federal regulator for electricity and gas. The Austrian Energy Agency promotes clean energy use in Austria.

Table 1. Division of energy policy responsibilities between federal and joint federal/state level in Austria (IEA 2008).

Federal	**Joint federal/state**
Taxation	Supply of heat, electricity and gas
Statistics	Energy conservation
Metering	Subsidies
Emergency supply	Prohibition of nuclear power

At the federal level, the governments of the nine states are responsible for policy making, setting subsidy levels, and implementing regulatory control of energy companies. Most of the states have their own energy agencies that operate similarly to the Austrian Energy Agency. At the local level, cities and municipalities have some possibilities for implementing energy measures concerning for example mobility and energy supply (Schilcher & Schmidl 2009).

In order to achieve its emission reduction targets, Austria has prepared a National Energy Strategy (Energiestrategie Österreich, http://www.energiestrategie.at/). The strategy was formulated between 2009-2010. Its preparation was coordinated by the Federal Ministry of Agriculture, Forestry, Environment and Water Management, and the Federal Ministry of Economy, Family and Youth. Various organisations both from the public and private sector were involved in the preparation of the strategy. Nine working groups were formed and within these working groups federal government, federal states, NGO's and relevant companies cooperated (EUBIONET 2009). 370 recommendations for measures were developed, which were then clustered into 42 measures by the coordination group of the strategy.

Sweden

In Sweden the Ministry of Enterprise, Energy and Communication is primarily responsible for energy policy on government level (Vik & Smith 2009, Figure 1). Within the ministry, the Division of Energy is in charge of the overall coordination and planning of the energy policy. Ministry of the Environment is in charge of climate policy (IEA 2008). Its Division of Environmental Quality takes care of the EU and global climate negotiations. It is also responsible for climate policy instruments. The Division for Sustainable Development takes care of the issues related to energy in buildings.

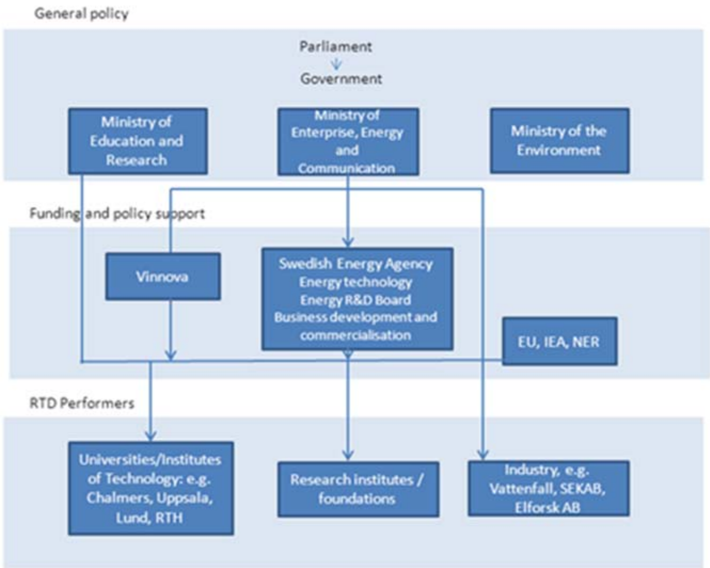

Figure 10 Key actors and institutions in the Swedish Energy Policy System (Vik & Smith 2009).

Ministry of Enterprise, Energy and Communication and Ministry of the Environment, together with Ministry of Education and Research have the political leadership for energy research funding in Sweden. Energy research is mainly organised through the Swedish Energy Agency and Vinnova. Of these, the Swedish Energy Agency is responsible for the country's national energy research programs while Vinnova is the State's innovation funding organisation. The Swedish Energy Agency is also the main government organisation responsible for the implementation of energy policy. Energy Markets Inspectorate, which was established in 2008, is the regulator for electricity, natural gas and district heat markets. The national transmission system is operated by the Svenska Kraftnät, which also operates the gas transmission system. Other government bodies operating with energy related issues include the Swedish Environmental Protection Agency, which is the government's central environmental authority. It works on climate change mitigation among other issues.

Sweden's target under the Kyoto Protocol was to limit its GHG emissions 4% above 1990 level in 2008-2012. In addition, the country is aiming to reduce its greenhouse gas emissions by 40% by 2020. Sweden has developed a strong innovation system in biomass and biofuels technologies. Influential for this development have been the introduction of green certificates and the strong forestry and pulp and paper industry (Vik & Smith 2009). Sweden is currently preparing its national Roadmap of how to reduce the country's net GHG emissions to zero by 2050 (Naturvårdsverket 2012a).

The Swedish energy policy aims to increase the supply of renewable energy sources (IEA 2008). Sweden has aimed for the promotion of renewable energy for many years (Regeringskansliet 2010). This implies phasing out oil and other fossil fuels in the long-term. Sweden was one of the first member states to implement the Renewable Energy Directive (RED) into national law through Government Bill 2009/20:128 (*Implementation of the Directive on Renewable Energy*) (USDA 2011, Regerienskansliet 2010). Sustainability criteria for biofuels and bioliquids have been implemented through Act 2010:258, and later amended through Government Bill 2010/11:152 (USDA 2011). From February 1, 2012 onwards, biofuels will need to have a Sustainability Decision from the Swedish Energy Agency in order to be eligible for tax incentives and to count for the national renewable energy targets. There is also a national system for sustainable biofuels in place.

Greece

The energy and climate policy formulation in Greece is the responsibility of the Ministry of Environment, Energy and Climate Change (MEECC). Annually the ministry publishes an Energy Strategy document which presents the energy planning options for a twenty years horizon, with the use of energy models. The coordination of this exercise is performed by a high level Committee (the Long Term Energy Strategy Committee) which is set up under the auspice of the MEECC. The participants of the committee are the CEOs of the Public Power Corporation and Public Gas Corporation, the Chairperson of the Regulatory Authority for Energy, the Hellenic Electricity Transmission System Operator, the Hellenic Gas Transmission System Operator, the Centre for Renewable Energy Sources and Saving, and a number of personalities that are key stakeholders in the field of energy policy (for example university professors, former DG Energy directors etc.). This committee is responsible for setting up the basic outline of the possible scenarios for the energy system development. The actual modelling work is undertaken by the Centre for Renewable Energy Sources and Saving (CRES).

