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EUSUSTEL

European Sustainable Electricity; Comprehensive Analysis of Future European Demand and Generation of European Electricity and its Security of Supply

Priority SSP-3
Policy Support and Anticipating Scientific and Technological Needs
Specific Support Action

Periodic Activity Report:

Mid-term Assessment

Period covered: from 01/01/2005 to 31/12/2005 Date of preparation: 10/02/2006

Start date of project: 01/01/2005 Duration: 24 months

Project coordinator name: W. D'haeseleer
Project coordinator organisation name: KULeuven Revision [1]

1. Introduction

1.1. General aspects

1.1.1. General information on the project

The proposed project aims at providing a fully consistent framework for a secure electricity provision, which is at the same time environmentally friendly and affordable. The conclusions of the project must result in policy recommendations for the member states and the Commission. The methodology used mixes two directions of analysis. In a first (horizontal) one, the existing electricity systems of the 25 EU countries are analysed and national policy choices and future projections are studied. Next, vertically then, a subject-wise treatment is considered, whereby both the demand side as well as the supply side technologies and system integration are treated. Furthermore, the regulatory and liberalised market framework for an integrated European electricity market is carefully examined and appraised. Based on these analyses, it is then in a combined approach attempted to summarise the 'static' overall social cost (private cost plus external cost) for electricity generation. Subsequently, these cost figures are used as input in carefully screened simulation models in order to perform some well-defined and contrasting scenarios, but in line with the regulatory framework of the energy market. From these results, it must be possible to obtain the so-called 'most optimal solution' (from an economic-effectiveness point of view —including environmental burdens) for the electricity provision in Europe.

To guarantee that the results of the obtained solutions are well defendable, it is necessary to do several 'quality control checks'. These checks are performed continually throughout the project through cross reviewing, but mainly by critical reviews and feedback from the '*Special-Focus Industrial Advisor*', Eurelectric. In addition, at particular instances during the project, structured interactions with other stakeholders, which are invited to become member of the *Consultative Committee,* are organised (see Section 1.1.3.2).

1.1.2. Organisation of the report

This mid-term assessment report describes the activities that have been carried out during the first year of this two year project (01.01.2005 – 31.12.2005). The report is written in the same structure of the project, i.e. by making use of different work packages (WPs). All WP-leaders have contributed to the chapters on the WPs, which they are responsible for. The different chapters summarise the targets of the specific WP, the activities that have been carried out and the main results and general trends. The full report(s) on all WPs can be found on the project website (see Section 1.1.3.1) or as an Annex.

A subdivision can be made between the different WPs. Firstly, there are the WP's, which are finished by the end of year one, i.e. WP1 *(Country-wise analysis for EU-25)*, WP2 *(Anticipation of future electricity demand)*, WP3 *(Electricity generation technologies and system integration)* and WP4 *(Regulatory Framework of Energy Markets)*. A full description of those WPs can be found in the Sections 2.1, 2.2, 2.3 and 2.4, respectively.

Secondly, WP5 *(Most optimal solution for electricity provision)*, has been partly carried out in the first year. The subtask WP5.2, a comparison and evaluation of simulation models & codes and existing scenarios for electricity generation, has been carried out. The work in WP5.1, on the determination of the overall static social cost for electricity generation, and in WP5.3, on performing and interpreting four scenarios, has started, but will be finished in year two. A complete overview of the finished work and the work in progress can be found in Section 2.5.

Lastly, there are WP6 *(Compatibility check & validation)*, WP7 *(Dissemination of results)* and WP8 *(Project guidance, coordination and management)*. As the content of those last three WPs is rather general, related to the project guidance and the overall quality standards of the project (i.e. activities which run throughout the project), they are treated in this section on the general aspects. WP6 and WP7 are treated in Section 1.1.3, and WP8 is treated in Subsections 1.2 and 1.3.

1.1.3. Exchange of information

Besides an extensive e-mail-communication between all partners to discuss on the topics treated in the different WPs, two other "communication tools" have been used; i.e. the project website and the project meetings.

1.1.3.1. Project website

To communicate the content of the project to the public and to exchange project and draft documents between the different partners, as stipulated in WP7, a website has been established[1]. Since March 2005, it has been operational. The website contains a public part, with the overall description of work and the presentation of the partners, and a restricted area, which currently contains most of the actual project information. Besides the useful contact information and the documents related to the meetings (minutes and presentations), the site is intensively been used for the exchange of draft reports (and related useful information) for the different WPs. It has become a platform for all information related to the EUSUSTEL project. Besides the project partners, all members of the Consultative Committee have access to the restricted area. So review of all draft documents is possible by both the academic and industrial partners.

All project deliverables are available on the website under the heading "Work Packages".

1.1.3.2. Project meetings

During the first year of the project, several meetings have been organised by the project coordinator, KULeuven. Besides all partners, the '*Special-Focus Industrial Advisor*', Eurelectric, has a representative at all meetings. So, at every time, a critical point of view and feedback can be given by Eurelectric.

1. Kick-off meeting; Brussels, January 21st 2005.

This kick-off meeting is the first visible human contact between the representatives of the 10 participants, for this project. The aim of this meeting is to give an overview of the project and the work to be carried out (distribution of work, deliverables, etc.). Besides the global introduction of the project, a first structured discussion on the implementation of the different WPs by the WP-leaders is held.

[1] www.eusustel.be; User name: "eusustel"; password: "EU123SUS".

2. Plenary partners meeting; Brussels, September 19th 2005

In this second meeting, all partners get the chance to discuss more thoroughly on the progress of work of all WPs. All WPs are treated and discussed one by one. Besides this, already now, the first preliminary results of some WPs (e.g. WP1) can be presented. It gives the opportunity to all partners to react on it.

3. Consultative Committee; Brussels, September 20th 2005

In this last meeting in 2005, besides all partners, the members of the Consultative Committee (CC) are present. All WPs are presented and discussed. The members of the CC can give their remarks and suggestions on the implementation of the different WPs. So, in this way, the CC helps to 'qualify' the results obtained in the different WPs.

Table 1 gives an overview of the represented organisations in the CC.

Eurelectric
Tractebel Engineering
Alstom Power
VGB
BNFL
Euracoal
ETSO (NGT)
UCTE (Elia)
Foratom
CEU DG Energy

Table 1 Overview members of the Consultative Committee

1.2. Objectives, boundary conditions and hypotheses of the project

1.2.1. Objectives

In the first sub-task of WP8, the scope, the general boundary conditions and the hypotheses to be used in this project are defined[2]. It is of utmost importance to do this, to have a consensus amongst the partners.

Under this heading, the 'objectives, boundary conditions and hypotheses', generic to the whole project are given. The objectives, 'boundary conditions and hypotheses' specific to the different work packages are mentioned whenever appropriate when addressing the work package itself.

The **strategic objective** addressed by the project EUSUSTEL is "*To provide the EU Commission and the member states with coherent guidelines and recommendations to optimise the future nature of electricity provision and the electricity generation mix in Europe so as to guarantee an* ***affordable, clean and reliable*** *, i.e., '****sustainable****', electricity supply system.*"

[2] For practical reasons, the 'objectives, boundary conditions and hypotheses' are dealt with in WP 8, but clearly, in the logical delineation of the project; they are to be presented first.

This strategic objective is translated into **measurable and verifiable objectives**, which are implemented in the different WPs.

1. Delineate the overall scope, boundary conditions and hypotheses of the project and establish a framework for the concept ‘sustainability’. (WP8)
2. Make a review analysis of the electricity provision in the EU-25 countries, and establish a summarising report per country. (WP1)
3. Make projections for reasonable evolution of demand for energy services and determine the relationship with electricity demand. Propose justified Demand Side Management (DSM) measures. (WP2)
4. Make an analysis of electricity generation technologies (including aids such as storage) and their integration into the overall generation system. For each technology, a realistic range of technical, environmental and economic characterising parameters are to be identified and future evolutions are to be estimated, with a horizon of 2030 (-2050). (WP3)
5. Make an analysis of the current regulatory framework and its technical and economic consequences concerning the liberalisation of the electricity market (and the influence of the directives on renewable energy, CHP and emission trading). Reflect on an ‘ideal’ fully consistent framework for a fully integrated European electricity market, so as to establish appropriate boundary conditions for the overall EU generation system (centralised versus decentralised, generation mix, geographical location of generation capacity, dispatch-able or not). (WP4)
6. Determine the total social cost for electricity generation, both statically and taking into account system interaction. Perform scenarios to determine the ‘most optimal solution’ for electricity provision in the EU. (WP5)
7. Assure that the results of this project are appropriately screened with respect to the degree of realism, compatibility with liberalised markets and the ‘desire’ for security of supply. Furthermore the results should be validated against international studies. (WP6)

1.2.2. Boundary conditions

The boundary conditions are defined as such or are fixed constraints. Table 2 gives an overview of the boundary conditions, used in this project.

Time horizon: focus on 2030; reflect upon 2050
Physical constraints: wind conditions, insolation, available area…(potentials)
No physical shortage of fuels (but at what price?)
Postulate common electricity & gas market effectively based on current directives (take perfect transposition)
Accept current environmental & safety standards of EU (NO_x, SO_x, PM10, …but not on GHG) throughout
Post-Kyoto too uncertain as boundary condition → via hypotheses
Other existing legislation & regulation as basis (other variations later as different hypotheses) EU & MS

Table 2 Boundary conditions used in the EUSUSTEL-project

1.2.3. <u>Hypotheses</u>

Although, by definition, hypotheses are those basic assumptions which are 'debatable', throughout study, some basic hypotheses act as boundary conditions. In the proper sense, hypotheses can be varied in different scenarios, by which the first set of hypotheses defines a 'reference' scenario. Making use of different hypotheses, allow a sensitivity analysis. Some examples of hypotheses are:

- Introduce varying schemes for DSM (e.g., white certificates)
- Post-Kyoto: -16% in 2030 (linear extrapolation of the -8% target in 2010 compared to 1990)
- Change nuclear policies: phase out or not

Another important hypothesis has to be made on the fuel prices. In this project, the latest (fall 2005) PRIMES evolutions are assumed. Table 3 presents the world fuel price projections that are currently used within the PRIMES exercise for the European Commission. The word *Base* indicates the baseline; *High-indep* means higher oil and gas prices but the gas price uncoupled to the oil price, and *High-depend* means higher oil and gas prices scenario whereby gas "follows" the oil price. Consistency is ensured through the world energy model Prometheus and the Poles model. Figure 1 gives a schematic representation.

PRIMES prices scenario									
Euro'00 per boe	1990	1995	2000	2005	2010	2015	2020	2025	2030
	1990	1995	2000	2005	2010	2015	2020	2025	2030
Oil high	18.71	14.14	30.57	39.32	45.05	49.21	56.51	63.49	71.74
Gas - independ.	7.55	6.95	14.47	22.07	25.19	28.28	30.41	35.12	40.66
Gas - depend.				22.07	26.82	32.55	38.61	44.33	53.38
Coal high	8.84	8.72	8.23	9.69	9.92	10.34	11.86	12.57	14.38
$05 per boe	1990	1995	2000	2005	2010	2015	2020	2025	2030
Oil	High			54.00	61.87	67.58	77.61	87.21	98.53
	Base			54.00	44.61	44.91	48.06	54.44	57.60
Gas	High - indep.			30.31	34.60	38.84	41.77	48.23	55.85
	High - depend.			30.31	36.84	44.70	53.03	60.89	73.31
	Base			30.31	33.89	34.22	36.98	42.87	44.75
Coal	High			13.31	13.63	14.20	16.29	17.27	19.75
	Base			13.31	12.54	13.36	14.07	14.59	14.95
(ratios)	1990	1995	2000	2005	2010	2015	2020	2025	2030
Oil/gas-base	2.48	2.03	2.11	1.78	1.32	1.31	1.30	1.27	1.29
Oil/gas-high depend	2.48	2.03	2.11	1.78	1.68	1.51	1.46	1.43	1.34
Oil/gas-high independ	2.48	2.03	2.11	1.78	1.79	1.74	1.86	1.81	1.76
Coal/gas base	1.31	1.55	0.81	0.63	0.52	0.53	0.52	0.46	0.46
Coal/gas high depend	1.31	1.55	0.81	0.63	0.48	0.41	0.36	0.33	0.28
Coal/gas high independ	1.31	1.55	0.81	0.63	0.51	0.47	0.46	0.41	0.37

Table 3 Fuel price assumptions according to PRIMES prices scenarios.

Units: boe = barrel of oil equivalent; Euro'00 = Euro of 2000; $05 = $ of 2005.

