EUROPEAN PARLIAMENT

Science and Technology Options Assessment

S T O A

FUTURE ENERGY SYSTEMS IN EUROPE

STUDY

(IP/A/STOA/FWC-2005-28/SC20)

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DIRECTORATE GENERAL FOR INTERNAL POLICIES

POLICY DEPARTMENT A: ECONOMIC AND SCIENTIFIC POLICY

SCIENCE AND TECHNOLOGY OPTIONS ASSESSMENT

FUTURE ENERGY SYSTEMS IN EUROPE

STUDY

Abstract

The European energy sector faces critical challenges in the future. In order to shed light on different pathways towards achieving these goals a number of energy scenarios for the EU27 have been developed within this project.

The focus of the scenario building procedure is on the overall energy system, showing how the different elements of the European energy systems interact with each other, and how different combinations of technology choices and policies lead to different overall results.

The project explores two essentially different developments of the European energy systems through a so-called *Small-tech scenario* and a *Big-tech scenario*. Both scenarios aim at achieving two concrete goals for 2030: reducing CO_2 emissions by 50 per cent compared to the 1990 level, and reducing oil consumption by 50 per cent compared to the present level.

Among the project recommendations are saving energy (as being less expensive than producing energy), stimulate the development of district heating and district cooling grids to facilitate the utilization of waste heat, large-scale integration of variable renewable energy sources, strengthening and coordinating the European electricity infrastructure, three levels of transformation needed in the transport sector (fuel efficiency, introduction of electric vehicles and modal-change, new resources (the sustainable European biomass for energy purposes, municipal waste). A continued effort is also required to researching and developing technologies (wave and solar power, Carbon Capture and Storage and safe nuclear power).

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FUTURE ENERGY STYSTEMS IN EUROPE

Scenarios towards 2030

Final project report

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1 EXECUTIVE SUMMARY

The European energy sector faces critical challenges in the future; fuel supplies must be secured and greenhouse gas emissions reduced significantly while maintaining a high level of economic growth. In order to shed light on different pathways towards achieving these goals a number of energy scenarios for the EU27 have been developed within this project.

The focus of the scenario building procedure is on the overall energy system, showing how the different elements of the European energy systems interact with each other, and how different combinations of technology choices and policies lead to different overall results.

Halving CO_2 emissions and oil consumption

The project explores two essentially different developments of the European energy systems through a so-called *Small-tech scenario* and a *Big-tech scenario*. Both scenarios aim at achieving two concrete goals for 2030: reducing CO_2 emissions by 50 per cent compared to the 1990 level, and reducing oil consumption by 50 per cent compared to the present level.

Small-tech scenario

The Small-tech scenario focuses on distributed energy generation, energy savings and efficient utilisation of energy through smarter devices and combined heat and power generation. In this scenario, so-called smart grids and better communication between all elements in the energy supply chain allow for the integration of a high share of non-dispatchable generation, wind and solar power for example.

Big-tech scenario

The Big-tech scenario explores the opportunities of more centralised solutions. In Big-tech, almost all new coal and natural gas power plants established from 2020 and onwards are equipped with CCS (Carbon Capture and Storage) technologies, and the generation from nuclear power is increased by 40 per cent compared to today. Moreover, it is assumed that all new large coal power plants commissioned in the period 2010-2020 are prepared for CCS and retrofitted in the subsequent decade.

Or a combination

The scenarios illustrate two different developments of the future European energy systems – which some might find extreme. Therefore, it is important to note that the measures in each of the scenarios are not mutually exclusive. For example, CCS technologies could be applied in the Small-tech scenario to reduce emissions even further, or more energy savings could be harvested in the Big-tech scenario to reduce the demand for energy. A combination of the two scenarios may lead to even greater reductions or provide added certainty of achieving the existing targets.

Another combination would be that some member states actively pursue the Small-tech scenario, while others pursue the Big-tech scenario.

Requirements for transformation

The requirements for transformation of the energy sector are quite different in the two scenarios. In the Small-tech scenario, European citizens play an important role as active consumers of energy, changing energy behaviour according to price signals and investing in energy-efficient appliances and buildings; grid owners must rethink their system architecture and the suppliers of energy will have to change sources gradually from large power plants to renewables and to distributed units located closer to the consumers.