In Greece, the above general approach was followed for the development of the National Renewable Action plan, required by the Renewable Energy Directive, as well as for the development of the National Energy Efficiency Action Plan (I and II) and for all the other policy documents issued by the MEEC. The Ministry is also preparing at the moment a long term energy strategy with a time horizon up to 2050, following the same approach.

Germany

In Germany, the Federal Ministry of Economy and Technology is primarily responsible for the formulation and implementation of energy policy (http://www.bmwi.de/English/Navigation/energy-policy,did=79110.html). In September 2010, the German government published a comprehensive energy plan with guidelines for the development of an environmentally sound, reliable and affordable energy supply in Germany (BMU, BMWi 2010). The plan stated the major quantitative energy and climate policy targets until 2050 with respect to the mitigation of GHG emissions, the extended use of renewable energy sources as well as the increase of energy productivity through a reduction of total energy consumption in line with the 20-20-20 goals on the European level. In order to reach these goals, various fields of action, like an efficient grid infrastructure for electricity or promotion of energy efficiency in the building sector, have been formulated. The original plan included the resolution to prolong the operational lifetimes of the existing German nuclear power plants by an average of 12 years. After the nuclear disaster at Fukushima in March 2011, however, it has been decided to phase out the use of nuclear energy in Germany until 2022. At the same time, the energy and climate policy targets of the original plan will be maintained and additional measures to accelerate the transformation to an energy system based on renewable energies and high levels of energy efficiency will be implemented.

Generally in Germany the decision-making process regarding the national energy and climate policy goals as well as the choice of the appropriate policy instruments is founded on several quantitative model analyses with long-term focus. Also in the monitoring of already implemented measures quantitative evaluation approaches are applied.

Netherlands

The Dutch energy policy is made up of a set of policies covering different sectors and topic areas. There are policies on, for example, energy production, energy saving in the built environment, energy use/savings in industry and technology development. There are horizontal (cross cutting) aspects by which the energy policy is linked to the environmental, industrial and agricultural policies. The preparation of the Dutch energy policies does not follow a strict procedure, but generally the following three phases can be distinguished:

1. Agenda setting by Parliament or Members of Government. In this phase the issues that require policies on energy are defined. The issues may originate from different sources, for example societal discussions, election promises, focus areas of the governing political parties, European Directives and International Treaties.

2. After agenda setting, possibilities for actions are explored in policy memos. These memos list possibilities for the government actions on the issues determined in the agenda setting phase, boundary conditions (e.g. International Treaties, EU legislation), the interaction with other domestic policies or other agendas, and other bottlenecks. This process is iterative and does not have a fixed structure or timetable. Depending on the policy and setting, preparation of policies is more or less an open process in which stakeholder representatives are consulted or even directly involved in the design process. In this phase studies are put out to provide answers to the issues that come up. These studies are commissioned on an ad hoc basis and they can cover different topics ranging from for example economic assessments to technical potential studies to studies in behavioral aspects and acceptance. The prioritization of the topics is set by the Ministries, and the models used in the studies as the Reference Projection and the Option Document may be adjusted accordingly.
3. If a policy passes through the exploration phase, a government working program emerges. This program defines the actions that will be taken on the issue from the agenda setting phase, but these actions may also cover other agenda's. The working program is the starting point for the design of legislation, subsidy schemes and other policy instruments.

After a policy's working program is established, its intended effects are evaluated on a regular basis. For energy policy, a Reference Projection is used for that purpose. It assesses where the business-as-usual scenario leads to and what will be the remaining policy task. The Option Document can then be used to determine, from a techno-economic point of view, how to close the gap at minimal costs.

Individual policy programs are evaluated ex post on an irregular basis. The evaluation is performed by non-government parties. Evaluation may range from modeling the effects of policies to assessing specific output indicators for instance from project data.

Spain

In Spain the **Sustainable Economy Act** in its Title III chapter I establishes the basis and procedures for the energy policy making process in Spain. According to this law, the Ministry of Industry, Energy and Tourism (State Secretary of Energy, General Directorate of Energy and Mines Policy, General Sub-Directorate for Energy Planning) is required to publish an indicative energy plan that includes several scenarios of the future evolution of the energy demand in Spain, the resources needed to meet this energy demand, the need for new capacity and other useful indicators to guide the private decision making and the public energy policy making process. Additionally, the law 54/1997 of the Electric Sector and the Law 34/1998 of the Hydrocarbon sector, state the need of a binding energy plan that assures the development of a secure, efficient and sustainable energy system. This binding energy plan is also drafted by the Ministry of Industry, Energy and Tourism and has to be approved by the Cabinet of Ministers and by the Parliament.

Policies and planning related to renewable energies are made by the Ministry of Industry, Energy and Tourism along with the Institute for Energy Diversification and Saving, IDAE. In Spain both indicative and binding energy plans Energy planning are mainly made with low involvement of any other stakeholder in the country. In the case of the renewable energy plans, IDAE has a more participative approach and commissioned several studies to research organisms, consultancy firms and universities in order to frame the PER (http://www.idae.es/index.php/id.674/relcategoria.3839/mod.pags/mem.detalle). Furthermore, policy making in the context of climate change is made in a more collaborative manner due to the creation of the National Climate Council (NCC) composed of representatives of different state general administration departments involved in the matter, as well as representatives of the Autonomous Communities, the Spanish Federation of municipalities and provinces, representatives of the research community, social stakeholders and NGOs. Functions of the NCC include the preparation, assessment and follow-up of the Spanish Climate Change Strategy. The coordination and verification tasks of this Strategy will be shared by the Commission for Climate Change Policy Coordination (CCPCC), a commission created with the approval of Law 1/2005, of 9 March, which regulates GHG Emission Trading, as a coordination and cooperation agency between the State General Administration and the Autonomous Communities. In addition, the Inter-ministerial Group of Climate Change, composed of representatives holding the rank of Secretary of State or Secretary-General and Director-General, will also be responsible for the follow-up of the Spanish Climate change Strategy.

The General Directorate of the Spanish Bureau of Climate change is the body of the State General Administration in charge of formulating the national policy in matters of climate change, as well as the proposal of regulations and development of the administrative planning instruments that enable the fulfilment of the objectives established by the said policy. Furthermore, The Spanish office of Climate Change is the secretary of the other national bodies related to climate change policy, including the Inter-ministerial Group of Climate Change, National Climate Council and Commission for Climate Change Policy Coordination (CCPCC).