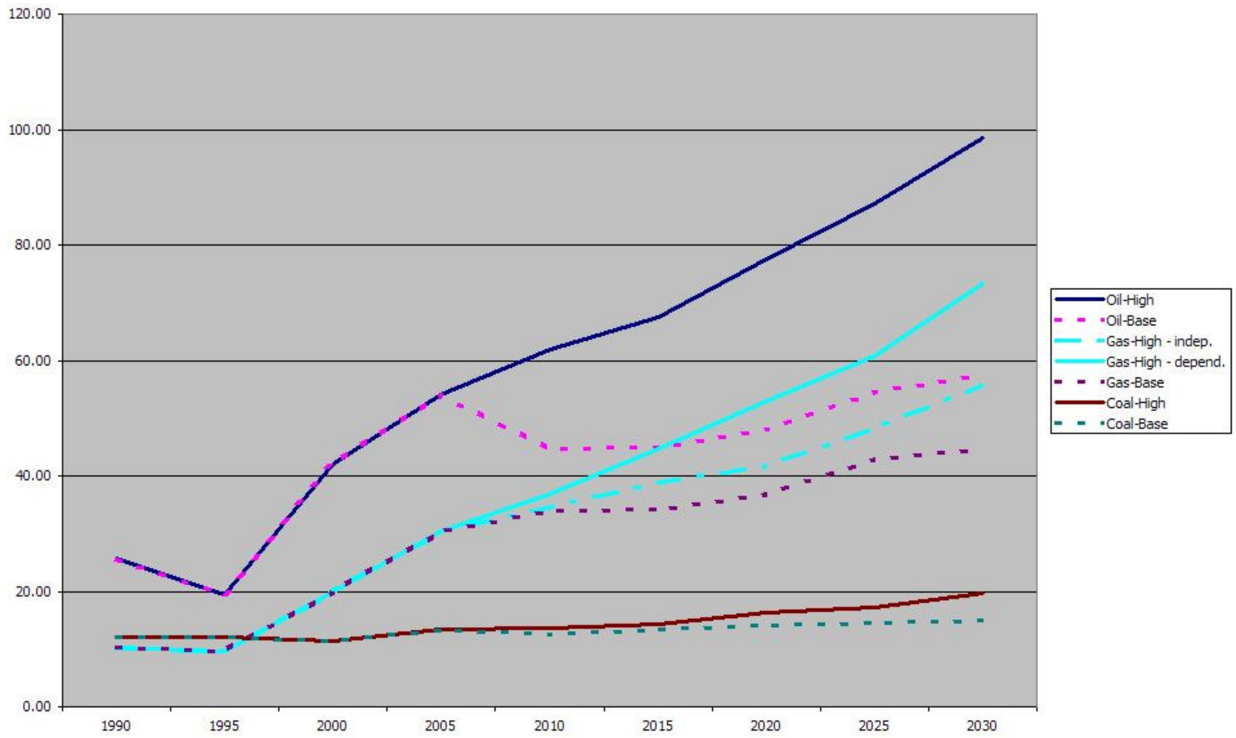

Figure 1 Fuel price assumptions according to PRIMES prices scenarios

In WP5, four scenarios, which represent four basic cases, will be studied. The scenarios are briefly mentioned here.

1. Baseline scenario: High[3] prices (= $60 per boe in 2030; "Base" in Figure 1) + no post Kyoto limit + baseline nuclear and other options
2. Same as baseline scenario, but with post Kyoto of -16 % in 2030
3. Same as Scenario 2, but free nuclear option (no extra promotion on other options)
4. Same as scenario 3, but promoted energy efficiency and distributed generation.

1.3. Framework for sustainability

To assure that everybody understands the same thing under 'sustainable development', a second task in WP8[4] is to establish a conceptual framework for sustainable electricity supply. The summary and the conclusion of the comprehensive deliverable can be found hereunder.

The concept of sustainable development is not a new one; generally accepted starting point of most of the present concepts is the definition of the World Commission on Environment and Development (WCED),

[3] "High prices" mean: "higher than the base prices in the PRIMES-scenarios "European Energy and Transport, Trends to 2030"

[4] Also here, for practical reasons, the sustainability framework' is dealt with in WP 8, but clearly, in the logical delineation of the project; it is to be presented first.

also known as the “Brundtland Commission. According to WCED, sustainable development reconciles improving the economical and social living conditions of all (present and future) generations with securing the long-term natural resources. However, there are several approaches proposed on how to define sustainability in precise terms, which include conflicting principles.

Sustainability concepts are among others characterised by the degree of substitutability. A central approach of the neo-classical school of thoughts is the so-called “weak sustainability”, which suggests a substitution paradigm according to which elements of the natural capital (renewable and exhaustible resources, assimilative and life preserving functions of nature) to a large extent can be replaced by man-made capital. Sustainability concepts however, attributed to the school of ecological economics follow the perception of “strong sustainability”, giving preference for ecologically based limitations as opposed to economic activities. Substitution between man-made and natural capital are strictly excluded in this concept. Both, the non-existent as well as the more or less unbounded substitution ability between natural and artificial capital, are not very reality oriented models.

Approaches for practical implementation often are based upon a mixed conceptual form of strong and weak sustainability, denominated “critical weak sustainability”. It embraces critical performance limits for some complementary functions of the natural capital, felt to be indispensable for life. Aside from those limits substitutability among the various components of natural capital is assumed. This perception of a “critical weak sustainability” seems to be the most appropriate approach for deriving practical guidelines from the sustainable development concept for the assessment of energy systems.

Most of the known sustainability concepts follow the idea of a Three-Pillar Model, i.e. pillars representing the ecological, economical and social dimensions under equitable ranking conditions. Sometimes additional installation of a “cultural” and/or “institutional” dimension is suggested. However, in practice the Three-Pillar Model turned out to be of limited value. The main reason for its’ limited applicability is that its’ three dimensions are strongly interlinked and connected an independent from each other.

A conceptually sounder understanding of sustainability is the integrated ecological, economical and social dimension concept. It is based on the understanding that natural resources and assets (including the environment) are exploited and used to be transformed via technologies to satisfy societal needs for goods and services, where the economy is the operator of this transformation process.

Any attempt to define the concept of sustainability in concrete terms can only be sound if it takes the laws of nature into account. In this context the second law of thermodynamics acquires particular significance. Thermodynamically speaking, life inevitably produces entropy by degrading workable energy (“exergy”) and available material and requires a permanent input of these constituencies. But available energy and material only constitute a necessary however not sufficient condition for life supporting states. In addition to this, information and knowledge is required to create states serving life. Knowledge and information, which may be defined as “creative capacity“, constitute a special resource. Although it is always limited, it is not consumed and can even be increased. Knowledge grows. Increasing knowledge or “creative capacity” resulting in further technological development is partially significant for sustainability, because it allows for a more efficient use of natural resources and an expanding of the economically available resource base for the generations to come.

Within the context of defining the concept of sustainability in concrete terms, the need to limit ecological burdens and climate change can certainly be substantiated. The energy and raw material base economically available is fundamentally determined by the technology available. As far as the use of limited stocks of energy is concerned this means that their use is compatible with the concept of sustainability as long as it is possible to provide future generations with an equally large energy base which is usable from a technical and economic viewpoint.

As far as the environmental dimension of sustainability is concerned, pollution connected with today‘s energy supply, is primarily caused by anthropogenic flows of substances, by material dissipation, i.e. the release of substances into the environment. It is not the use of workable energy which pollutes the environment but the release of substances connected with the respective energy system, for instance the sulphur dioxide or carbon dioxide released after the combustion of coal, oil and gas. The increasing use of workable energy and a reduction in the burdens on the climate and the environment are not, therefore, a contradiction in terms. It is the emission of substances that have to be limited, not necessarily the energy uses themselves, if we want to protect the environment.

The economic dimension deserves a special attention within the sustainability definition, as it is quite often misunderstood or misinterpreted. Economical efficiency is always associated with efficient use of scarce resource in an economy, given that all scarce resources are accounted for in decisions of the actors.

This is to say that the general economic principle is in correspondence with the principle of efficient resource use of the concept of sustainability. This principle in connection with the provision of energy does not only refer to energy resources, but includes all other scarce resources, such as non-energetic raw materials, capital, work and environment necessary to provide energy services. In order to fully account for resource use, it is necessary to internalise the external cost. Total social costs are a suitable yardstick for measuring the utilisation of scarce resources.

Summarising the interpretations of sustainability concepts and its deductions the following preconditions as for *sustainable energy supply systems* can be established. An energy supply system is sustainable, if

- the potential for an economic provision of energy services increases or does not decrease for the next generation,
- the substance release due to energy use does not exceed the natural assimilation capacity as a sink,
- energy services are provided with the least resource input possible, including the “environmental resource”.

These general rules for a sustainable energy supply system are not directly applicable when it comes to the comparison and assessment of energy technologies and energy supply chains. Here the assessment has to be based on comparative measures of the various sustainability aspects on a functional unit basis, e.g. a kWh of electricity produced or a unit of energy service provided. The relative sustainability of energy technologies is basically determined by the overall consumption of resources including environmental resources on a functional unit basis. One useful measure for the overall resource consumption, that is the relative sustainability are the total social cost per unit of energy service. These include the private as well as the external cost of an energy chain to provide an energy service.

2. Work packages

2.1. WP1: Country-wise analysis for EU-25

WP-leader: KULeuven

2.1.1. Description of work

Work package 1 gives a critical overview of the overall electricity provision for all 25 EU-member states. All EUSUSTEL-partners make the review for their own home country, but as there are more member states than partners in this project (25 member states vs. 10 partners), some partners review some neighbouring countries as well. Concerning the 10 new member states, the work is distributed among the partners. Table 4 gives an overview of the distribution of work.

Sub 1.1	BeNeLux	Partner from BE
Sub 1.2	Germany & Austria	Partner from DE
Sub 1.3	Finland	Partner from FI
Sub 1.4	Greece	Partner from EL
Sub 1.5	Sweden	Partner from SE
Sub 1.6	Italy	Partner from IT
Sub 1.7	UK & Ireland	Partner from UK
Sub 1.8	France	Partner from FR
Sub 1.9	Spain & Portugal	Partner from ES
Sub 1.10	Denmark	Partner from DK
Sub 1.11	Baltic States	Partner from FI
Sub 1.12	Cyprus & Malta	Partner from EL
Sub 1.13	Hungary, Poland, Slovakia, Slovenia, Czech Republic	Partner from EL, BE and DE

Table 4 Distribution of work - Work package 1

The review is based on known energy-related and other relevant documents. Firstly, international and European documents on the country (e.g. IEA-reports; European Energy and Transport, Trends to 2030…) are studied. In a second phase, national documents (e.g. reports of electricity producers, regulators, national energy studies and committees…) are considered. The final result, which is cross-checked by the 'special-focus industrial advisor' from electric industry – Eurelectric –, gives a critical analysis of the national energy/electricity policy. As the different authors are closely related to the national energy situation, their criticism results in an added value; the deliverables are more than just a simple summary of existing documents.

Although there are no project partners from the new member states, they are involved in this project. In WP1, a considerable number of local energy specialists were contacted to help to provide useful information on the national energy policy, as this information is not widespread over the EU and as it is very often only available in local languages.

2.1.2. Deliverables

The deliverable for WP1 is a combination of 25 country reports, which all counts approximately 10 pages. To minimise the author's interpretation on the structure of the report, a template is provided to all partners. The template consists of five major parts. The first part gives the present factual information on geography, demography, economy, energy, electricity and environment. The next part discusses the trends on the abovementioned issues in past, present and future. The third part discusses the results of energy studies, carried out on the national level. This part is optional, as it only can be written in the case if such studies are available. The fourth part discusses the national policy on energy, electricity and environment and the last chapter deals with country-specific peculiarities.

Although a template is provided, the final result shows the different emphases, depending on the country's interpretation of it. This different interpretation and the varying resulting reports illustrate the European Union as a *mosaic* of cultures, policies, strategies… within a EU-framework.

During the writing process of the reports, draft versions were put on the project website, to give all partners (both academic and industrial) the chance of reviewing the documents.

2.1.3. Results & general trends

This section describes the main, general trends, results and emphases which can be found in all reports. No detailed, country-specific information is given here; this can be found in the separate deliverables. It is important to realise that WP1 gives a snapshot of the existing situation; so one has to be very careful when extrapolating the given results.

2.1.3.1. Demography & Economy

Although the population in the EU is not 'fast growing' – i.e. rather stabilising –, the number of households is increasing. Households become smaller and tend to have only 2 persons instead of 3 in the past. The process is already in an advanced phase in the EU-15 states, but the same trend is ongoing in the new member states.

In general, GDP is increasing in all member states, but there are some differences in growth rate. The newcomers see a more rapidly economic growth, with annual growth percentages up to 5%, while some old members have only a 1% GDP growth rate. But it is expected that those fast growing rates will gradually decrease to a more modest percentage of approximately 3%. The European economy tends to become more and more service-based, and the share of agriculture and (heavy) industry is decreasing all the time. In the different member states, the share of the services to the overall GDP varies between 50 and 80%. The industry takes 15 to 45 % for its account, while agriculture is only responsible for a 0.5 to 5% share.