In the Big-tech scenario, the existing structure of the energy supply system remains essentially unchanged, and the large suppliers of electricity become the main actors. Thus, the implementation of the Big-tech scenario depends on relatively few decision-makers.

Transport sector

The transport sector undergoes fundamental changes in both scenarios in order to achieve the targeted oil reduction. In the Small-tech scenario, electric vehicles and plug-in hybrids displace oil consumption, and information and communication technologies are put in place to decrease the demand for "physical" transportation.

In the Big-tech scenario, 2^{nd} generation biofuels and natural gas become important means, in addition to the electrification of the transport sector. Moreover, and of great importance, both scenarios assume that the significant technical potentials for improving the fuel economy of conventional vehicles are partly realised.

Results

In the Small-tech scenario, it is foreseen that the gross energy consumption is reduced by almost 20 per cent in 2030 compared to 2005. In the Big-tech scenario, gross energy consumption increases by 7 per cent compared to today. This increase, which is slightly higher than in the 2030 reference projection, is mainly due to increased utilisation of carbon capture and storage technologies which are expected to require a considerable expenditure of energy, particularly for the capture and transportation of CO_2. In the Big-tech scenario, compliance with the CO_2 reduction target is secured by annually storing almost 1 Gt of CO_2 underground in 2030.

Figure 1: Gross energy consumption in 2005 and projections for 2030 (excluding fuels for non-energy purposes)

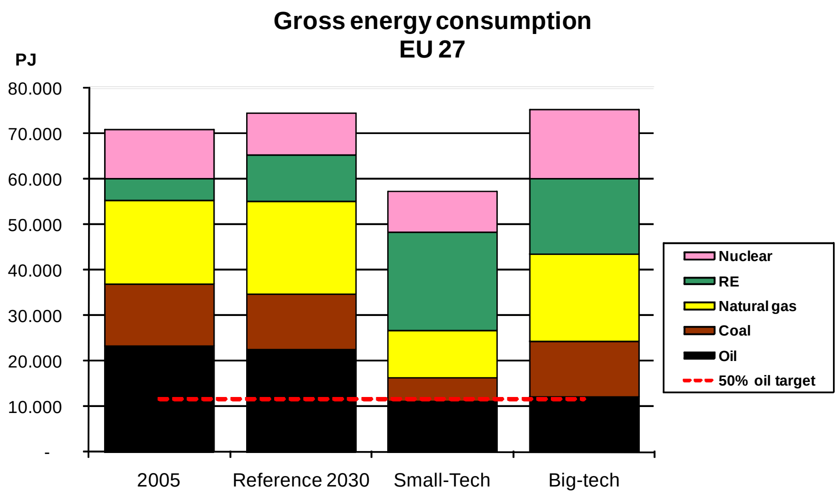
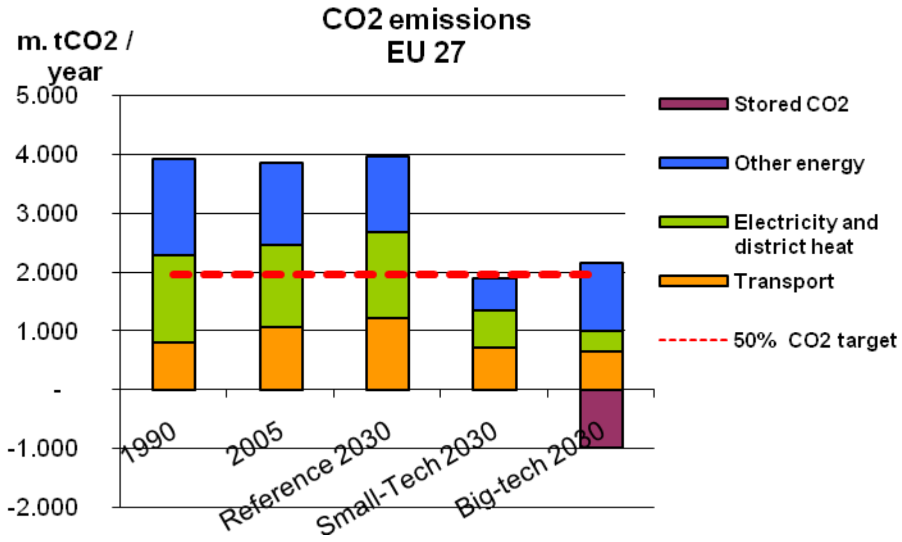


Figure 2: CO_2 emissions from the energy sector in 1990, 2005 and projections for 2030



"Other energy" includes oil, gas and coal used in households, industry and the trade/service sector.