Ministry of Agriculture, Food and Environment (State Secretary of Environment, General Directorate of Environmental Quality and Evaluation) is in charge of making both the Inventory of the GHG emissions of Spain and the projection of these emissions. The methodology used to project these emissions makes use of an engineering model to evaluate emission projections developed by the Polytechnic University of Madrid (Lumbreras Martin, J et al 2008).

The Spanish Climate Change and Clean Energy Strategy (EECCEL) is part of the Spanish Sustainable Development Strategy (EEDS). The EECCEL includes different measures that contribute to sustainable development within the scope of climate change and clean energy. The strategy is based on the reference framework of the "*Spanish Strategy for the fulfilment of the objectives under the Kyoto Protocol*" approved by the Plenary session of the National Climate Council on 5 February 2004, and it takes into account the measures and Programmes adopted by the Autonomous Communities during the last few years, some of which have been specially active. However, the numerous initiatives undertaken by the State General Administration and the Autonomous Communities since then have substantially changed the regulatory and planning framework and they have allowed the evolution towards scenarios with some trend changes in trends. Nevertheless, emissions forecasts show the need to include additional measures to create a scenario for economic, social and environmental sustainable development.

The Government, within the jurisdiction of the State, has adopted a Plan of Urgent Measures (PMU), which together with the 2008-2012 Energy Saving and Efficiency Action Plan , aims to consolidate the trend change of GHG emissions in Spain initiated in 2006

Italy

In Italy, the Ministry of Economic Development (MISE) has the responsibility for national energy policy. Within the Ministry, there is the Department of Energy, established by the government a few years ago, which consists of three Directorates-Generals (DG): DG for Energy and Mineral Resources, DG for Security of Supply and Energy Infrastructures and DG for Nuclear and Renewable Energy (IEA 2009). The Ministry for the Environment, Land and Sea is responsible for climate change policy and coordination. In addition, together with the Ministry of Economic Development, it is responsible for the promotion and development of renewable energy and energy efficiency.

The Regulatory Authority for Electricity and Gas (AEEG) is an independent body which regulates, controls and monitors the electricity and natural gas markets in Italy[1]. The Antitrust Authority is also an independent institution which examines claims made against abuse of dominant position and reviews possible mergers and acquisitions (IEA 2009).

Part of the legislative and regulatory powers is allocated to the regions in Italy (IEA 2009). In energy production, transport and distribution sectors, the state and the regions have concurrent legislative powers. Regions can enact legislation if it does not conflict with the framework principles set at the State level.

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[1] It has been established by the law November 14th 1995, n.481 with the purpose to protect the interests of users and consumers, promote competition and ensure efficient, cost-effective and profitable nationwide services with satisfactory quality levels.

The future development of Italy's energy policy will be set out in the new National Energy Strategy, which is presently being prepared by the Ministry of Economic Development.

Concerning nuclear energy, Italy is the only G8 country that does not have its own nuclear plants as its last reactors were closed in 1990. After the Fukushima accident and the referendum held in June 2011 in which all the nuclear initiatives were rejected, Italy has proposed a halt to its plans for developing nuclear power launched by the government in 2008, which included plans to produce 25% of Italy's electricity from nuclear power by 2030.

Central government, and within it, the Ministry for the Environment, Land and Sea is responsible for overall climate policy coordination whereas the Ministry of Economic Development holds responsibility for national energy policy (IEA 2009). The National Action Plan 2003-2010 of Italy established an inter-ministerial Technical Committee for Greenhouse Gas Emissions (CTE). The Minister for the Environment, Land and Sea chairs this committee. The Committee monitors progress on the implementation of policies and measures regularly and carries out cost-effectiveness analyses to identify additional measures required to meet the Kyoto targets (IEA 2009). The committee consists of representatives of the regions and various ministries.

In order to meet the emission reduction targets, many sectoral and cross-sectoral policies and measures have been implemented in Italy. These include participation in the EU-ETS Scheme, the white certificate system for promoting energy efficiency and delivering emission reductions in all energy end-use sectors, support for co-generation through various incentive schemes and legislation for the improvement of the energy efficiency of buildings (IEA 2009).

In June 2011, in accordance with theArticle 14 of Directive 2006/32/EC, Italy submitted to the European Commission the second *Energy Efficiency Action Plan* (EEAPThe plan aims to achieve an overall national indicative energy savings target of 9 % by 2016 to be reached through energy efficiency improvement measures.

In order to achieve its RES targets and in line with the provision of Directive 2009/28/EC, Italy has presented the National Renewable Energy Action Plan (NREAP 2010) in which the country is aiming to consistently increase the use of renewable energy sources for electricity production, heating and cooling, and transport.

In Italy, the Law No 13/09 provides that the EU targets for renewable energy use set for Italy will be divided between the Italian regions, with shared methods for achieving these targets (NREAP 2010). The general policy lines set out in the Italian NREAP have been converted into legislative provisions by the Legislative Decree No 28 of 3 March 2011 and a *Burden Sharing* degree has been promulgated by the Ministry of Economic Development (March 2012) in order to split between regions the national renewable target (NREAP 2010).

United Kingdom (UK)

The policy-making process in the UK can be described as an open procedure. Following changes in the structure of the UK Government in October 2008, Department of Energy and Climate Change (DECC) and the Devolved Administrations have joint responsibility for the policy framework for mitigation, while the Department for Environment, Food and Rural Affairs (Defra) and the Devolved Administrations for the policy framework for adaptation (Committee on Climate Change Framework Document).

Focusing the attention on state actors, a prominent role is played by DECC. It was set up in 2008 with the aim to take over some of the functions of other Departments; more in detail, DECC acquired functions on energy policy from the Department for Business, Enterprise and Regulatory Reform, and on climate change policy previously exerted by the Department for Environment, Food and Rural Affairs.

DECC leads climate change policy-making process. More in detail, analysts within DECC are engaged in research in order to produce evidence base that will inform the Department's policy formulation and implementation.

The policy-making process is influenced by the Climate Change Committee's (CCC) suggestions. Unlike DECC, CCC it is a non-departmental public body, composed by independent experts (i.e scientists and economists) and corporate staff. As part of its duties, the Committee advises DECC on setting and meeting carbon budgets and on preparing for the impacts of climate change. It also reports to Parliament on the progress achieved by Government in GHG emission reductions. Finally, CCC provides other advice on climate change, economics and policy[2].

The UK's ambitious energy and climate change policy is driven to achieve targets set at the EU level as well as an intention to lead the other nations globally. International decisions and targets informed British Government's actions to implement energy and GHG reduction policies. In this regards, the British Government launched The Climate Change Programme in 2000, following the commitment expressed at 1992 United Nations Conference on Environment and Development. The Programme, reviewed in 2006, set out the measures to reduce greenhouse gas emissions in key policy sectors: energy supply, business, transport, domestic, agriculture, forestry and land management and public and local government.