Both the above described trends on demography and economy, influences the energy management (use and intensity), as will be discussed further on.

2.1.3.2. Energy

Fossil fuels are very important in the EU. *Oil* is the most important one, as it the base product for the chemical industry and even more important, for transport. *Natural gas* is especially important for electricity generation and for heating appliances in houses and recently, the interest in *coal* is again increasing (especially for electricity generation), especially with the increasing gas prices.

The EU is heavily dependent on imports for natural gas and oil, as the EU-domestic resources are very limited, or even poor. Coal is abundantly available in the central and eastern member states of the Union.

The aim is to unbundle the GDP-growth and the energy use as much as possible. On the one hand, the industry makes a really good effort on the field of energy intensity and energy use. But on the other hand, the service & commercial sector, the households and the transport sector face an increasing use of energy. Although the energy market is liberalising, the interest in district heating – a regulated activity –, is increasing.

2.1.3.3. Electricity

Electricity use is growing, and it is not expected that this growth will slow down in the near future. Electricity is an important form of energy.

Table 5 gives an overview of the most important electricity generation options as they are found in the EU. The right column gives some remarks, questions or topics of interest which are mentioned very often in the case of the specific generation technology.

Electricity production technology	Peculiarities
Nuclear	Waste & safety issues; legal phase out in some MS
Natural gas	Heavily relying on fuel imports
Coal/lignite	Environmental concern; existing EU-domestic resources
Hydro	Largest share of existing renewable potential (for large scale hydro power plants) used
Oil	Very small use
CHP	Increasing interest
RES[5]	High interest, R&D-efforts needed, grid issues

Table 5 Overview most important electricity production options & remarks

For the future electricity generation, a broad range of technologies is envisaged. Until recently, both in the context of low gas prices and the environmental concern, gas-fired power plants were seen as the most important contributor to the future electricity provision. Low emissions, a small investment cost and a short construction time were seen as its major advantages. But with the recent gas price surges – the continuation of which is everybody's guess, the interest in clean coal technologies is increasing and a lot of R&D-efforts exist (and are still needed) on coal. Also in the discussion on the security of supply issue, coal-fired and new

[5] RES = Renewable Energy Source

nuclear power plants are important options. Besides those three "classical[6]" options, renewable energy sources are of interest as well. Although generally, the growth ratio is large in most of the EU-members, the absolute and relative share in the electricity provision differs from country to country. E.g. in Spain, Germany and Denmark, the impact of wind power is large, but in other countries (e.g. Belgium), until now, renewable energy sources only provide a marginal share in electricity generation.

To ensure a reliable electricity provision, all member states realise the importance of a good electricity network. Sufficient cross-border transport capacity is a key issue to make import and export possible. Countries where new nuclear base load capacity is foreseen (e.g. France and Finland), realise that this choice is important for the region import/export strategy. Import and export, which is closely related to security of supply, becomes a strategic issue.

2.1.3.4. Environment

The reduction of emissions, which is the major environmental concern in the EU, is double-sided. On the one side, the reduction measures for SO_x-, NO_x-, NMVOC[7]-emissions seem to be successful. Emissions are reducing. But on the other side, reaching of the Kyoto target, by reduction the emission of greenhouse gases, especially CO_2, is much more challenging. The ever increasing mobility and transportation,, with the mounting use of oil, and the increasing use of energy in the households and the service & commercial sector, make up a large share of the emissions. In industry, the shift of the activities towards less heavy industry has a positive effect on the emissions, but it is important to realise that this is not as a result of a good environmental policy. On the other hand, industry does make a substantial effort to reduce the emissions, e.g. by the introduction of the use of covenants.

To promote renewable energy sources – the most important ones are wind energy and biomass – the most member states use comparable mechanisms: feed-in tariffs, guaranteed prices, taxes and obligatory supply. All countries mention the link between the emission reduction strategy and the national economic competitiveness. So as not to punish the countries with a progressive emission reduction policy, measures on a European scale are of major importance. A good example is already the EU-ETS[8].

Although all member states take measures to reduce to CO_2-emissions, most countries realise that national measures are not sufficient to reach the Kyoto target. And so, they count on the flexible mechanism to reach their goal: Clean Development Mechanisms (with development countries), Joint Implementation (between industrialised countries) and international emission trade. The awareness of the fact that extra flexible mechanisms are necessary to reduce the emissions is already a good thing, but one may not forget that in the end, someone has to make the real physical effort (which is not entirely guaranteed, given the e.g. over-allocation of the Russian Federation with GHG allowances).

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[6] In which "classical" does not mean that those options are not under development. "Classical" is to be interpreted as "generally known as electricity production method, without specifying the advanced features."

[7] NMVOC = Non Methane Volatile Organic Components

[8] ETS = Emission Trading Scheme

2.1.3.5. Liberalisation

All member states are gradually opening up their energy market at a pace which differs from country to country. Mostly large users and industrial clients profit from the liberalisation process. Small, residential users do not seem to make a lot use of it.

Although the energy markets are (or become) liberalised, long term contracts remain responsible for the largest part of the energy deals. The market is free, but the major clients search for stable trade mechanisms. The power exchanges, which deal with the short term markets and the balancing activities, deal only with a small share of the power flows. To increase this share, many member states stress the importance of liquidity.

The role of the regulator is comparable in most countries: supervision of the liberalisation process, price & tax advice, supervision of the market, etc. Very often, the decision power of the regulators is very restricted, so they have only a control function and an advisory role. Although privatisation has mostly been carried out, in some member states, the state (especially in the Eastern European countries) tries to keep a strategic share in the energy sector.

Due to the historic evolution of the energy markets, on many national markets, dominant players are present. And even, if they do not abuse their market power, they put a barrier to potential newcomers on the energy market.

Recently, a consolidation trend can be seen on the national level. Different small players merge again and there is a vertical re-integration. More and more, competition takes place on the international level. Large, dominant national players compete on a European scale. A remarkable trend is that some incumbent EU-15 players enter at the markets of the EU-newcomers.

2.1.3.6. Policy

When analysing all national energy policies, the same concerns come forward all the time. The first, and major concern, is *security of supply*; security of supply, both in the sense of reaching a high reliability and safety standard, and of import dependency. The geographical position of the Central Eastern European countries can play a strategic role in the future import policy (especially for natural gas).

A second major concern is the *economic competitiveness* of the electricity and energy provision. It goes hand in hand with the *environmental policy*, which has to present cost efficient measures, so national productivity is not harmed. A clear regulatory framework and good communication between the several authorities is necessary to ensure a high level of *security of investment*. These are necessary base conditions to stimulate potential industrial investors.

Another important issue is the *social involvement* and the *social side of the energy policy*. A good price policy is of major importance. Prices have to reflect costs. This was certainly not the case in the formal centrally-planned states, where cross-subsidies and artificial low prices (in favour of the people) were normal practice. Now, those transition economies make their price policy cost-based. Very often this goes together with price surges, but in any case, it makes people aware of the costs of the energy they use. Taxes have a very large influence on the final energy prices as they can make prices artificially high. Between industrial and residential users, there exist large price differences. To conclude this paragraph on price policy, it is worthwhile mentioning that a good price policy can indirectly have a positive effect on the introduction of RES-technologies.

A last important policy concern is the *energy efficiency*. All member states are taking measures to unbundle the GDP-growth and the energy use. A lot of member states mention the importance of indicators for the evaluation of their policy.

It is worthwhile mentioning that two electricity production options are rather controversial in the EU, i.e. nuclear and coal-fired power plants. Camps, both in favour and against, exist among the member states. For the nuclear-based electricity production, some countries opt for a phase-out, because of alleged safety and environmental concerns, while others choose for new capacity and further R&D in the interest of fuel diversification and security of supply. A similar discussion is held for coal-fired plants, although this debate is less controversial.

To conclude, it follows from the analysis of the country reports and national policies, that the governments focus very much on the industry. For potential energy savings and efficiency measures, the households, the service & commercial sector and the transportation sector are rarely looked at.

2.1.4. Conclusion

It can be seen clearly that WP1 is an introductory chapter in the EUSUSTEL-project. Without going too much into details, it gives a good overview and a critical analysis of the energy and electricity provision of all 25 EU member states. Although all country reviews are written according to a provided template, national influences can be found in it. The reports reflect the European Union as it is: a mosaic of 25 countries, with their own culture and heritage, but within a global framework.

Nevertheless, it is not impossible to draw some general conclusion. All countries are faced with comparable challenges concerning energy, electricity and environment, and very often, comparable policies exist – within the national context – to cope with them.

Although the template is not focused on a small time window, it is important to realise that WP1 gives only a snapshot of the current situation of the member states: market situation can changes rapidly and policies can swing with elections, etc. This makes that the described results may not be extrapolated as such.

2.2. WP2: Anticipation of future electricity demand

WP-leader: AIEE

2.2.1. Introduction

All the activity concerning this WP was carried out during 2005, from the identification of the main specifications of the WP to the collection of bibliographic material and results of models to the production of the final report. The work was carried out by AIEE (Rome), KULeuven (Leuven) and ICEPT (Imperial College, London).

2.2.2. Mandate

Following a discussion among the involved partners and the coordinator of EUSUSTEL, the objectives of WP-2 were identified as follows:

1. Supply input data on: demography; economic evolution (GDP); price of primary fuel; other indicators to the Work-package 5, "Most optimal solution for electricity provision" and in particular to the Subtask WP 5.3 "Performing and interpretation of four (contrasting) scenarios with one or two of the most appropriate models (with 'improved' input data)"
2. Evaluate trends of demand for energy services and electricity demand (mostly by a top-down, macroeconomic approach)
3. Evaluate the effects of energy efficiency policies and DSM measures (particularly by using bottom-up models).

In consideration of the time and resources available for this Work-package, it was decided that recourse should be made as much as possible to the results already available from other projects modelling the energy and electricity scenarios for the European Union.

The reference time horizon for this study is 2030. The *geographical reference is EU-25*, i.e. the 25 Member countries of the European Union after the enlargement in 2004.

2.2.3. Scenarios considered

The main scenario studies the results of which have been used for the present analysis have been:

- EU-DG TREN European energy and transport trends to 2030 (PRIMES)
- IEA World Energy Outlook 2004 (WEO)
- US-DoE/Energy Information Agency, International Energy Outlook (2004 and 2005)
- EU-DG TREN White and Green Project results 2005

  These scenarios have been used both as concerns the choice of the exogenous input data and for the results of their modelling, particularly as concerns the anticipation of energy demand.

Data and insights have also been derived from the following sources:

- EU- DG RES, WETO-2030 World Energy Technology Outlook to 2030; WETO 2050
- EUROSTAT
- UN-Habitat
- IIASA

- World Energy Council

The final report analyses each of these models in terms of input, methodology etc.

2.2.4. Basic input data for the models

The inputs of the various models and in some cases their results have been analysed and compared in order to identify the most reasonable inputs to suggest for the modelling work to be carried out within EUSUSTEL (WP-5). They concern:

- Demography (where all models are very close to each other and predict a substantial stability of the population of the EU)
- Gross Domestic Product (where an yearly growth rate just above 2% is expected)
- Energy prices (where two scenarios are considered: a "low price" scenario that considers the present high prices as temporary and expects a return to the long-term trend, and a "high price" scenario where this rise is seen as structural).

Other possible inputs that have been considered include:

- The number of households (where the trend is toward an increase, even with a stable population, as the average number of persons per household tends to 2)
- The age distribution of the population (shifting to an older population in the EU, with possible repercussions on the type of energy services required).

2.2.5. Results

2.2.5.1. Top-down prediction of energy demand

The energy demand is evaluated first in a macroscopic, top-down approach in a rather aggregated form. The method followed is to correlate energy demand with GDP (Gross Domestic Product) through the consideration of energy intensity (energy demand per unit of GDP) taking into consideration that this intensity (in industrialised countries) is generally decreasing with time, both as a consequence of shifts in the composition of GDP towards less energy-intensive goods and services, and as a result of the introduction of progressively more efficient technology that allow to obtain the same (or equivalent) service or products with less energy. The energy demand may be subdivided in sectors (such as industry, transportation, residential and commercial) but the demand is not examined in detail.

Although the energy intensity is expected to decrease with time, its rate of decrease will not compensate for the increase of GDP, so that in the reference scenarios (i.e. in the absence of new, stringent initiatives in favour of energy efficiency) the absolute value of energy demand will continue to grow, although more slowly than the economy as a whole. The projected EU final energy demand by 2030 is just below 1500 Mtoe per year.

2.2.5.2. Top-down prediction of electricity demand

In this macroscopic approach, electricity demand is calculated starting from the energy demand (discussed above) by means of the "electricity penetration", i.e. the share of the final uses of energy that is covered by electricity.