Ensuring the security of the fuel supply poses a big challenge in both scenarios – and particularly in the Big-tech scenario due to its relatively high gross energy consumption. Oil production in the EU27 will only be able to meet approx. 15 per cent of oil demand, since oil production in 2030 is expected to be only a third of the current production. In the Big-tech scenario, the dependence on imported gas is projected to be 80 per cent compared to 66 per cent in the Small-tech scenario.

Indigenous coal production and consumption balance in the Small-tech scenario, whereas about half of the consumed coal has to be imported in the Big-tech scenario.

Economics

An economic comparison of the scenarios and a business as usual projection for 2030 show that it is not more costly to reduce CO_2 emissions and oil dependency than to continue on the present track. This is the case with "high" fuel prices ($ 108 per bbl of oil), and when a more conservative fuel price projection is applied ($ 62 per bbl of oil).

In both reduction scenarios the average annual economic growth rate is assumed to be well over 2 per cent in the period until 2030.

To realise the scenarios, investments in the energy sector need to be increased considerably. In the Small-tech scenario, there is a need for additional investments of around 135 b€/year, and in the Big-tech scenario the figure is around 85 b€/year when reaching 2030. However, these investments are more than offset by fuel cost savings and costs of emitting CO_2. In the calculations, a CO_2 price of 45 €/ton is applied for 2030.

Scenario characteristics

Scenario characteristics and key figures are summarised in Table 1.

Table 1: Scenario characteristics and key figures

		2005	2030 Small-	2030 Big-tech
Annual GDP (Gross Domestic Product)		-	2.1%	2.1%
Total final energy demand		50,300 PJ[1]	42,400 PJ	52,500 PJ
Gross energy consumption		70,900 PJ	57,400 PJ	75,300 PJ
System conversion losses		29%	26%	30%
Electricity demand		10,100 PJ	10,800 PJ	14,200 PJ
District heating/cooling (% of final energy demand[2])		4%	18%	9%
Renewable energy (% of gross energy consumption)		7%	38%	22%
Electricity supply (% of electricity production)	Power plants CCS	0%	0%	25%
	Nuclear	30% (134 GW[3])	23% (104 GW)	30% (174 GW)
	Wind	2%	16%	9%
	Solar	0.2%	5%	0.8%
	Wave	0%	2%	0%
	Bioenergy[4]	4%	19%	13%
Transport[5]	Fuel economy	160 g CO_2/km	100 g	100 g
	Electric	0%	15-25%	15-25%
	Biofuels	1%	5%	15%

[1] PJ (Peta Joule)

[2] Excluding final energy in the transport sector

[3] GW (Giga Watt)

[4] Including biomass, biogas and municipal waste

[5] The transport figures apply to passenger cars

Critical assumptions

The actual implementation of the scenarios and associated benefits depend on a number of critical assumptions summarised in Table 2. Most important in the Small-tech scenario is the assumption that it is possible to realise a substantial share of the huge theoretical potential for energy savings.

In the Big-tech scenario, the access to and availability of gas, coal and uranium at reasonable prices is probably the most critical assumption. Moreover, CCS technology needs to be commercialised.

Table 1: Critical assumptions for the realisation of the scenarios

Critical assumptions	
Small-tech scenario	**Big-tech scenario**
• Energy saving potentials are realised (many barriers that are not only economic) • Local planning effort to expand district heating and cooling systems (to enjoy benefits of combined heat power) • Significant improvement of the economy of solar power	• Natural gas, coal and uranium are accessible at reasonable prices. • Commercialization of carbon capture and storage technology is necessary • Public support for more nuclear power
Both	
• Considerable improvement of the fuel economy of new cars • Electric vehicles or plug-in hybrids are commercialized	

The way forward

The scenarios focus on the technical and financial perspectives of the various technologies. Which policy measures could or should be applied to reach the desired outcome has not been analysed in detail. Consequently, the effects of trade in CO_2 quotas, certificate systems, taxes and similar measures have not been examined separately in the work with the scenarios.