In recognizing challenges to climate change, the Royal Commission on Environmental Pollution (RCEP) recommended a ground-breaking CO_2 reduction target of 60% by 2050 from 1990 levels (RCEP 2000). This target was adopted by the government in a subsequent Energy White Paper (EWP 2003), which set the main framework of the UK's energy policy and its goals. Particularly, EWP 2003 established the objective to cut the UK's CO_2 emissions by 60% by 2050, with significant improvements by 2020.

The Climate Change Programme of March 2006 widened the scope of these energy policy goals by identifying priorities and policies for different sectors (from households to industry and transport) and segments (public sector vs local government) of the economy.

The need for long term planning of energy policy has been resonated in the Energy White Paper May 2007. By using a long term energy system model, the EWP presented endemic uncertainties and different energy system pathways that might emerge under different scenarios and their associated implications on resource use and costs to the economy up until 2050. With the introduction of Climate Change Bill into the Parliament on November 14, 2007, the UK government not only acquired a statutory force to deliver 60% reductions by 2050, hence setting an international example by strengthening the institutional framework, but also would be accountable. As part of this Bill, the UK government is required to publish 4-yearly carbon plans. The last Carbon Plan 2011 covers the period 2023-2027.

A more effective engagement in GHG reduction of the UK was established by the Climate Change Act of 2008, whose main aim was to support the transition towards a low-carbon economy. Among other things, the Act introduced a legally binding target of at least an 80% cut in greenhouse gas emissions by 2050, to be achieved through action in the UK and abroad.

The Energy Bill, subsequently Energy Act 2010, implements low carbon actions introduced in previous documents. Given the highly liberalized UK electricity market and the close interactions with the market, the UK government designed Electricity Market Reform (EMR) White Paper 2011, which defined actions to enhance investments in electricity market as well as to encourage the deployment of renewable energy sources. The reform package included for example a Carbon Price Floor with the purpose of limiting investor uncertainty. Moreover, the Energy Act 2011 defined energy efficiency measures to homes and businesses, and made improvements to the framework to ensure low-carbon energy supplies and fair competition in the energy markets.

In order to cut GHG emissions, the Government has elaborated a package of energy policies. These include the Green Deal, the Renewable Heat Incentive and roll-out of Smart Meters, which along with EU-wide policies (for instance the EU Emissions Trading System - EU ETS) and regulations on CO_2 emissions standards of new cars and vans, are deemed to curb emissions in the UK over this decade as well as to achieve further emissions cuts in the following decades (EWP 2007).

With the UK Low Carbon Transition Plan 2009 the Government has set a reduction of at least 34% in greenhouse gas emissions by 2020.

In order to In order to fulfil its requirements set in the Renewable Energy Directive (RED), various energy efficiency interventions have been put in place in the UK. Among them, the Renewables Obligations and Feed-in Tariffs are aimed to support an increase in renewable electricity. To boost RES deployment, the Renewable Heat Incentives have been recently introduced. The aim of RHI is to support the switch

[2] http://www.theccc.org.uk/

from fossil fuels to renewable energy sources by providing a financial incentive to install renewable heating. Such incentive scheme has been deployed through a

Another important step towards 2020 targets is the Electricity Market Reform. The package of reforms, defined in the white paper 2011, is intended to ensure that future energy supply will be secure, sustainable and affordable. This goal will be achieved by putting in place four main measures, which include long-term contracts; institutional arrangements to support this contracting approach; supporting the principle of no retrospective change to low-carbon policy incentives, within a rational planning cycle and improvement of market liquidity, thus enabling existing energy companies and new entrants to compete on fair terms.

Use of models to support decision-making energy and climate policies in the studied countries

Spain

Both documents, the indicative and binding energy plan produce estimations of the evolution of the energy demand in Spain considering the past evolution trends and European and world scenarios. Simulation models are used to produce these estimations although explicit reference on which specific model is being used could not be found. It seems that the only model that has been used to support policy-making in Spain during the recent years, has been the MED Pro model, which have been used to estimate CO2 emissions. The MED Pro model is a bottom-up model for long term energy demand, load curve and greenhouse gases forecasts. The model belongs to the MEDEE models family, policy and strategic purposes and it is the only commercial model of the MEDEE Suite (see . http://www.enerdata.net/enerdatauk/solutions/energy-models/medpro-model.php). The Med-Pro is used in two steps: First to produce a base-line scenario of the what will be the consequencesof current socio economic and technological evolutions, as well as the current GHG mitigation policies, for the studied country or region. Secondly, to evaluate the change induced by energy efficiency, energy substitutions and GHG mitigation policies and measures as compared to the "base-line" situation.

The indicative energy plan includes forecasts on the future demand and resources behaviour, evolution of market conditions to guarantee the supply, and the environmental protection criteria. This is the starting point of the obligatory or compulsory planning.

Three scenarios have been built: a central scenario considered as the most probable, and a higher scenario, and a lower scenario to analyse the effects of possible deviations regarding the central one. The last two scenarios are based on a higher and lower energy demand growth as a consequence of a different GDP and final energy intensity growths.

A starting point of the scenarios for the binding energy plan is the Plans in force. Also the growth of the renewable energies and save and efficiency measures are taken into account according to the estimated potentials for the different renewable energy sources as well as for the CHP. At international level, the scenario considers the forecasts of the analysts on social and economic evolution, European integration and energy markets. It is assumed continuity in the intensifying process of global trade and economic globalization with an increasing participation of the offer of industrial products from companies located in non-occidental countries, mainly in Asia.

In the occidental countries, economic growth remains being influenced by demographic changes derived by immigration although at the same time there is a movement of more energy intensive productions and workers to third countries. Environmental objectives represent the most relevant constraint regarding type of energies, transformation and end use technologies and energy efficiency evolution.

The methodology used to project the final energy demand is based on simulation models starting from scenarios coherent with the international and European framework. A sensitivity analysis is done for changes on basic hypothesis or demand policies. Social, technical, economic and regulatory factors able to modify the energy consumption rules are considered.

In order to forecast future energy consumption scenarios for the Spanish National Renewable Energy Action Plans(NREAP), a prospective exercise was conducted in two energy scenarios: one called the reference scenario and the other the additional energy efficiency scenario. Both scenarios predict the same future course of the main socio-economic variables – i.e. population and gross domestic product

(GDP) – and of international oil and natural gas prices, but differ in the savings measures and energy efficiency contemplated.