In the majority of EU member countries, electricity penetration grows with time, both because the demand shifts towards more sophisticated energy services that are more likely to involve electricity than fuel (such as informatics and telecommunication) and because higher efficiency and increased automation can be obtained through electricity-based processes. This trend is expected to continue in the future, and the EU is likely to reach values of electricity share closer to countries like US and Canada, which are at least 2 to 4 %-pts higher than the average for the EU.

With an electricity penetration growth rate of 0.2-0.3% per year, electricity demand is expected to grow at a rate of about 1.3-1.4% per year, slowing down with time. Electricity demand in 2030 is expected to be of the order of 4000 TWh.

2.2.5.3. The demand for energy services

Passing from the top-down approach to the determination of the energy demand to a more detailed analysis based on a "bottom-up" approach, one should start from the definition of the demand for "energy services" which is the basis of this demand. Using indicators (such as population, GDP and number of households) as the starting point, the evaluation of the demand for energy services in the EU until 2025, calculated for each service by means of the WEU MARKAL model is presented. These demand values, coupled with a detailed data base on end use technologies, can be used for a bottom-up prediction of the energy demand. The following section goes back to a more macroscopic examination of the trends of energy consumption in the EU, but divided by sectors, based on the results of the ODYSSEE study of the EC.

2.2.5.4. Policy instruments to increase energy efficiency

A complex array of factors influences the evolution of demand for genuine energy services. Final energy demand is further influenced by the efficiency of device providing the service. The tension between increased demand for energy services (resulting in increased aggregate consumption) and improving energy efficiency is important. This can be done both by promoting a more "rational" behaviour by the consumer (in particular by discouraging waste) and by promoting (or enforcing) the adoption of more energy-efficient solutions.

The fact that externalities[9] are not included (or at least not fully included) in the price paid for energy, makes it unlikely that the market, left to itself, will take these externalities into account. For this reason, most people consider it appropriate that governments regulate the energy market and introduce price signals that take into account the societal aspects of the energy cycle, such as the protection of the environment, the stability of global climate etc.

Many types of energy policy instruments to improve energy efficiency are available and have been used in different contexts. On overview of the variety of such instruments and some attempts to classify them are presented in the report. A brief history of the recent efforts in directing legislation towards the promotion of energy efficiency at the level of the European Union is followed by an overview of the status of legislation in the Member countries, based on the results of the ODYSSEE study.

Finally, the problem of the promotion of the improvement in the efficiency of the final uses of energy is approached from a somewhat more general viewpoint, which discusses the theoretical approaches to Demand Side Management and Integrated Resource Planning: a view that may help in planning future moves towards converging instruments in the EU.

2.2.5.5. Bottom-up prediction of the effects of efficiency policies

The bottom-up approach starts with the break-down of the energy demand into sectors, and for each sector into specific energy services (e.g. for the domestic sector the energy services required will include space heating and cooling, lighting, cooking, food refrigeration and freezing, dish and laundry washing, entertainment etc.)

The demand for each service can be linked to an exogenous driver: population; GDP per capita; age distribution; family size etc.

The first step is therefore the identification of these drivers, their links with demand for specific energy services, their evolution with time. Once one has the projection of the demand for energy services, one can look into the best way (from the point of view of the market) to satisfy this demand: by which energy carrier and by which end-use technology (either already on the market or supposed to come to the market as time goes by).

The so-called “Negawatt debate” has shown that one can reach very different conclusions according to the assumptions made; some clarification of these bases is attempted. Without taking side in this controversy, some general requirements are identified in order to arrive at reasonable conclusions.

The representation of the policy instruments in the MARKAL models is then discussed. Although MARKAL, or other similar simulation instruments, are rather versatile and flexible, a sensible representation of the different policy instruments requires some care. Transaction costs are one of the elements that need to be taken into account.

Some results from the MARKAL EU simulation model obtained in the course of the White and Green Project are reported. They indicate that a saving of 15% in energy consumption would be economically possible even without considering indirect costs (externalities). If indirect costs are taken into account, this saving could reach 40%. Accompanying actions to remove market imperfections would be required.

Some limits of the model are then discussed. They include rebound effects, transaction and administrative costs and the phenomenon of “free riders”. The main recommendations issuing from the White and Green project are then listed: they go very much along the same lines identified in the present work.

2.3. WP3: Electricity generation technologies and system integration

WP-leader: HUT

2.3.1. Description of work

This work package concentrates on the description and analysis of the electricity supply. The most important technologies for electricity generation (and storage) have been treated, ranging from well-established ones all the way up to unconventional and even speculative conversion technologies. Each of these technologies has been scrutinised, especially with its potential for further development in the future. In addition, the integration of decentralised generation into the overall electricity generation system has been treated, both from an energetic-technical and environmental point of view. For each sub-work package, several partners (at least two) have been involved, to avoid bias. This work package is therefore subdivided into 4 sub-work packages, that is *Fossil-based electricity generation technologies*, *Nuclear electricity generation*, *Renewable flows and alternative technologies and carriers*, and *System integration*. These sub-work packages were in turn subdivided in subtasks, as listed below in Table 6.

3.1 Fossil-based electricity generation technologies:	
a.	Coal fired technologies
b.	Oil & gas fired technologies
c.	Combined heat and power
d.	CO2 capture and storage
3.2 Nuclear electricity generation	
a.	Nuclear fission
b.	Nuclear fusion
3.3 Renewable flows & 'alternative' technologies & carriers	
a.	Wind power
b.	Photo-Voltaic conversion
c.	Biomass applications
d.	Hydro power
e.	Geothermal conversion
f.	Fuel cells
g.	Hydrogen economy
h.	Electricity storage
i.	Less-conventional and speculative forms of renewables
3.4 System integration	
a.	Integration of centralised and decentralised generation; influence on the grid
b.	Greenhouse-gas emissions due to interaction centralised and decentralised generation

Table 6 Sub-work packages and subchapters of work package 3

The objective of the analysis of electricity generation technologies and their integration into the overall generation system was to result in identification of a realistic range of technical, environmental and economic characterising parameters for each technology, with a time horizon of 2005-2030. As this data would be used as input for work package 5, some effort was invested to achieve a good quality for the gathered material. Common templates were made for the sub reports themselves as well as the parameter lists to be gathered. This also aimed at helping the compilation phase of the reports that will be made on each sub-work package.

2.3.2. Results

In the following paragraphs, a brief overview of all technologies is given. Table 7 gives a *first overview* of the investment cost of some different technologies

Technology	Investment cost - range
Lignite, IGCC	± 1100 €/kW
Lignite, IGCC, with CCS	± 1400 €/kW
Lignite, ST, Advanced Techn	± 930 €/kW
Lignite, ST, Current Techn	± 1200 €/kW
Natural Gas, CC with CCS	830 – 950 €/kW
Hard coal	1100 – 1200 €/kW
CCGT	400 – 800 €/kW
CHP, large scale, coal	± 1200 €/kW
CHP, large scale, gas	± 500 €/kW
CHP, small scale, gas	± 600 – 1500 €/kW
Nuclear fission	1300 – 1600 €/kW
Wind power	800 – 1000 €/kW
Photo-voltaic conversion	3 -10 €/W
Biomass applications	1200 – 2200 €/kW
Hydro power	1400 – 1900 €/kW
Fuel cells (depending on type)	1000 – 70 000 €/kW
Marine & tidal	0.07 – 0.2 €/kWh

Table 7 First overview of investment cost of different technologies

2.3.2.1. Coal Fired Technologies

For Europe, coal, both hard coal and lignite, is an important energy carrier and part of a balanced energy mix. As the electricity demand is anticipated to continue to grow also in Europe, coal is expected to further on play an important role in the energy mix.

For the coal fired technologies, the Pulverised Coal Combustion and Integrated Gasification Combined Cycle (IGCC) power plant types using lignite have been analysed. Since IGCC power plants still are in their early stage of development, supercritical steam power plants will probably be the preferred coal-based power generation technology for installation of new capacity in the short-term, with a development towards more advanced steam conditions.

2.3.2.2. Oil and Gas Fired Technologies

Oil-fired power plants are not that common any more, and for the most part, electricity producers no longer invest in oil-fired capacity. Peak units running on jet fuel do exists, but more and more, they are replaced by more efficient and environment friendly gas turbines. These turbines can be used in a simple configuration (SCGT) or in a combined cycle (CCGT), which is the more advanced form of generation.

Gas turbines can be used to fire natural gas, biogas, or their combination. With the combined cycle the plant efficiency is very high and its exhausts limited, which makes it the most environmentally friendly of the currently popular fossil based technologies. Further improvements with CCGTs are going to be achieved by increasing further its efficiency.

The limited and regional nature of the natural gas resources is an energy security issue, when gas turbines are considered. Most likely by 2025 most of the European and North-African gas resources will be depleted and gas must be completely imported from far away locations. This makes the future gas delivery very vulnerable.

2.3.2.3. Combined Heat and Power

If used properly, cogeneration of heat and power is a very interesting technology to obtain primary energy savings and accompanying reductions in CO2 when generating electricity and heat. Also, economically, this technology may be attractive, although market circumstances may necessitate subsidy schemes to promote a certain market penetration.

From a technical point of view, several mature CHP-options are available, including steam turbines, gas turbines, reciprocating engines, and combined cycle power stations. Depending on the required power range, steam turbines, gas turbines, combined cycles or reciprocating engines are well-known solutions. New options for cogeneration applications, like the Stirling engines and fuel cells, are under development, but considerable advances have to be made before they will become competitive.

District heating is a widespread application of cogeneration. Several configurations, which make use of gas- or coal-fired technologies, are used. To increase the flexibility of the heating system, back-up boilers or heat storage tanks can be used. Although there are some examples where the use of district heating is advantageous, both from an energetic and economic point of view, one does not come to the same conclusion in every case. Especially the investment in a new heat-distribution grid may be precarious. Since newly built houses minimise the heat demand, due to the more stringent insulation requirements, and since the natural gas grid becomes more and more widespread, one needs to carefully analyse whether the centralised heating option is economically be preferred over individual heating.

2.3.2.4. CO_2 Capture and Storage

One way to reduce emissions from the use of coal is by capturing and permanently storing (sequestering) carbon dioxide. While capture and geological storage of CO_2 has not yet been demonstrated for the specific purpose of abating emissions from power stations, CO_2 separation is common in natural gas production and in gasification processes at petrochemical refineries. The injection of CO_2 into geological formations is being carried out routinely at more than 70 sites in enhanced oil recovery (EOR) operations globally.

It is unlikely that any technology combination that includes CO_2 capture and storage will be competitive with conventional coal-based PF generation, basically because of the additional efficiency loss and infrastructure. While those costs are certain to fall significantly over time, there is considerable uncertainty about both the cost of abatement and the impact on generation costs.

2.3.2.5. Nuclear Technologies (Includes WP3.2.1-2)

Nuclear energy, which already produces around 35% of the European electricity, is a key technology to fight again carbon dioxide emissions and for energy security supply. It also plays an important role in the energy security, as it produces electricity at a cheap price which remains stable for several decades almost independent of fuel prices.

The nuclear technology used to produce electricity in Europe, as well as in the whole world, is based on fission induced by slow neutron. Slow nuclear reactors burn essentially 235U which represents only 0,7% of natural uranium. The future of nuclear energy will be fast reactors which will be able to use also 238U. This new capability will make nuclear power really a long term energy solution.

Although nuclear power does not exhaust green house gases, it produces a radioactive waste. The highly radioactive nuclear waste is a long term waste that needs storage and a long term disposal site, which creates a significant expense. Another related expense is the dismantling of a nuclear power plant, when large amounts of low radioactivity waste need to be disposed.

Much effort is also put to further increase the security of nuclear power plants, as the marginal, but still existing potential for catastrophic accidents remains a public concern.

The fusion technology, on the other hand, can potentially provide a much less radioactive waste producing and safer power generation unit. Unfortunately, the commercial prospects of fusion technology have not been projected before 2050.

2.3.2.6. Wind Power

In Europe the best wind potential is available at the coasts UK, Ireland, Holland, France, Germany, Spain, Denmark and Norway, while the windy areas around Europe also offer a good potential. As these resources have been utilised, the European wind power generation capacity has experienced a large expansion during the last decade, leading to a total of 17GW installed in Germany alone by 2004. The increase in generation capacity has been much due to governmental support that is still needed before the technology becomes competitive without incentives.

The cost per produced kWh for new wind power units is decreasing regularly, mostly due to the increase in production volumes and average turbine size. Although reduction of the prices continuously slows down, it still offers a considerable future potential. Scaling up the turbine sizes will be the trend of the future as well, while the transport infrastructure is bound to set an upper limit at some point.