Most of the technologies applied in the scenarios are already commercially available, but research, development and demonstration efforts are urgently needed to further develop electric vehicles, CCS technologies and certain renewable energy technologies, such as solar and wave power. Therefore, it is important to *keep all doors open*: having the possibility of combining measures from the two scenarios provides greater certainty that the long-term objectives can be achieved. The measures in each of the scenarios are not mutually exclusive.

Long-term targets for the energy and transport sectors are needed as well as framework conditions and measures that may contribute to pushing the development in the desired direction. Energy savings is a very important measure for securing future energy supply and reducing CO_2 emissions.

The legal framework concerning energy savings is present at many levels. At the EU level it will be important to further develop ambitious efficiency measures, labelling, and norms for appliances and buildings.

Locally, municipalities and cities are important stakeholders with respect to shaping transport policies, facilitating district heating infrastructure and setting and enforcing standards for energy consumption in buildings, for example. Furthermore, through procurement policies and renovation of public buildings, the local authorities have a great chance to promote best practices.

Project recommendations

Saving energy is less expensive than producing energy. A number of studies indicate that there is a large potential for cost-effective energy savings in Europe. A continued and amplified effort is required at all policy levels to realize this potential. Electrical appliances have a quick turnover, and therefore actions taken in this field will have significant impact in the short term. Measures to improve the insulation of buildings are often most effective, when carried out as part of a renovation and for this reason have a longer time horizon.

Today, vast amounts of energy are lost at thermal power plants across Europe, because the surplus heat from electricity generation is not used for energy purposes. A targeted effort is required to stimulate the development of **district heating and district cooling grids** to facilitate the utilization of waste heat. This calls for a changed power plant infrastructure with more small units located closer to the consumers of heat and cooling.

Large-scale integration of **variable renewable energy sources** like wind power, solar power and wave power will make new requirements to the way electricity systems are designed and operated. Flexible markets are needed, where consumers, through tariffs and price signals are encouraged to respond to the variations in energy prices – and where inter connectors between different systems are fully utilized to enjoy cross-border trading and to smooth out variations from renewable energy generators. **Strengthening and coordinating the European electricity infrastructure** will become a key measure in the future to allow for a high share of variable renewable energy sources.

Three levels of transformation are needed in the transport sector. Firstly, the **fuel efficiency** of conventional cars has to be improved considerably. Technically, an improvement by at least a factor of two is possible. Secondly, to reduce the dependency of oil and further increase the energy efficiency of cars, it will become essential to introduce **electric vehicles** in large scale in the transport sector. Alternatives are hydrogen based vehicles and biofuels, but the conversion and transformation losses for these technologies are considerable higher than for electric cars. Thirdly, measures have to be taken to encourage **modal-change** (car/flight/lorry => train/light-rail/bike,) and new ways to improve the mobility in society, without increasing the demand for physical transportation – for example by increasing to use of **Information and Communication Technologies**.

The sustainable European **biomass** for energy purposes will become a most wanted resource in a carbon constrained future. To obtain as high a replacement of fossil fuels as possible, from an energy system perspective, it is recommended to use the biomass mainly for power and heat generation, because of the process energy required to produce biofuels for the transportation sector.

Municipal waste is an overlooked energy resource in many European countries. By utilizing municipal waste in new effective combined heat and power plants it can deliver a significant share of the demand for heating and electricity.

A continued effort is required to **researching and developing** technologies like wave and solar power, which today are not competitive for large scale electricity generation. Demonstration of Carbon Capture and Storage and safe nuclear power is also recommended though it should be acknowledged that due do the reliance on fossil fuels CCS may only be a transitional solution to the long-term challenges faced by the energy sector.

2 PREFACE

In 2007-08, the Science and Technology Options Assessment Panel in the European Parliament, STOA, commissioned the project Future Energy Systems in Europe (FESE).

The project was conducted by the Danish Board of Technology, one of the partners of the STOA framework contractor within the European Technology Assessment Group (ETAG).

The Danish Board of Technology cooperated with consultants from Ea Energy Analyses, Denmark and Risoe National Laboratory for Sustainable Energy, Technical University of Denmark.

Supervisors of the project were MEP, Mr. Joel Hasse Ferreira and MEP, Mr. Anders Wijkman.