Projections of GHG emissions have been made taking into account both the inventory of emissions of the latest inventory year and also the estimations of the evolution of socioeconomic drivers considered in the Mandatory and Indicative Energy Plan and several sector related prospective studies (industry sector, transport and mobility sector and agricultural sector). Furthermore, as part of the revision of the European National Emission Ceilings Directive, other atmospheric emission projections for European Union countries are being calculated.

The methodology used is an original methodology to evaluate emission projections developed by the Polithecnic University of Madrid (Lumbreras Martin, J et al 2008). Emission projections are calculated for each emitting activity that has emissions under three scenarios: without measures (business as usual), with measures (baseline) and with additional measures (target). The methodology developed allows the estimation of highly disaggregated multi-pollutant, consistent emissions for a whole country or region. In order to assure consistency with past emissions included in atmospheric emission inventories and coherence among the individual activities, the consistent emission projection (CEP) model incorporates harmonization and integration criteria as well as quality assurance/quality check (QA/QC) procedures. This study includes a sensitivity analysis as a first approach to uncertainty evaluation. The aim of the model presented in this contribution is to support decision-making process through the assessment of future emission scenarios taking into account the effect of different detailed technical and non-technical measures and it may also constitute the basis for air quality modelling. The system is designed to produce the information and formats related to international reporting requirements and it allows performing a comparison of national results with lower resolution models such as RAINS/GAINS. The methodology has been successfully applied and tested to evaluate Spanish emission projections up to 2020 for 26 pollutants but the methodology could be adopted for any particular region for different purposes, especially for European countries.

Netherlands

In the Netherlands the design and evaluation of energy policies is mainly supported by the Reference Projection (Referentieraming). The outputs from the Reference Projection give general guidance to the Dutch Ministries for ex ante assessing potential impacts of different policy options and evaluations of the (future) impact of policies for example for giving account to parliament. This is complemented by the Option Document by which additional impacts beyond the Reference projection can be analyzed.

The effect of no policy, current policy and future policy is assessed in the Reference Projection (Referentieraming) by the Ministries of Economic Affairs, Agriculture & Innovation and Infrastructure & Environment. The interval is not fixed, but every 4-5 years a new baseline is defined. There are updates in between. Complete versions were developed in 1998 and 2006. Since 2006 there have only been partial updates. The Reference Projection is a joint publication by the Energy Research Centre of the Netherlands (ECN) and the Environment Assessment Agency (PBL). Prior to publication, the results are discussed with stakeholder Ministries of Economic Affairs, Agriculture & Innovation, Infrastructure & Environment, Internal Affairs and Finance. The models used for the Reference Projection are owned by ECN and PBL with the exception of the spatial transport model system, which is owned by AVV. The Reference Projection uses ECN's Netherlands Energy Outlook Modeling System containing gas/power market models, an economic sector model, final energy demand models, energy supply models and models on energy related emissions.

The model types range from accounting, optimization and simulation to behavioral tools. For the Reference Projection, PBL uses its models on transport and non-CO_2 Greenhouse gases (GHGs). Depending on the prioritizations set by the Ministries, ECN and PBL develop new models and/or functions to existing models. These organizations also carry responsibility for updating the models.

The translation of concrete policy instruments to application of various energy or climate options (amongst others : renewables, energy savings, electricity and gas markets) takes place in sub models of the Netherlands Energy Outlook Modeling System (used in the Reference Projection). Many of these models simulate the investment or operational behavior of households and businesses, thereby taking into account the impact of policies. As such, the Reference Projection, assesses the impact in terms of avoided

GHG emissions, energy use, air pollution, etc. Effects of additional measures can be analyzed by the Option Document.

To assess the effects of implementing additional potentials of emission reducing technologies and measures, the Option Document is updated from time to time, mostly following an update of the Reference Projection. The update was commissioned by the Ministry of Economic Affairs, Agriculture and Innovation, lately by the Ministry of Infrastructure and Environment. The Option Document is produced jointly by ECN and PBL. ECN is responsible for the content concerning energy, and GHG and NEC emissions from stationary sources, PBL is responsible for the GHG and NEC emissions of the non energy sectors. The Option Document is a stand-alone modeling tool and uses its own Analysis tool which acts as interface for input, analysis and result managing. The Option Document can work in optimization mode (standard) to determine cost-effective ways to apply available (technical) options, without or with additional boundary conditions. It can also be used as an accounting tool to calculate the effects of additional measures and packages.

Germany

The contents of the German energy plan are founded on model-based scenario analyses (*Energieszenarien*) commissioned by the Federal Ministry of Economics and Technology and carried out by the following German research institutes: Energiewirtschaftliches Institut an der Universität zu Köln (EWI), Gesellschaft für Wirtschaftliche Strukturforschung (GWS) und Prognos AG (Schlesinger et al. 2010). In addition to a business-as-usual scenario, which describes the development of the German energy system under the assumption that the current policy framework is kept unchanged, eight target scenarios with different operation times for the existing German nuclear power plants are calculated. Moreover, in the target scenarios fixed target values for the overall GHG emission reduction in Germany, the usage of renewable energy sources and, in some cases, the annual progress rate in energy efficiency are laid down exogenously as agreed upon with the Federal Ministry of Economics and Technology. Hence, the aim of these target scenarios is not to determine the possible long-term climate and energy policy targets for Germany, but to evaluate how a number of preset targets can be reached and what kind of adjustments within the energy system are necessary for that.

Several quantitative models have been employed to generate the scenario results. In the case of final energy consumption, a number of sectoral bottom-up simulation models with a high level of technological detail have been applied, complemented by econometric procedures to account for the price elasticity of final energy demand. Apart from that, the European electricity market model DIME, a dynamic optimization model, has been used to specify the development of the European power plant portfolio under the assumption of covering electricity demand in Europe at minimum cost. Finally, the macroeconomic effects of the different scenario settings have been assessed with the help of the econometric input-output model PANTA RHEI.

Also prior to the *Energieszenarien*, the German government has commissioned a number of quantitative, model-based scenario analyses, to evaluate the long-term development of the German energy system and the impact of different energy climate policy goals. Here, especially the *Energieprognose 2009* (IER et al. 2010), based on the energy system model TIMES PanEU, the electricity market model E2M2s and the general equilibrium model NEWAGE, and the *Energiereport IV* (EWI, Prognos 2005), based mainly on extrapolations of historical developments and expert judgments (with the exception of the power sector where the electricity system models CEEM and GEMS have been used) are worth mentioning.