2.3.2.7. Photovoltaic Conversion

When individual photovoltaic conversion devises, namely solar cells, are combined into a solar panel, they provide an intermittent, renewable and easily available power source. When in use, solar panels need no maintenance and they have no moving parts, so the lifetime of a panel is up to 40 years. However, the system that delivers the electricity to the grid need occasional maintenance.

The environmental footprint of solar panels originates from their production. Main concerns are some hazardous substances that are needed with certain models and some types have very specific needs of rare materials. The overall energy payback time for a solar panel is 2-4 years.

Crystalline silicon solar cells are currently dominating the solar panel market with 94% share. The thin film cells that now have a 6% share still provide a very promising potential due to their much lesser need of the expensive silicon. It has been predicted that thin film tech should pass the crystalline cells in market share by 2030. In addition, many potentially significant solar cell concepts have been developed, but they most likely are not going to play a significant role in the market before 2030.

The increase in annually sold solar panels shows an exponential behaviour. As the production volumes increase, the prices per kW continuously reduces, feeding the process. Although this trend can only be temporal, very significant increase is expected in the contribution of photovoltaic conversion to the European energy generation in the next 25 years.

2.3.2.8. Biomass Applications

Biomass based electricity generation provides about 1.5% of the EU-15 energy generation capacity. The biomass power plants are generally applied as combined heat and power (CHP), where heat produced is utilised in industrial processes or district heating. In addition to direct combustion, also biomass co-firing with coal provides an interesting option for the power utilities. Other, typically small scale means of utilising biomass are gasification, pyrolysis, and anaerobic digestion.

Main issues that limit the competitiveness of bio electricity generation are the small unit sizes and the large transportation need of the feedstock due to its low energy content. Although biomass combustion is not yet competitive with the fossil fuels, the carbon neutral nature of the generation promotes its use. With CO_2 capture, bioelectricity potentially offers a sink for CO_2. In addition, further development of the pyrolysis techniques can provide a partial solution in the future to the transport issue of biomass feedstock.

2.3.2.9. Hydro Power

There are two principally different kind of hydro power plants, the medium to large scale units with a damn and a significant water reservoir, and the small size run-by-the river units, that lack any significant reservoir. The small size run-by-river units provide a rather intermittent energy source, where the electricity generation is depending on the seasonal water flow cycles of the river. There is still some potential in Europe for these small scale units, but their overall significance remains small.

Medium and large scale hydro with the water reservoir is economically very competitive although not without environmental controversy. As the units also provide a flexible tool for responding to load variation, suitable sites for hydro plants have already been well developed. On the environmental side the strong influence on the local water system has been most significant source of controversy in assigning new units. On the other hand, the GHG emissions of the water reservoirs are a climate dependent issue that can be addressed. Good deforestation and cleaning of pool area cuts down effectively emissions in the future as the pool is filled up.

Technical advances in hydro power turbines allow increasing the plant efficiencies with some percentages when old units are refurbished and equipped with state of art technology. This is the main development path available for the already build hydro power sites.

2.3.2.10. Geothermal Conversion

Geothermal energy is utilised by converting heat from the earth's molten interior to electricity. Presently, this conversion can be performed at natural hydrothermal systems such as hot springs, but in the future geothermal energy may also be gained from hot dry rock, magma and geopressurised systems. The primary benefits of geothermal energy are reliability, predictability, easy regulation of production and limited land usage. The environmental effects of geothermal energy are in general small, although CO_2 emissions can vary a lot depending on the geological structures of the thermal reservoir.

The price of geothermal energy today is in the range 16–80 € / MWh. The price is significantly affected by the difficulty of predicting the potential of geothermal energy on a given site. At the present time, about 50% of initial investment costs are needed for identification and characterisation of suitable heat reservoirs. The technologies being used today include conventional steam plants and binary cycle plants. The worldwide geothermal electrical capacity today is approximately 9 000 MWe, and a linear extrapolation of recent growth data suggests that it could reach 14 000 MWe by 2030.

2.3.2.11. Fuel Cells

Fuel cells produce electricity through reactions between oxygen and a suitable fuel, with water as the primary reaction product. Potential application areas for fuel cells have a very wide power-range from battery replacement in consumer electronics to domestic power, transportation, CHP production and large-scale power generation. The versatility arising from the modularity of fuel cell systems and the high efficiency at partial load are some of the main attractions of fuel cells. Fuel cells are also environmentally benign. The CO_2 emissions in fuel cell usage depend mainly on the type of fuel used, but fuel cells are in general competitive in terms of emissions when compared to other energy conversion methods for each fuel. Using hydrogen in fuel cells gives electricity without any CO_2 emission.

Material research is a key component of fuel cell development. Technologies can be grouped into solid oxide, molten carbonate, polymeric electrolyte, direct methanol, phosphoric acid and alkaline fuel cells. In general, the first two of these are at the present time considered best suited for large scale electricity production, but significant developments in fuel cell technology are expected in the future so predictions are difficult to make. Demonstration projects from 1 kW to 250 kW have been implemented, but fuel cell technology will be used also in larger applications as the technology develops. The market for fuel cells is still quite limited today, but micro CHP is expected to be the first area where significant commercial growth can be expected.

2.3.2.12. Hydrogen Economy

Hydrogen is considered a promising energy carrier for the future, particularly as a fuel in the automotive sector. It has recently been estimated that the share of hydrogen vehicles could be 15% of the European car fleet in 2030. Hydrogen can be produced and transported in several different ways. The costs and environmental aspects of hydrogen economy scenarios therefore depend strongly on the assumptions being made regarding future developments in these areas. The market for hydrogen energy applications is very small today, so the economic aspects of hydrogen utilisation are difficult to estimate. Studies on the CO_2-emissions of hydrogen transportation applications have yielded estimates between 20 to 400 g of CO_2 per MJ. Hydrogen energy technology includes fuel cells and electrolysers, and also internal combustion engines for hydrogen. In addition to transportation applications, hydrogen energy usage can be considered beneficial if the primary energy resource is remote, if the availability and demand for energy do not coincide and as back-up or off-grid power.

2.3.2.13. Electric Storage

To be submitted.

2.3.2.14. Less-Conventional and Speculative Forms of Renewables

Marine current energy converters can be used to harness tidal and ocean currents for electricity production. In today's applications, energy is usually captured from free-flowing water rather than from gradual release through a tidal barrage. The primary benefit of tidal energy is that it is very predictable and has a high degree of utilisation, approximately 80%. Marine energy converters do not produce any emissions during operation, but the total environmental impact of this energy source has not yet been investigated.

No full scale marine energy farms have been implemented yet, but different converter types have been demonstrated with success. These include particularly marine current turbines and oscillating hydrofoils. The cost of marine and tidal current energy has been estimated to be below 0.12 € / kWh in the first commercial applications, and costs in the range 0.04 – 0.10 € / kWh should be realistic in the future. An important challenge at hand is demonstration of the technical viability of the currently available converters. This is expected to mark the beginning of commercial marine current and tidal electricity generation.

2.3.2.15. Environmental assessment and life cycle analysis

In this sub-task chosen electricity generation technologies were analysed from the environmental point of view, with a horizon of 2030-2050. The technologies under the scope are pulverised coal combustion, integrated gasification combined cycle (IGCC), combined cycle gas turbine (CCGT), combined heat and power, and CO_2 capture and storage (CCS), and biomass gasification. The methodology used to perform this task is largely based in the *Life Cycle Analysis methodology*, using nine different impact categories.

The analysis included four phases: classification, characterisation, normalisation and weighting. In the classification phase, the qualified and quantified environmental loads are assigned, on a qualitative basis, to the impact categories. In the characterisation step, the environmental loads, previously assigned qualitatively to one or more impact categories in the classification phase, are quantified in terms of a common unit for that category by using characterisation factors. Normalisation serves to indicate the share of the results in a worldwide or regional total. The last phase in the impact assessment is the weighting. In this phase the normalised indicator results for each impact category are assigned numerical factors according to their relative importance, multiplied by these factors and aggregated into a single score that represents the environmental performance of each technology.

For current technologies, biomass gasification and CCGT have turned out to have the lowest impacts while lignite ones have had the highest results. For future technologies, those with CO_2 capture and sequestration showed the best results. Regarding the different impact categories, the more relevant, from highest to lowest, have been global warming, acidification, eutrophication, and photochemical oxidation.

2.3.2.16. Integration of Centralised and Decentralised Generation; Influence on the Grid

Definition

The term distributed generation (DG) is commonly used, although there is currently no common agreement on its exact definition. The term distributed generation will be further used to depict an electric power generation source connected directly to the distribution network or on the customer side of the meter.

Benefits

Distributed generation main contributions are improved electricity market liberalisation and ecological benefits.

In a liberalised market environment, distributed generation allows customers to look for the electricity services best suited for them. One of the most interesting features is the flexibility of DG that could allow market participants to respond to changing market conditions. DG can be used to hedge against price fluctuations.

DG can provide additional quality of supply and reliability. Due to the incentives for cost-effectiveness, and the re-regulation of network companies, reliability levels could decrease. DG could be a means to increase the total reliability. Apart from reliability problems, DG can provide additional power quality improvement.

Environmental policies or concerns are currently probably the major driving force for DG in Europe. Environmental regulations force players in the electricity market to look for cleaner energy and cost-efficient energy. Many of the DG technologies are recognised as environmentally friendly. Furthermore, being by nature small-scale and dispersed over the grid, DG units allow the exploitation of cheap fuel opportunities.

Difficulties

The relation between power quality and distributed generation is not straightforward. On one hand, distributed generation contributes to the improvement of power quality. In the areas where voltage support is difficult, distributed generation offers significant benefits for the voltage profile and power factor corrections. On the other hand, large-scale introduction of decentralised power generating units may lead to instability of the voltage profile. The bi-directional power flows and the complex reactive power management can be problematic and lead to voltage profile fluctuation. Additionally, short-circuits and overloads are supplied by multiple sources, each independently not detecting the anomaly. An increasing share of DG will generally increase the capital cost per kW installed, as DG technology is quite expensive.

Distributed Generation Trends in EU-15

DG in Europe consists mainly of wind power and CHP. The largest installed wind power generation capacities are in Germany, Denmark and Spain. Denmark, Finland and Netherlands have the highest installed CHP capacity. Turbines and reciprocating engines fuelled by natural gas and oil are the dominant technologies for distributed generation applications. Microturbines are increasing their shares and fuel cells may have good prospects in the field if cost reductions can be achieved.

For the year 2000, CHP accounted for almost 10% of electricity generation in the EU-15. Denmark, followed by the Netherlands, were the leaders in CHP-based electricity production, while Greece and Ireland display the smallest figures. Germany's CHP electrical output in absolute figures (60.8 TWh) is the highest in Europe.

2.3.2.17. Greenhouse-gas Emissions Due to Interaction Centralised and Decentralised Generation

In order to make an evaluation where all aspects of electricity generation, including interaction of the different generation units and their emissions of GHGs, are kept in mind, a detailed simulation is required. In this discussion, detailed simulation results for a typical generation mix in Belgium were used to find the overall CO_2-emission of the whole system, including decentralised generation.

Case studies clearly demonstrate that some impacts can be estimated with simple back of the envelope calculation, but that precise quantification of an impact always has to be the result of a simulation. When a scenario becomes complicated (for instance simultaneous demand and supply side actions), a-priori statements are difficult or even impossible to be made. Therefore, simulation of electricity generation for all relevant scenarios is essential in order to study the impact of demand or supply-side options, or both at the same time.

If an application is promoted or prohibited, the instantaneous fuel mix for electricity generation changes. Reduction (increase) in demand does not result in the same relative reduction (increase) for all active power plants. Instantaneously, only the most expensive plants are shut down (activated) or modulated. The properties of the *average* system are not relevant because incremental changes in demand only affect the activation of this limited number of plants, characterised by their own emissions, efficiency and fuel costs.

2.3.3. <u>Conclusions</u>

While the fossil based technologies still offer a backdoor option for electricity generation the next 25 years, there are no fundamental breakthroughs on sight that would provide a smooth transition to green house gas free power generation. Nuclear power combined with the bioelectricity would have the capacity, but at the same time some EU citizens have clearly expressed their discontent towards a large-scale utilisation of nuclear power. If other options are desired, significant policy measures might be needed concerning the renewable technologies and/or clean coal technologies to speed up their progress. But then again, who is ready to pay?

Work package 3 attempts to gives a detailed description of all energy generation technologies that are commonly utilised in the EU. Although all technology reviews are written according to a provided template, some differences in the quality of the reports and in particularly in the related data remain. This issue needs to be addressed in one form or another, but still the main objectives of this work package have been achieved successfully.

2.4. WP4: Regulatory and Market Framework of Energy Markets

WP-leader: KULeuven

2.4.1. Description of work and deliverables

In the full report on this work package, provided as an annex to this summary, firstly the current legislation and regulation of energy markets are discussed. In this first section, the content of the main European Directives and Regulations establishing the current energy market in Europe are discussed. Next, a state of affairs of the internal energy market is presented. Finally, boundary conditions and guidelines for the proper functioning of future energy markets are provided.