It was a main goal of the project to have a dialogue with politicians in the European Parliament and to involve different actors within the European energy fields - researchers, consultants, enterprises and institutions – so as to stimulate interdisciplinary discussions on energy scenarios, energy data, energy modelling and energy options for the future. This is done from a systems-perspective in the sense that the project is not so much a conjunction of singular energy-technology analyses but instead offers an analysis of the interconnectedness between such technologies in the total energy system.

The project involved a wide range of experts who engaged in dialogues with stakeholders and politicians to improve the level of details as well as the scope of the scenarios for the future of European energy systems. It was also important to encourage discussions on robust energy solutions based on energy system considerations and a mix of technology - rather than focussing on separate technology solutions.

Based on the objectives of improving the security of fuel supply and significant reductions in future oil consumption and CO_2 emissions, the STOA project on "Future Energy Systems in Europe" developed a set of technology scenarios for the energy systems in Europe by 2030. The different characteristics, opportunities and priorities for the energy sector in different parts of Europe were integrated in the energy scenarios for five archetypical EU countries representing different conditions in their existing energy sector and different opportunities to meet the objectives. Common EU27 scenarios were developed based on the regional energy scenarios.

A major achievement of the project was the application of the STREAM energy model, previously developed for the array of energy technologies and geographical situation existing in Denmark, to the European level. The energy model is capable of delivering fast, user-friendly pictures of both present and future energy situations in Europe.

The STREAM model is a public domain open source modelling tool. The original set of energy technology data has been expanded to also include nuclear power and Carbon Segregation and Storage (CSS), which are or may be of relevance to the European energy systems. Further, a data import module has been added in order to provide for easy update of the European energy data from the European Commission. Some modifications in functions and references in the spreadsheet calculations have been coded in order to make the STREAM model applicable on these European data sets. The STREAM model, thus, has shown to be applicable on the broader European energy systems, on specific EU27 countries as well as on European regions with different geographic conditions.

The scenario work was presented and input was provided by MEP´s and stakeholders in the energy field of Europe at a workshop in November 2007 in The European Parliament, Brussels, at a Dinner Debate in April 2008 in the European Parliament, Strasbourg and at a workshop in September 2008 in The European Parliament, Brussels.

In addition, several meetings with the supervisors of the project were held concerning the planning of the project process.

The project facilitated an open process between members of the European Parliament, energy specialists and stakeholders. Participants were eager to give feedback on the data, the scenarios and assumptions that were used as input in the STREAM model. The workshop in November 2007 emphasised stakeholder and expert-feedback, and underlined the importance of a system approach to the energy sector, in order to create an intelligent energy infrastructure that can facilitate more renewable energy sources, including solar power and more efficient use of energy, such as district heating and cooling. These points were welcomed by the project team and helped forming future process of refining the STREAM scenarios.

The Dinner Debate in April 2008 presented an opportunity for members of the European Parliament to have a focussed and detailed interaction with the energy experts. This created more understanding of both the ongoing EU policies on energy and how these considerations could be taken into account in the scenarios. It was recommended that a separate scenario assessing the potentials of the CCS technology (Carbon Capture and Storage) be included in the project and it was suggested to explore the potentials of policies to promote Information and Communication Technologies as a means to reduce energy consumption by facilitating less energy-intensive social practises, such as video conferences in favour of flying people in for a meeting..

It also became even clearer that the municipalities and cities have a very important role to play if the scenarios of the project are to be implemented in practice.

As a consequence the final workshop in September 2008 presented several speakers from cities in Europe to discuss the present and future challenges for the future energy systems in Europe. The latest STREAM model scenarios were presented, the Big-Tech and Small-Tech scenarios, as the two major scenarios to focus on when having discussions on possible energy system pathways in Europe 2030. These were discussed and the result was useful input for the project-team to finish the scenario – and project work.

As a key outcome of the project, two essentially different developments of the European energy systems were described and quantified through the above-mentioned Small-tech scenario and a Big-tech scenario. Both scenarios aim at achieving two concrete goals for 2030:

- Reducing CO_2 emissions by 50 per cent compared to the 1990 level and
- Reducing oil consumption by 50 per cent compared to the present level.

This report presents the Small-tech scenario and the Big-tech scenario, the key measures in each scenario, the systems' impacts and environmental and economic consequences. The modelling tool STREAM, including all data and results, can be downloaded from the website of STOA and the Danish Board of Technology[6].