In parallel, scenario analyses have been conducted to examine the long-term development of the GHG emissions in Germany and the reduction potential of national policy measures. The *Politikszenarien* are primarily used to establish emission reduction goals and to assess current as well as future policy measures. They have been issued under the direction of the Federal Environment Agency (a subagency of the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety) since 1996 at irregular intervals. The latest edition (UBA 2009) was published in 2009 describing the following two scenarios: a With Measures Scenario, taking into account all climate and energy policy measures that have been introduced between 2000 and 2008; and a Structural Change Scenario, in which the effects of additional instruments, which are currently planned or in discussion, are accounted for. The analyses are carried out using a variety of sector-specific bottom-up models based on either a simulation or an optimization approach, whose results are linked into a consistent model framework with the help of an iterative process.

The formulation of the national policy goals with respect to the long-term development of renewable energy sources has mainly been based on another series of studies, called *BMU Leitstudie* (latest edition: BMU 2010), which have been published since 2007 on a yearly basis on behalf of the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety. The results of these studies were also used to set the targets for the National Renewable Energy Action Plan for Germany (Bundesrepublik Deutschland 2010) and in the decision-making process on which instruments to use for the promotion of renewable energies. The analyses assess the future possible development of renewable energies in Germany using a highly detailed database on regional renewable potentials as well as technical and economic parameters of a large variety of renewable technologies. The quantitative modeling puts a strong emphasis on the use of renewable energy sources in electricity generation employing the European energy system optimization model REMix (focused on the modeling of the European electricity supply system with large shares of fluctuating energy sources) and the German simulation model for the electricity market SimEE. For the other possible areas of renewable energy usage (mainly heat production and transportation) smaller modeling approaches, mainly based on forward projections, are applied.

Austria

As part of the background work for the National Energy Strategy of Austria, two different emission scenarios were constructed: WM (with measures) and WAM (with additional measures) (Krutzler et al. 2009). The scenarios were constructed in cooperation by the Austrian Institute of Economic Research (WIFO), Energy Economics Group of the Vienna University of Technology (EEG), Austrian Energy Agency (AEA) and Environment Agency Austria. Different models were used to construct the scenarios (see Fig. 2). These included LEAP[3], BALMOREL and ERNSTL.

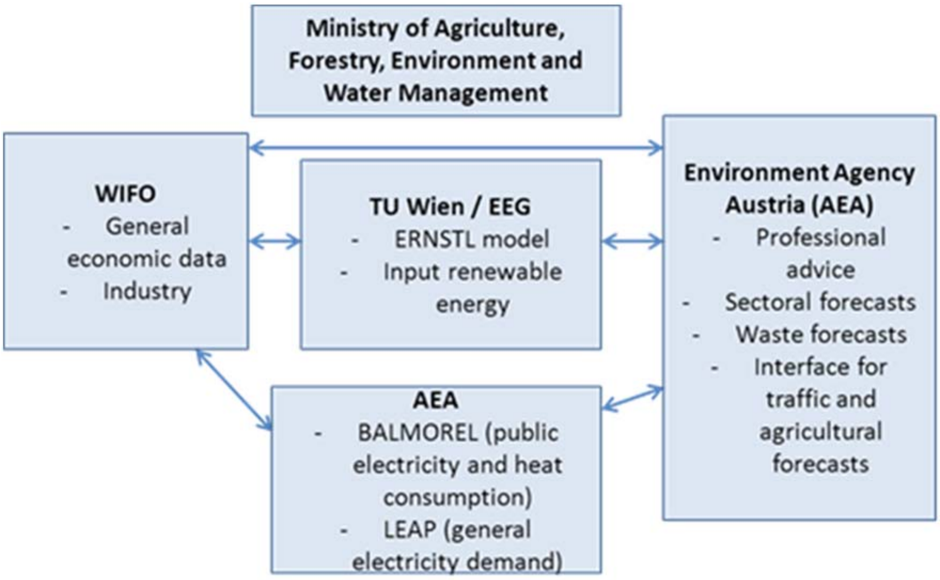

Figure 11 Structure of the energy modelling for the emission reduction scenarios of Austria (adapted from Krutztler et al. 2009).

[3] Long range Energy Alternatives Planning System

Furthermore, Sustainable Europe Research Institute (SERI) and the The Institute of Economic Structures Research (GWS mbH) have also conducted several projects on modelling of the Austrian energy system during the past years. These projects have been funded by the Federal Ministry of Agriculture, Forestry, Environment and Water Management or the Klima und Energifond. Within the projects, the integrated environment-energy-economy model 'e3.at' has been developed (Stocker et al. 2011, see also http://www.energiemodell.at/). For example, the model has been used to simulate different renewable energy technology scenarios under different developments of renewable energy use in Austria up to 2020 (Stocker et al. 2011).

Finland

During the past years, the Finnish Ministry of Employment and the Economy (MEE) has commissioned many background studies related for example to electricity market, energy efficiency and saving, emission trading and renewable energy sources. Energy scenarios used as the background for the most recent National Energy and Climate Strategy were prepared at VTT using the TIMES Finland model. Economic impacts of the scenarios were calculated at the Government Institute for Economic Research (VATT) with the general equilibrium VATTAGE model. As there had been many changes (e.g. economic recession, close-down of pulp and paper mills) in the operational environment of energy policy after the strategy was made, it was considered necessary to re-model the development of energy demand. New scenarios on the development of energy demand by 2030 were published by the Ministry of Employment and Economy in 2009. The scenarios were made by the Energy Department of the Ministry based on forecasts on economic growth and expected consequences of policy changes concerning e.g. renewable energy. In addition, estimations on the development of the forest industry sector published by the Forestry Research Institute (Metla) were used. Both VATT and VTT are also involved in the new energy and climate strategy assessments,which will be published by the end of the year 2012. VTT has further developed its TIMES energy system modelling framework to better consider the systems and markets outside Finland (i.e. Nordic and Global versions of the VTT Times models are being used).

Sweden

Sweden is currently preparing its national Roadmap of how to reduce the country's net GHG emissions to zero by 2050 (Naturvårdsverket 2012a). The Swedish Environmental Protection Agency has been commissioned by the Swedish government to draw scenarios and policy proposals, which should be ready by December 2012. The purpose of the work is to set a basis for the political decision on the roadmap to net zero GHG emissions (Naturvårdsverket 2012b). The Swedish EPA published an interim report in the beginning of 2012 in which a summary and a comparison of seven Swedish energy and climate scenarios published previously was made.