2.4.2. WP 4.1 Analysis of the current legislation & regulation

2.4.2.1. The Directives

Firstly, the two founding Directives 96/92/EC and 2003/54/EC concerning common rules for the internal market in electricity are being looked at. These Directives establish common rules for generation, transmission, distribution and supply of electric energy. Generally, the first Directive allowed nearly everything, except an integrated internal market. The second Directive 2003/54/EC is characterised by shorter-term deadlines and less freedom. This is reflected among others in the rules on market opening. Where the first Directive aimed at a slow, gradual and partial opening of the Member States' markets, the new Directive 2003/54/EC dramatically accelerated this process: all non-households customers are eligible from 1 July 2004 and all consumers will be eligible from 1 July 2007. Also the access to the grid is regulated more strictly in the 2003 Directive. Under the first Directive, Member States could choose between negotiated or regulated third party access or the single buyer procedure when organising the access to the transmission and the distribution networks. Directive 2003/54/EC limits the options to one regime, being regulated third party access, and requires the appointment of a regulator, having to approve tariffs, monitor congestion management, and act as a dispute settlement authority. Under both Directives, Member States must designate one or more transmission and distribution system operators. While the first Directive required only an administrative unbundling of these network operators, the second goes a step further requiring legal unbundling. Both directives allow Member States to impose public service obligations on electricity undertakings in their market within one of the following five categories: security of supply, regularity, quality and price of supply and environmental protection, including energy efficiency and climate protection. Regarding the stimulation of investment in new capacity, the main instrument under the second Directive is the authorisation procedure. In case of insufficient investments in generation capacity when using such a procedure, Member States must stimulate investments in new capacity through a tendering procedure.

2.4.2.2. Florence Forum and ERGEG

The Directives set out the general framework and principles for the introduction of competition in the electric energy industry. However, in line with the principle of subsidiarity, much of the practical and technical details of implementation are left open to national interpretation. Nevertheless, while creating an internal market, co-operation and co-ordination between Member States are of vital importance. Therefore, the Electricity Regulatory Forum of Florence (*"Florence Forum"*) was set up as consultative body to discuss the creation of a true internal electricity market. Participants are national regulatory authorities, Member States, the European Commission, transmission system operators, electricity traders, consumers, network users, and power exchanges. Another advisory group established to assist the European Commission in consolidating the internal market is the European Regulators Group for Electricity and Gas (ERGEG). Its members are all regulators from the EU, with regulators from new Members States and the European Economic Area acting as observers. Also the Commission is represented and will keep the European Parliament informed on the Group's activities on an annual basis. With the establishment of ERGEG, regulatory co-operation and co-ordination have been given a formal structure. ERGEG's primary responsibility is to help ensure a consistent application in all Member States of the most recently adopted Directives and Regulations and to coordinate the preparation of the progress reports national electric energy regulators must publish yearly under the 2003 Electricity Directive.

2.4.2.3. Congestion management and cross-border exchanges of electric energy

Several initiatives have been taken to increase the amount of cross-border electricity trade. The European Union co-finances electricity and gas transmission infrastructure projects of European interest under the Trans-European Energy Networks program (TEN-E). A annual budget of about 25 M€ is spent mainly for supporting feasibility studies. Also, Regulation 1228/2003 on conditions for access to the network for cross-border exchanges in electricity was issued. In this Regulation, a compensation mechanism for cross border flows is established and harmonised principles on cross-border transmission charges and on the allocation of available interconnection capacities between national transmission systems are introduced.

2.4.2.4. Security of energy supply

In 2000, the European Commission adopted a Green Paper on Security of Energy Supply. The main incentive of this Green Paper was Europe's constantly increasing external dependence for energy. The Green Paper outlines a long-term energy strategy with an emphasis on controlling demand by, for example, promoting more energy efficiency. Also, an analysis of the contribution of nuclear energy in the middle term is recommended, as well as a stronger mechanism to build up strategic stocks and to foresee new import routes for increasing amounts of oil and gas.

The debate on the Green Paper resulted in 2003 in a Proposal for a Directive. The proposed Directive establishes measures aimed at ensuring the proper functioning of the EU internal market for electric energy by safeguarding adequacy of supply and by ensuring a sufficient level of interconnection capacity between Member States to ensure competition at European and national level. According to the Proposal, Member States have the duty to ensure that network operators comply with co-operation such as the UCTE's operational handbook. The Proposal repeats that Member States are obliged to take appropriate measures, including supporting efficient use of energy as well as encouraging new generation companies to enter the market, to ensure that there is a balance between the supply of electric energy and the availability of generation capacity. It adds that Member States in particular have to require TSO's to ensure an appropriate level of reserve capacity. In addition, Member States may take additional measures to achieve these objectives, including but not limited to:

- Promotion of demand management
- Interruptible customers
- Obligations on suppliers and\or generators
- The establishment of a wholesale market framework with a sufficient number of competitors that provides suitable price signals for investment and consumption.

Both for the transmission and distribution networks, investments in demand side management measures should be given priority in so far as they can replace the need for network or generation investments. Under the Proposal, TSO's regularly have to submit a document setting out their investment intentions for the provision of an adequate level of cross-border interconnection capacity to the regulatory authority. After having approved investment plans, the regulatory authority has to take the TSO's investment strategy into account when approving the methodology for network access tariffs and needs to ensure that TSOs are adequately rewarded for investments made. In the event that, for whatever reason, the TSO fails to make sufficient progress in important infrastructure projects, the regulatory authority is given certain rights to ensure that progress on the approved investment strategy is satisfactory, in particular by one of the three following measures:

- Imposing financial penalties on TSO's whose projects fall behind schedule.
- Issuing an instruction to the TSO to undertake work by a certain date.
- Arranging for work to be undertaken by a contractor through a tender process.

2.4.2.5. Sustainable energy

In 2001, a Directive on RES was issued aiming at increasing the contribution of RES to electric energy generation up to 12% of gross inland energy consumption from RES for the Community as a whole by 2010, of which electric energy would represent 22.1%. It concerns electric energy generated from non-fossil energy sources such as wind, solar, geothermal, wave, tidal, hydropower, biomass, landfill gas, sewage treatment plant gas and biogases. In the Directive, national indicative targets for the share of electric energy generated from renewable energy sources in gross electric energy consumption for 2010 are published. In order to attain these targets Member States can apply mechanisms according to which a generator of electric energy receives direct or indirect support. According to the Directive, by the end of 2005 the Commission should present a report on the experience gained concerning the application and coexistence of the different support schemes in the Member States. If necessary, this report will be accompanied by a proposal for a Community framework for support schemes for RES-E. Also according to the Directive, Member States should issue guarantees of origin to enable RES-E generators to prove that the electric energy they sell is generated from RES. These guarantees of origin are to be mutually recognised by the Member States, exclusively as proof of electrical energy's origin. One major barrier to the further development of RES-E is the administrative and planning procedures that potential generators must respect, which is particularly a problem for small and medium-sized companies (SMEs), making up a significant share of companies in this sector. With this in mind, Member States are required to review their existing legislative and regulatory frameworks concerning authorisation procedures in order to reduce obstacles. Moreover, connection to the grid can be expensive for generators of RES-E. To this end, Member States are to require network operators among other things:

- To guarantee the transmission and distribution of RES-E. Member States may agree on priority access for RES-E. When dispatching generation installations, priority shall be given to installations using RES insofar as the operation of the national electricity system permits.
- To define and publish standard rules on responsibility for the costs of technical adaptations needed to enable a new RES-E generator to feed its electric energy into the grid. The Member States may require network operators to bear some or all of these costs.

Member States must ensure that transmission and distribution costs do not in any way discriminate against RES-E. Member States are also required to examine measures to be taken to facilitate the access of RES-E to the grid, considering in particular the need to introduce two-way metering.

In 2004, a Directive has been issued on the promotion of cogeneration, employing similar principles regarding support schemes, guarantees of origin, grid connection issues and so on. However, for cogeneration no national indicative targets are published. Member States must analyse the national potential for the application of high-efficiency cogeneration. In the Directive, “high efficiency cogeneration” is defined as combined generation of heat and electric energy resulting in energy savings of at least 10%, compared to separate production. The Directive aims at establishing a harmonised method for calculation of energy savings by CHP. The Commission must by 21 February 2006 establish harmonised efficiency reference values for separate production of electric energy and heat for the purpose of determining the efficiency of CHP. The Commission will review these harmonised values every four years, to take account of technological developments and changes in the distribution of energy sources.

2.4.2.6. Climate Change

In 2002, the European Union ratified the Kyoto Protocol to the United Nations Framework Convention on Climate Change. By this, the EU-15 committed themselves to reduce their collective emissions of the six key greenhouse gases by at least 8% during the period 2008 to 2012 compared to 1990-levels. The Member States distributed this target among themselves using a so-called “bubble”. Equally New Member States are assigned individual targets under the Kyoto Protocol. In order to achieve the emission reduction objectives in the most cost-effective way, the Kyoto Protocol allows 3 flexible mechanisms: Joint Implementation (JI), Emission Trading (ET) and the Clean Development Mechanism (CDM). As of 1 January 2005, an emission trading scheme is in operation in the European Union. Initially it is limited to CO_2 and to the energy sector, iron and steel production and processing, the mineral industry and the wood pulp, paper and card industry, but it can easily be expanded to other greenhouse gases and sectors. It starts with an initial three-year commitment period, followed by subsequent five-year periods as of 2008. In this context, "allowance" means the entitlement to emit a ton of CO_2 or an amount of any other greenhouse gas with an equivalent global warming potential during a specified period.

The Directive stipulates that from 1 January 2005, all installations in the sectors mentioned that are emitting the greenhouse gases included must be in possession of an appropriate permit issued by the competent authorities. Each Member State draws up a national plan, indicating the allowances it intends to allocate for the relevant period and how it proposes to allocate them to each installation. At least 95% of the allowances for the initial three-year period are allocated to the installations free of charge. For the five-year period beginning 1 January 2008, Member States must allocate 90% of the allowances free of charge. Allowances issued by a competent authority of another Member State must be recognised for the purpose of meeting an operator's obligations. Any operator failing to surrender the required quantity of allowances is obliged to pay an excess emissions penalty. The penalty is €100 for each ton of CO_2 equivalent (€40 during the first three-year period starting on 1 January 2005) and does not release the operator from the obligation to surrender an amount of allowances equal to the excess emissions the following year. Member States shall provide for the establishment and maintenance of a registry in order to ensure accurate accounting of the issue, transfer and cancellation of allowances.

The so-called "Linking Directive" of 2004 reinforces the link between the Union's emission allowance trading scheme and the Kyoto Protocol by making the latter's "project-based" mechanisms (JI and CDM) compatible with the scheme. This linking enables operators as of the five-year period starting 1 January 2008 to use allowances obtained by both mechanisms in the allowance trading scheme to fulfill their obligations. During the first three-year period, only credits from projects under CDM can be used in the Community scheme. According to the Kyoto Protocol, the project-based mechanisms should be supplemental to domestic action. Therefore, Member States should decide on limits for the use of credits from CDM/JI.

Current state of affairs on electricity markets

To what extent the regulatory framework described above has resulted in a true European internal energy market can be evaluated based on the overall progress reports issued yearly by the Commission. Besides these annual progress reports, the European Commission publishes annual benchmarking reports, providing an overview of market opening, third party access, unbundling, etc. per Member State. Also, the Commission has recently published a detailed report outlining the progress made on creating the internal electricity market requested by the 2003 Directive.

In this report, the lack of integration between national markets is identified as the most important and persistent shortcoming of the internal market. Two key indicators are mentioned in this respect: the absence of price convergence across the EU and the low level of cross-border trade. These are said to be generally due to the existence of barriers to entry, inadequate use of existing infrastructure and insufficient interconnection capacity between many Member States, leading to congestion. Moreover, according to Regulation 1228/2003 non-discriminatory market based mechanisms have to be applied for the allocation of capacity on congested interconnectors from 1 July 2004 onwards. This has not happened in all cases. Many delays have been recorded and not all Member States have complied with this deadline.

Moreover, it is reported that many national markets display a high degree of concentration and industry has been further consolidating since market opening started, impeding the development of effective competition. In addition, an increasing number of cross-border acquisitions and a tendency towards vertical integration between generation and supply in some Member States are observed. Another indicator of the lack of real competition raised is the fact that switching by customers remains limited in most Member States, and that choosing a new supplier from another Member State remains the exception.

Full, complete and effective implementation of the second Directives is said to be the main immediate action necessary. Most Member States missed the deadline of 1 July 2004 for their transposition, some not yet having them implemented at all. On top of that, many have taken a rather "minimalist" approach in implementing the Directives, which needs to be re-considered. The Commission states they will continue to insist on compliance, and already opened infringement procedures against Member States for failure to implement the Directives.

2.4.3. WP 4.2 Specification of boundary conditions and guidelines for proper functioning of future energy markets

In March 2004, the European Commission's DG for Energy and Transport proposed a practical way forward in its medium term Strategy Paper, which sets out the Commission's vision on the development towards an internal electric energy market. Moreover, there is a broad consensus within the industry regarding its content since this document has been compiled in response to the request and with the co-operation of the participants in the Florence Forum. Also academics have expressed their view on the development of the electric energy market in Europe. The "Sustainable Energy Specific Support Assessment" project (SESSA project), funded by the Sixth EU RTD Framework Programme and grouping researchers as well as energy stakeholders, was closed in September 2005 by the conference "Implementing the Internal Market of Electric energy: Proposals and Time-Tables". From the SESSA research program, 20 priorities on what to do next were derived. In the second part of this fourth work package, seven key action areas are discussed based on the Commission's view on the main issues presented in its Strategy Paper, supplemented with positions of various industry groups. Finally, a section is added on the technical consequences and implications of regulatory decisions.

2.4.3.1. Increasing role of regional markets

The reality of today's electric energy network is that Member States are electrically not particularly well interconnected. In addition, certain countries have already adopted common harmonised rules that, in some cases, go beyond those envisaged by the 2003 Directive and the Regulation on cross-border trade. Therefore, the development of regional markets, not defined according to mere geographical criteria but containing Member States between which interconnection is reasonably strong, may be a necessary interim stage. The proposed approach is that a pan-European market should evolve through the development of these regional markets which should then be linked together to form the internal electric energy market. Within these regional markets, a more developed harmonisation of the regulatory approach taken to most or all issues, is expected, including degree of market opening, determination of transmission tariffs, rules for bilateral trading and congestion management methodologies involving standardised day ahead and intraday markets. In some cases, regulations governing balancing and ancillary services might also be harmonised to some degree. However, any such effort needs to take into account, for example, the different generation plant characteristics in Member States and the costs involved in implementing such measures.

2.4.3.2. Integrating markets

Increasing coupling between member state submarkets is another step to be taken in the development of the European internal electric energy market. In its road map to a pan-European market, Eurelectric declares that a series of strongly interlinked wholesale markets resulting in as large price areas as possible and ultimately – if possible – in one single pan-European price area is the way towards a well functioning pan-European market for electric energy. Therefore, participants of different national or regional wholesale markets must be able to act in different markets and consequently a high level of compatibility in structures, market rules and the regulatory framework is needed, although full harmonisation is not required. According to Eurelectric, it is essential that marketplaces fulfil at least the following criteria:

- Have a sufficient number of market participants in the day-ahead and forward markets, in particular more large consumers from the demand side;
- Provide transparent access to common sets of market information;
- Have market-based mechanisms for congestion management;
- Have liquid day-ahead and forward markets and open balancing and intra-day markets with trustworthy prices.

The need for a balancing market is also stressed in the SESSA research program and the second Directive. Also at the Florence mini-for a, the further integration of European electric energy markets through regional intra-day and balancing markets is said to be beneficial and feasible.

2.4.3.3. Developing cross border trade: transmission tarification and congestion management

According to the Commission's Strategy Paper, the following specific objectives should be pursued in the medium term in the context of cross-border trade:

- Inter TSO compensation should allow for suitable compensation between Member States for, as a minimum, transit flows and other cross border flows in some cases;
- Transmission charges on generators should be harmonised within a fairly narrow range with, if appropriate, some locational signals introduced at EU level;
- Interconnection capacity should be allocated by non-discriminatory, market based mechanisms consisting of either:
  - within regional markets, a single common co-ordinated market-based mechanism which allows for both "market coupling" encompassing existing day-ahead and possibly intra-day spot markets via the adoption of a common timetable, as well as long term financial hedging;
  - between regional markets**,** specific market based mechanisms which as far as possible allow for coupling of wholesale markets;
- A high degree of transparency should be provided to network users, including publication of necessary data relating to transport capabilities of interconnector lines.

Finally, in this context it is important to review the rules used by TSOs to deal with internal transmission congestion. TSOs should not, in general, be permitted to systematically transform internal constraints into constraints at borders. This is for example done in Nordel, where it is the rule that all internal problems are shifted as much as possible to the borders, after which the market is splitted. Reasonable balance must be drawn between the needs of national network users and those from other Member States.

Congestion management was also the topic of a separate round of regional Florence mini-fora organised end of 2004 and the beginning of 2005. Resulting from the mini-fora, there are plans now for all interconnectors with non-market based capacity allocation methods to move to market based methods by the beginning of 2006. ERGEG stated in its overall assessment of the mini-fora that a compatible congestion management method for Europe must be able to accommodate both implicit and explicit auctions, with explicit auctioning being the minimum requirement for congested interconnectors in Europe.

2.4.3.4. Reduction of market concentration

According to the Strategy Paper, Member States should seek to dilute the market power of dominant generating companies and\or to prevent the abuse of dominant positions as follows:

- Investment and capacity release could be used in some cases to reduce the level of concentration, with reciprocal measures between two or more Member States with similar concentration problems;
- Appropriate design of mechanisms to allocate interconnector capacity should mitigate and not add to market power problems within certain Member States and regions;
- Market design should encourage an appropriate mix of both short term trading and longer term bilateral arrangements in order to avoid encouraging collusion;
- The relevant authorities should, on the basis of the necessary information provided by TSOs and power exchanges, monitor the behaviour of market participants closely and should act, using, inter alia, existing competition law and other relevant legislation, to protect consumers from manipulation: ad-hoc intervention in the market should be avoided and this points to the embedment of appropriate market rules designed to prevent undesired manipulations;
- Generators should be required to make transparent, in a consistent manner at European level, their decisions on the availability of generation plants and, where appropriate provide forecasts of availability;
- Demand side participation in wholesale and balancing markets should be encouraged in order to significantly increase the elasticity of demand for electric energy within individual settlement periods and thus reduce the scope for abuse of dominant positions.

Despite the need for some measures to reduce market dominance, it is also important to acknowledge that some of the expected benefits of competition are likely to arise from consolidation to take advantage of economies of scale and scope that exist in this capital intensive industry. Companies should not, in principle, be prevented from taking such actions to improve their performance provided that customers are protected from monopolistic or oligipolistic practices and that new entrants and smaller companies are not unduly disadvantaged. This comment is also made by Eurelectric, that underlines the fact that big players should not be considered responsible for the fact that their size is already of a European dimension whereas the market dimension is lagging behind. Eurelectric notes that the electric energy sector is a capital intensive industry and that the critical mass therefore is rather large. In their opinion, calling for divestment and related measures merely because of the size of market players would constitute unfair discrimination inconsistent with competition law. There, it is a consistent principle that dominant players in a market do not raise any concern as long as these players do not abuse their dominant position: according to Eurelectric, behaviour and not size should be the criterion.

2.4.3.5. Adequacy of supply

It is necessary for Member States and Regulators to decide what approach they intend to take to the issue of maintaining the balance between supply and demand and stick to it. The Commission's Strategy paper stated that ad-hoc intervention in electric energy markets should be avoided. The proposed Directive on Infrastructure and Security of Supply therefore requires Member States to publish their approach to this issue. A clearly stated approach is vitally important to obtain a stable "market design" at national level in order to encourage the appropriate investments. The proposal also seeks to clarify the responsibilities, in particular, of transmission system operators in ensuring the ongoing balance between supply and demand in real time. The proposed Directive does not, at this stage, explore a more fundamental question about whether the issue of adequacy of supply should be dealt with at national or regional level. From the point of view of economic efficiency, it is clearly of benefit if Member States can share reserve capacity since it means a lower level of reserve is needed in each individual Member State. However at the very least, in an integrated market, a strong unilateral approach to adequacy of supply would not be appropriate. This has implications for treatment of interconnection capacity if one country is relying on another to provide reserve capacity. It also means that there needs to be a clear code of conduct on TSOs wishing to take action to restrict cross border flows in emergency situations.

A different issue relating to generation investments are the procedures required in terms of authorisation and planning approval. The process may be unnecessarily heavy in some Member States and be an unnecessary obstacle to investment. A more streamlined and harmonised process would remove such obstacles. It may be that a comparison of the authorisation and planning process between Member States would allow for the spread of a best practice approach.

2.4.3.6. Consistent support framework for sustainable energy

Although this is not a requirement of the Directive, Member States are encouraged to develop schemes to promote RES and CHP being the least interfering with competition and consistent in terms of the basic framework and include mutual recognition of energy generated from RES/CHP. This would have the advantage of establishing competition at two levels: in the generation market for conventional fuels as well as, separately, in the green market and this would be expected to increase the cost effectiveness of support. Existing support schemes should therefore be reviewed with a view to bringing them further in line with market mechanisms. Due attention must be given to avoid disproportionate distortions of the market, in particular through Member States adopting different and potentially incompatible policies.

The different support schemes for RES, CHP, energy efficiency and the ETS will interact and have an important impact on the functioning of the electric energy market. Because of the different goals these different programmes pursue they might reduce each others efficiency. Therefore, interactions between these different programmes should be carefully monitored to guarantee that one programme’s targets do not counteract another. In a recent report published by the European Commissions DG for Environment, the interactions between the EU ETS and certificate systems are discussed. This report illustrates that the presence of these different programmes on one hand influence key variables of the electric energy market such as the wholesale and retail electric energy price, the demand for electric energy and so on. On the other hand, it is shown that one programme might affect the goals of the others and that these programmes interact in complicated ways, with interactions transmitted through wholesale and retail electric energy markets, through markets for the various commodities created by the programmes (i.e., CO_2 allowances, green certificates, and white certificates), and through other markets (e.g., fuel, labour).

Besides the different goals and interactions of the different support schemes, another issue to consider is a possible European harmonisation of support schemes for RES and CHP. On 7 December 2005, the Commission published a report on the support for RES. The currently implemented support schemes were assessed based on their level, effectiveness and investor’s profit per technology. As expected, the Commission did not regard it as appropriate to present at this stage a harmonised European support scheme. Instead, it calls for a coordinated approach based on two pillars: cooperation between countries and optimisation of the impact of national schemes.

Consistent regulation

Interactions between Directives and Regulations do not only occur in the field of sustainable energy. Eurelectric showed that in the energy field, a number of Directives reinforce and support each other, but that there is also evidence of conflicting effects among a number of Directives. Such inconsistencies have the potential to create confusion and uncertainty and, in the case of the electric energy industry, tend to increase the industry's risks and costs. They could in some cases even undermine the ability of the industry to deliver efficiently on energy policy goals. In the EU regulatory and law-making process the single energy market, security of supply and environmental sustainability are on a separate agenda. This could result in failures instead of synergies. For instance, renewable energy policies often raise new obstacles to competition on wholesale markets and to availability of interconnections. The regulatory framework in the energy field, as in all other areas, should be coherent and consistent with the general framework of a single European market.

Technical consequences and implications of regulatory decisions

The European Internal Electricity Market is not only governed by legislation, but also by the laws of physics. Therefore, the legislative and regulatory framework has to comply with the technical boundary conditions. This is vitally important when considering the representation of the electricity grid, where a choice has to be made between simplicity and correctness.

The European electricity grid is quite well interconnected. Especially in the UCTE area, power flows in virtually any region influence the remainder of the synchronous area. However, the general grid management philosophy applied in Europe is that the internal networks of each country are strong enough to accommodate any possible internal load and generation dispatch: the control zones are considered to be copper plates. The main constraints are assumed to be located on the international interconnections. This makes Europe a zonal market, with the control areas (generally countries) treated as copper-plates connected with thin threads representing the constraints on cross-border flows. The consequence of this zonal approach to grid management is the treatment of cross-border capacity. As in a zonal model each country is represented by its equivalent node, it is impossible to capture the influence of the internal dispatch on individual cross-border lines. Moreover, due to the highly meshed nature of the European grid, even in the presence of balanced control areas (no imports/exports) there are significant power flows on the cross-border lines.

Zonal models are the easiest to implement and are most commonly used in market models, where in each country there is one price, and where a market between neighbouring countries can exist. This model however disregards the difference between transmission capacity and transfer capacity, introducing difficulties. Physically, the electrical grid consists of nodes connected by lines and/or transformers. However, in a zonal model, clusters of nodes (typically belonging to the same control area or a country) are aggregated into zones. Such zones are considered as copper-plates, i.e. internal transmission constraints are ignored. Zones are connected to other areas by means of virtual links, which in some way aggregate the transmission capacity of individual, physical lines linking nodes belonging to both zones. The capacity of these virtual links is designated as transfer capacity.