Table 2 Swedish climate and energy scenario studies (Naturvårdsverket 2012a).

Study	**Description**	**Methods and model /-s used**
Kungliga Ingenjörs Vetenskaps Akademien (IVA) 2009. Vägval energy.	Purpose of the project was to present different strategies for the Swedish energy system in 2050 with a zero emissions target. Funded by the Swedish Energy Agency, Formas, Svensk Energi, Svenskt Näringsliv and Åforsk.	Qualitative
Åkerman et al. 2007 (KTH X) Tvågradersmålet i sikte? Scenarier för det svenska energi- och transportsystemet till år	The project was commissioned by the Swedish EPA. Presents five scenarios on 85% GHG emissions reduction by 2050.	Back-casting, mainly qualitative

2050.		
Profu I Göteborg AB 2010. Scenarier för utvecklingen av el- och energisystemet till 2050.	The study has been ordered by Swedenergy, an organisation for companies in the field of electricity supply. Presents scenarios for GHG emission free electricity production in 2050.	Energy system model MARKAL-Nordic
Gode et al. (IVL) 2010. Swedish long-term low carbon scenario. Exploratory study on opportunities and barriers.	The aim of the study is to develop one potential energy scenario for Sweden with minimised fossil fuel use in 2050, and identify limitations and barriers.	Calculation (beräkning) of a possible scenario under certain assumptions
IVL/WWF 2011. Energy scenario for Sweden 2050.	In the study assumptions are made on limits of biomass output, bioenergy, hydropower potentials etc. The resulting potentials are then applied as resource limits in the energy scenario constructed.	Måluppfyllande KÄÄNNÖS scenario, backcasting also used.
Kungliga Vetenskapsakademin (KVA) 2010. Sveriges energikarta	Aim of the study is to present a scenario on 75% reduction in fossil fuel use by 2050. Scenario is based on different energy studies of KVA.	Calculation of the potential energy mix
Lund Institute of Technology (coord.) 2009-2013. Low Carbon Energy and Transport Systems for 2050 (LETS 2050).	Studies what societal transitions are needed to achieve low-carbon energy and transport systems by 2050, and how these changes can be governed and implemented.	Combination of methods from different disciplines, ranging from social sciences to economics and engineering.

The work on the National Roadmap will be continued with new scenario analyses on how different sectors can contribute to emission reduction. Reduction costs, cost-efficiency and policy measures will also be studied. The work will be conducted together with the Swedish Energy Agency, National Institute of Energy Research and other relevant sectoral offices (Naturvårdsverket 2012a).

Scenarios on the contribution of different renewable energy technologies to meet the Swedish targets under the RES directive have been conducted by the Swedish Energy Agency (Regerienskansliet 2010). The forecasts have been made using the MARKAL-NORDIC model. In the calculations 2002 has been used as the base year and the model forecasts outcomes for 2009, 2016 and 2023. In the model, distribution of the production between different technologies is based on cost-optimisation and the forecast is based on a target of 25 TWh new production eligible for electricity certification schemes by 2025 compared to 2002 being reached.

Italy

The Markal-Italy and the TIMES-Italy are the main models used by ENEA to support national policy-makers. The MARKAL-TIMES methodology has been developed in Paris since 1976 by the Energy Technology Systems Analysis Program of the International Energy Agency (IEA/ETSAP). Developed in the early '90 to evaluate GHG emissions reduction potential and costs, the Markal-Italy has been used to prepare scenarios for the Italian Government (both ministries of industry and environment) for:

- 2nd/3rd/4th National Communication to UNFCCC (Reference and Alternative scenario);
- Reference scenarios for the National Conference on Energy and Environment;
- Analysis of EU package 20/20/20 for the Italian government (as support to negotiations for EU burden sharing);
- Periodical production of scenarios for the Ministry of Economic Development;

- Energy input scenario to be used by Rains model at IIASA for National Emission Ceiling directive update and CAFE program;
- National detail for IEA ETP 2008;
- Annual ENEA Report on Energy and the Environment (plus contribution to several other ENEA publications);

Developed during the period 2008-10, the TIMES-Italy has been used to prepare scenarios, in particular:

- Reference and policy scenarios to support the National Energy Strategy and to identify guidelines for future policies on energy (Ministry of Industry –MiSE);
- Confindustria support for the evaluation of the effects of different incentives scheme for renewable energy in the consultation process between MiSE – stakeholders;
- Evaluation of the effects of national energy efficiency plan (PAEE) on the consumption of primary energy (ministry of industry)

The model MINNI (National Integrated Model to support international negotiations on air pollution issues, http://www.minni.org/) is a national-scale modelling system to simulate, over the long term, the dispersion and chemical transformation of the main air pollutants (SMA-GAINS Italy). Born from "'Programme Agreement ENEA-Ministry of the Environment", in collaboration with Arianet Ltd (http://www.aria-net.it/) and IIASA (International Institute for Applied Systems Analysis, Laxemburg AT) the project aims to provide a scientific tool to Italy to participate, with their own assessments, the international negotiation. Currently MINNI is also a project, coordinated by ENEA, scientific support to the Ministry of Environment on air pollution, which includes the development and continuous updating of the National Integrated Model and its experimental verification.

Greece

The steps followed in modelling for energy and climate policy making in Greece are described below:

1. The high level Energy Strategy Committee discusses and formulates the basic background parameters for the modelling approaches. This ensures a consensus among the national institutions and companies directly involved with the energy sector on issues like the renewable energy potential (per source), technology cost development, fossil fuel prices development, required infrastructure and related costs etc.
2. The storylines and the specific figures related to each scenario are turned into model's scenarios by the Energy Systems analysis Laboratory of the Centre for Renewable Energy Sources. The modelling tools used are:
    a. The MARKAL/TIMES implemented on a national basis. A detailed representation of all the energy sector of Greece is included in the model, including all the specific issues of interest (e.g. non-interconnected islands, possibility of natural gas network extension etc). The solution of MARKAL/TIMES offers an overall pathway for the development of the energy system and produces a forecast (among others) for the electricity demand. This is used as an input for the next modelling step.
    b. The forecasted electricity demand is used as an input for the Wien Automatic System Planning - WASP. WASP is performing an optimal electricity system expansion modelling, using the forecasted system load as an input, and a more detailed analysis of the electricity sector, calculating specific parameters like Loss of Load Probability (LOLP) etc.
    c. The generation expansion pathway which is the output of WASP is then used as an input to the COST+ model. COST+ is an in-house model, which performs hourly operation simulation of the Greek electricity system. The interest in this model comes from the fact that under high RES penetration in the electricity system, part of the renewable production might be curtailed, at specific times. This is only captured by an hourly simulation model and the minimisation of curtailment is a target that is pursued with the use of storage technologies (e.g. Pumped Storage hydro, plug-in cars etc). The combination of the three models described up

to now offer a comprehensive approach to the energy scenarios for the whole of the energy system, using the optimisation approach.