Since the TSO's must ensure that the power flows always comply with security limits, some restrictions might be put on the cross-border flows. These limits are expressed in terms of cross-border transfer capacities, giving the maximum power exchange between the zones concerned. However, the latter is not equal to the sum of the physical capacities, but is a result of existing or forecasted network conditions, strongly depending on nodal power injections and power flow patterns.

Aggregated transfer capacities in a zonal network model can also be affected by the shifts of generation within a control zone, as they influence the power flows on the interconnections. Depending on network topology and predictability of the internal dispatch pattern, variations of nodal power injections can have a significant influence on the variation of cross-border flows. Therefore, these capacities are very sensitive not only to the investments (reinforcement of cross-border interconnection, new transmission lines, FACTS and other flow control devices), but also to the changing load and generation pattern. However, both investment decisions and changing power flow patterns are difficult to forecast. Additionally, increased penetration of unpredictable wind energy systems leads to less predictability of the load generation dispatch, negatively influencing the accuracy of the zonal network representation and the capacity available for trade.

Distribution of power flows in the grid can be simulated using either full AC power flow or a simplified DC approximation. The DC method introduces a number of simplifications in the way the grid is studied (i.e. neglects line resistances and reactive power management), but, provided certain criteria are met, it proves to be sufficient to model active power flows. Thanks to its robustness and simplicity the method is very often employed for techno-economic studies.

2.5. WP5: Most optimal solution for electricity provision

WP-leader: IER

2.5.1. Description of work

The main focus of this work package is to analyse an optimal solution for electricity provision based on already available data as well as data that has to be evaluated within in the EUSUSTEL study regarding energy technology and its development, related external effects, energy prices and policy measures. The work package is divided into three subtasks, i.e. "Determination of the overall static social for electricity", "Comparison and evaluation of simulation models and existing scenarios for electricity generation" and "Performing and interpreting four (contrasting) scenarios with one or two of the most appropriate models (with 'improved' input data")."

2.5.2. Organisation of Work package 5.1

The main objective is to determine the overall static private and external cost of electricity generation technologies for the years 2005, 2010, 2020 and 2030 (cf. Figure 2). For the cost calculation discount rates of 5% and 10% per annum real are going to be intended.

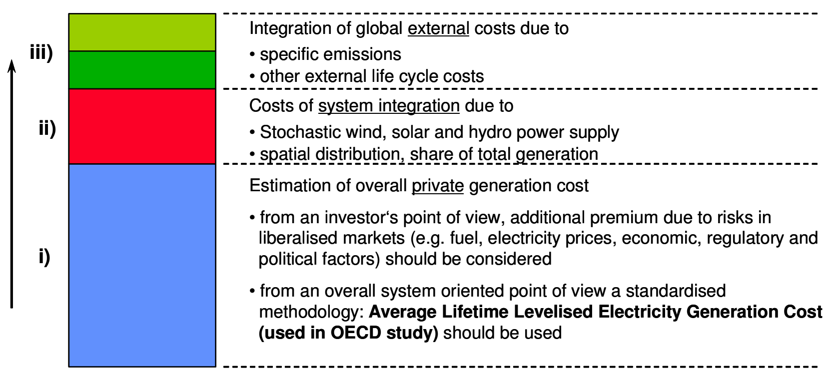

Figure 2 Approach for calculation of overall static social cost of electricity generation[11]

2.5.2.1. Subtask 5.1.i

Taking into account the data provided by the project partners of WP 3, the private cost of electricity generation for the various technologies will be determined using the "Average Lifetime Levelised Electricity Generation Cost" approach. Considering the private cost calculations for generation technologies going to be installed in 2025 or 2030, fuel price projections (as given in the hypotheses in WP8) are required for at least 2030 plus 40 years.

[11] The 'overall static social cost of electricity generation' is defined in the Description of Work at p. 14. This is the combination of all private and external costs at rated/nominal conditions of the technology. Another term for this cost is, 'Total average lifetime levelised electricity generation cost'.

2.5.2.2. Subtask 5.1.ii

The determination of the cost of system integration (ct/kWh) should be provided mainly for RES technologies such as wind, solar, hydro, geothermal and others fluctuating energy sources (cf. Figure 3). This information should be based on representative stochastic energy supply for different countries, e.g. averaged solar radiation in Italy and Spain for solar PV and averaged wind speed for Denmark and Germany for wind power production. A distinction has to be made between centralised and decentralised generation. Following the IEA/OECD study 2005 the cost factors that should at least be considered are:

- Operational costs in managing intermittency wind power
- Costs in keeping additional reserve generation as backup
- Costs in reinforcing the grid and maintaining system control

The information about costs of system integration will be considered within the calculation of the overall static social cost for electricity generation.

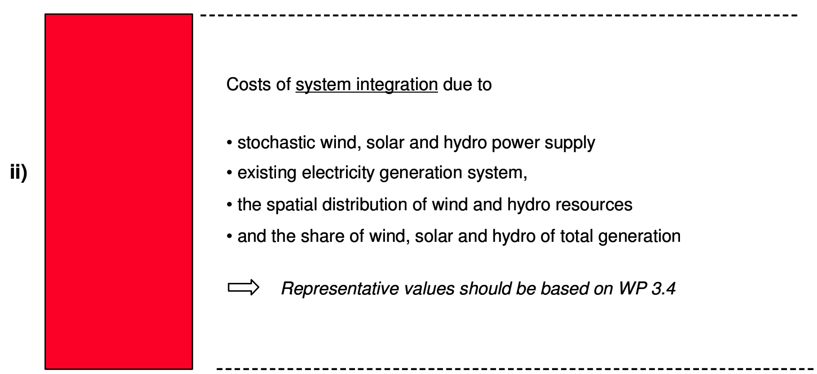

Figure 3 Cost of system integration

2.5.2.3. Subtask 5.1.iii

For calculating the global external costs for each generation technology in subtask 5.1.iv, data concerning the ecology and resource use provided by WP 3 are required as input. It is necessary that the emission data include both, the direct emissions by operation (tonne/GWh) and the indirect emissions based on construction (tonne/kW) of the regarded power plant as well as the related fuel cycle. These data should be available in detail at least for the air related emissions such as CO_2, SO_2, NO_x, PM_{10}, etc. The information is required for both direct and indirect emissions, i.e. separately.

Given the various emission categories, the external costs will than be calculated applying the EXTERNE approach, restrict the monetisation to air pollution. Assuming linerarised dose-response relationship, external cost calculations will be provided for the years 2005, 2010, 2020 and 2030. It is recommended that the above information will be provided for different countries within the EU-25.

2.5.2.4. Subtask 5.1.iv

Beside the technology-oriented calculation of the overall static social costs of electricity generation, the differences of CO_2 emissions due to electricity generation in different countries as recommended in subtask 5.1.iii will be identified. These analyses can be based on the generation mix of some particular countries. Given this information, it is possible to qualitatively interpret (and to 'qualify') the results to be obtained in the subtasks of 5.1.

2.5.2.5. Results

Work package 5.1 is projected to be finalised until the end of month T_0+15 of the project. Work is in progress.

2.5.3. Organisation of Work package 5.2

The main objective is to compare and evaluate existing scenarios for electricity provision in Europe as well as the energy models used to provide impact to the design of the scenarios in work package 5.3 and to identify appropriate models to perform the scenario runs.

For comparing and evaluating the scenarios and the energy models, which focus on the development for electricity provision in Europe up to the year 2030, five studies will be analysed.

1. World Energy, technology and climate policy outlook – WETO
2. World Energy Outlook – WEO
3. European energy and transport – Trends to 2030
4. Assessing Climate Response Options: POLIcy Simulations – ACROPOLIS
5. System Analysis for Progress and Innovation in Energy Technologies – SAPIENT

The selected studies are supposed to be a good survey of scenario based analyses for the European energy systems. Taking Europe as one world region or focusing on different countries within Europe, one will get a broadly based overview of possible scenarios and adjunct probable outcomes of European energy policies.

To describe these studies with respect to selected scenarios, the evaluation of the main focuses and main assumptions of the studies as well the used energy models are analysed in a standardised way. The organisation structure of the analyses is as follows:

2.5.3.1. Part A: Scenario and Model Review

I. Scenario Review

The comparison and evaluation of the scenarios of each above mentioned study, address the following aspects and make the following information available.

1. Main Focus of the Study: What are the main focuses of the studies and which technology and policy oriented questions are addressed? Key questions could be:

- Technological Developments in Electricity Generation
- Security of Supply
- Environmental Impact of Different Policy Scenarios

2. Key framework assumptions – Development of parameters over time for the years 2005, 2010, 2020 and 2030

- Gross Domestic Product
- Population
- Households
- Fuel Prices
- Policy for Nuclear Electricity Supply
- Regulatory Framework

3. Scenarios analysed within the different studies

- Philosophy and Characterisation of the Analysed Scenarios
- Description of the Main Scenario Assumptions

4. Main results of the different scenarios with special focus on the electricity provision. Results should be provided in form of a table (see Table 8) for the years 2005, 2010, 2020 and 2030.

<table>
<tr><th>Scenario</th><th colspan="2">Indicator</th><th>Fuel</th><th>2005</th><th>2010</th><th>2020</th><th>2030</th></tr>
<tr><td rowspan="13">Baseline

Scenario (i)

..

Scenario (n)</td><td colspan="3">Cost of Electricity Generation [Euro Cent/kWh]</td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="10">Installed Electricity Generation Capacity and Production in Europe by Fuel</td><td rowspan="5">Installed Capacity [GW_e]</td><td>Coal</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Gas</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Oil</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Nuclear</td><td></td><td></td><td></td><td></td></tr>
<tr><td>RES</td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="5">Electricity Generation [TWh]</td><td>Coal</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Gas</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Oil</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Nuclear</td><td></td><td></td><td></td><td></td></tr>
<tr><td>RES</td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="3">CO_2 Emissions by Electricity Generation</td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="3">Share of Domestic Primary Energy Supply [%]</td><td></td><td></td><td></td><td></td></tr>
</table>

Table 8 Reporting table for main results of the various scenarios

II. *Model Review*

The analysis of the models used for computing the different scenarios within the selected studies provide rationales for the deviating results. Taking a more differentiated look on the modelling and analytical framework, one might better understand the differences in the model results and might have a more comprehensive overview of the reasons for the observed deviations.

Reviewing the different approaches is fruitful for analysing the specific strength of the models and the necessities regarding the regional and technological diversification of the models for providing sophisticated scenario results for the European Union. For describing the existing models with respect to the selected studies, the following aspects provide an overview of the main differences in the used models.

- Type of model, e.g. optimisation, simulation, applied general equilibrium, top-down, bottom-up
- Objective function, e.g. overall cost minimisation with respect to energy or electricity, utility maximisation
- Regulatory framework, e.g. assumptions on the European energy and electricity markets, respectively
- Modelling of dynamic behaviour within the model, e.g. perfect foresight or myopic expectation, i.e. intertemporal or recursive dynamics, respectively
- Regional diversification and degree of aggregation, e.g. EU-15, EU-25, individual countries
- Time horizon, e.g. 2020, 2030, 2050, 2100
- Segmentation with respect to
  - Time steps
  - Markets, e.g. energy, electricity, heat, emission rights
  - Sectors, e.g. industry, conversion, transport, households
- Environmental aspects which are taken into account

III. Comparison of Various Scenarios and Models

Comparing the various scenarios and models by using the standardised information and data is a basis for analysing the deviating results that could be found within the available studies. It provides good insights for policy makers to interpret model results and evaluate the analysed scenarios.

2.5.3.2. Results

An overview of the ACROPOLIS project can be found in the appendix WP5-2-A. For the World Energy, Technology and Climate Outlook (WETO) project results can be found in appendix WP5-2-B. The analyses of the studies World Energy Outlook, European energy and transport – Trends to 2030 and SAPIENT is ongoing. Due to the ongoing work on the overview reports for these studies, a scenario and model comparison can not be provided yet.

2.5.4. Organisation of Work package 5.3

The main objective is to perform and interpreting four (contrasting) scenarios with one or two of the most appropriate models (with 'improved' input data). The model based scenario analyses will among other things take project results of WP2, WP3, WP5-1 and WP5-2 into consideration.

Given the evaluation of technological and cost related data in the previous WPs, the following models will be applied to analyse the four scenarios:

Model 1: TIMES-EE, developed and applied by IER – University of Stuttgart
Model 2: PRIMES, developed and applied by E3M Lab – National Technical University of Athens

1. Baseline scenario: High prices + no post Kyoto limit + baseline nuclear and other options
2. Same as scenario 1, but post Kyoto of -16 %
3. Same as scenario 2, but free nuclear option (no extra promotion on other options)
4. Same as scenario 3, but promoted energy efficiency and distributed generation.

Detailed scenario assumptions and promotion measures in scenario 4 have to be further discussed.