d. Apart from the combination of models described up to now the ENPEP model is also used in the scenario analysis. The ENPEP model uses a simulation approach of the energy system which makes it particularly useful in the analysis of energy demand development, energy efficiency measures and emissions accounting. The ENPEP model is used in the sense of sensitivity analysis of the various scenarios, in order to see the effect of the inherent theoretical model assumptions on the energy sector development that is produced as a model output.

3. The scenario analysis described above leads to the production of a working document that includes assumptions, scenario definitions and model results. This is used as a discussion document within the Energy Strategy Committee at first. Once a consensus is reached within the committee about the scenario results, the document is circulated to all the stakeholders for comments and inputs. The process is moderated by the committee secretariat, and suggestions that are considered important are included in the final version of scenarios and in the final document.

Overall the process for energy policy formulation that is followed by the Ministry of Environment, Energy and Climate Change, includes energy modelling in order to quantify the effects of various parameters, under the guidance of a committee of experienced stakeholders of the energy sector. The final stage includes a public consultation for a broader discussion and acceptance.

UK

CCC and DECC employ a broad range of econometric models to provide the Government with empirical analyses. Among these models, UK MARKAL model is widely used to analyse CO_2 reduction policies. The UK-MARKAL has been developed since the 1990s by AEA, UCL, and various public sector organisations in order to adapt the model to the UK contest. It models the entire energy system at an aggregate level and all aspects of the energy system, from imports and domestic resources (e.g. coal, oil, natural gas) through upstream fuel processing and supply; it represents infrastructures, conversion to secondary energy carriers (including electricity, heat and hydrogen), end-use technologies and energy service demands in the industrial, commercial, residential, transport and agricultural sectors (AEA 2011).

Variants of the MARKAL model have been used, including MARKAL MACRO for EWP 2007, MARKAL Elastic Demand used in Carbon Plan 2011, and its stochastic version used by CCC to advice the Government on the 4th carbon budget period (Usher and Strachan 2010).

DECC Energy and Emission Model has been used to inform Government policy on energy and environment since 2000. It is a partial equilibrium model that provides projections of energy demand and emissions in the UK. It covers all spectrum of the economy including final consumptions and electricity generation, and all CO2 emissions in the NAEI and international aviation (bunker fuels basis) and Land Use Change. It also covers Sulphur Dioxide and Nitrogen oxides. Emissions from Overseas Territories are excluded (Barrs 2008).

A short/medium-term model has also been employed in EWP 2007. This model has been developed by Oxford Economics. The UK energy system has been implemented to capture induced technological change resulting from climate change policy (EWP 2007).

Additionally, the Distributional Impacts Model for Policy and Strategic Analysis (DIMPSA) has been employed by DECC to assess the impact of energy and climate change policies on gas and electricity prices and bills. This model is built upon a series of algorithms designed to model the costs and benefits of policy delivery. It relies on the Living Costs and Food (LCF) survey and on data from the 2006 English House Condition Survey (EHCS) was therefore used to generate a predictive model to identify wall type, loft insulation levels and heating system age/communal heating in the LCF dataset (DECC 2010).

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Appendix B: Material of the roadmap process

Pre-work for the WP6 roadmap exercise before the video conference in March 13th, 2012

Deadline for the pre-work: 29th February, 2012

We ask you to contribute to the formation of the WP6 roadmap by giving your insights to the following questions. Based on your insights, we will formulate a combined version of the roadmap for discussion and edition in our video meeting on March 13th.

When you answer the questions, bear in mind **the overall vision of the roadmap: Advanced models and tools for efficient SetPlan implementation**. This vision statement follows the overall goal of WP6.

The timeline of the suggested roadmap runs from Present (0-3 years) to Middle Term (3-6 years) to Long Term (7-10 years). This timeline has been chosen because the multidisciplinary analysis concerning the efficient SetPlan implementation (2020/2050) with these advanced tools and models must be made within this time period.

There are four sets of questions that we would like you to answer for each of these time periods. They are the following:

1. **Megatrends, drivers, challenges, and policies (global, EU level): What are the overall, upper-level factors driving the development of energy policies and energy systems? Please name these factors for present, middle, and long term.**

Present:

Middle term:

Long term:

2. **Technologies, energy systems, consumer behaviour needed for the SetPlan implementation: What kinds of technologies, energy systems or consumer reactions are emerging / being developed as a reaction to the above-mentioned megatrends, challenges and policies? Consumer here refers to all energy users (e.g. individuals, communities, companies and institutions).**

Present:

Middle term:

Long term:

3. **Models and tools development (including databases): What kinds of models, tools and databases should be developed and/or how the existing tools, models and databases should be modified in order to monitor and enhance the above-mentioned development and the SetPlan implementation? What are the problems/challenges related to the use of complementary models and tools when monitoring and enhancing SETPlan development?**

Present:

Middle term:

Long term:

4. **Actions: Which actions are needed in order to achieve the above-mentioned model and tool development? How could the problems and challenges related to the use of complementary models and tools be solved and/or challenges treated?**

Present:

Middle term:

Long term:

Comments on the ATEsT WP6 roadmaps

3rd Workshop in Brussels 26th March, 2012

Consider the following questions concerning the ATEsT WP6 roadmaps, which are attached. You can use first 5-10 minutes for individual thinking and make notes on this paper. After that, discuss the questions in a group to formulate a shared view. The groups are asked to report the outcomes of discussion to other groups.

My group discusses the following roadmap:

◯ Socioeconomic Roadmap

◯ Techno-economic Roadmap

1. **Comment the proposed actions: are they important and feasible?**

2. **Are there some essential actions that are missing from the roadmap?**

3. **Which actions are the most important ones?**

4. **Is the timing of the actions good or should there be some changes in the timeline?**