[6] http://www.europarl.europa.eu/stoa/default_en.htm;
http://www.tekno.dk/subpage.php3?article=1442&survey=15&language=uk

The project team would like to thank the two supervisors of the project MEP, Mr. Joel Hasse Ferreira and MEP, Mr. Anders Wijkman for their commitment and devoted interest.

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And thanks to Mr. Miklós Györffi from the STOA administration for his cooperation on the many events during the project period.

Figure A: Chronological process of the project

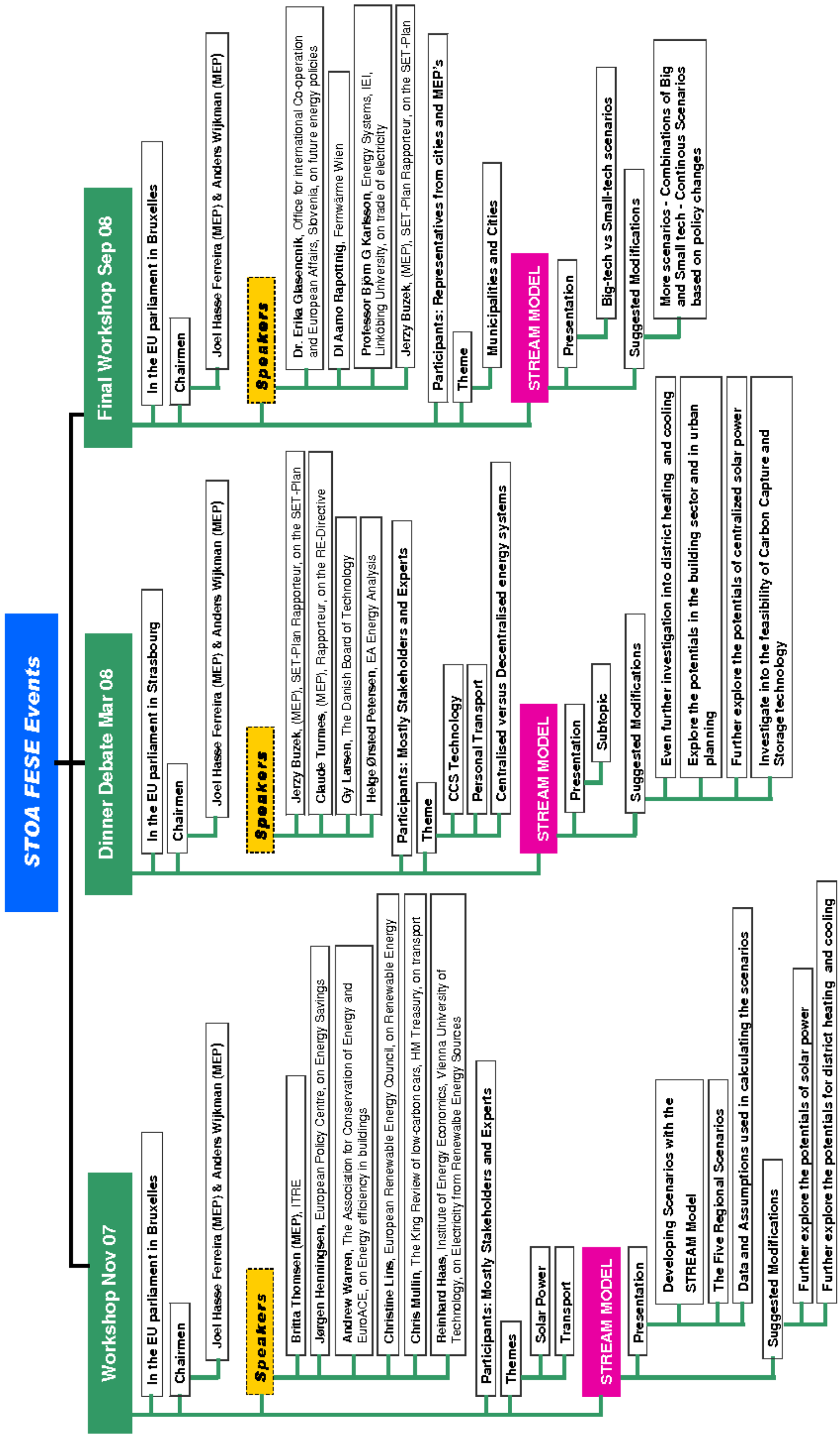
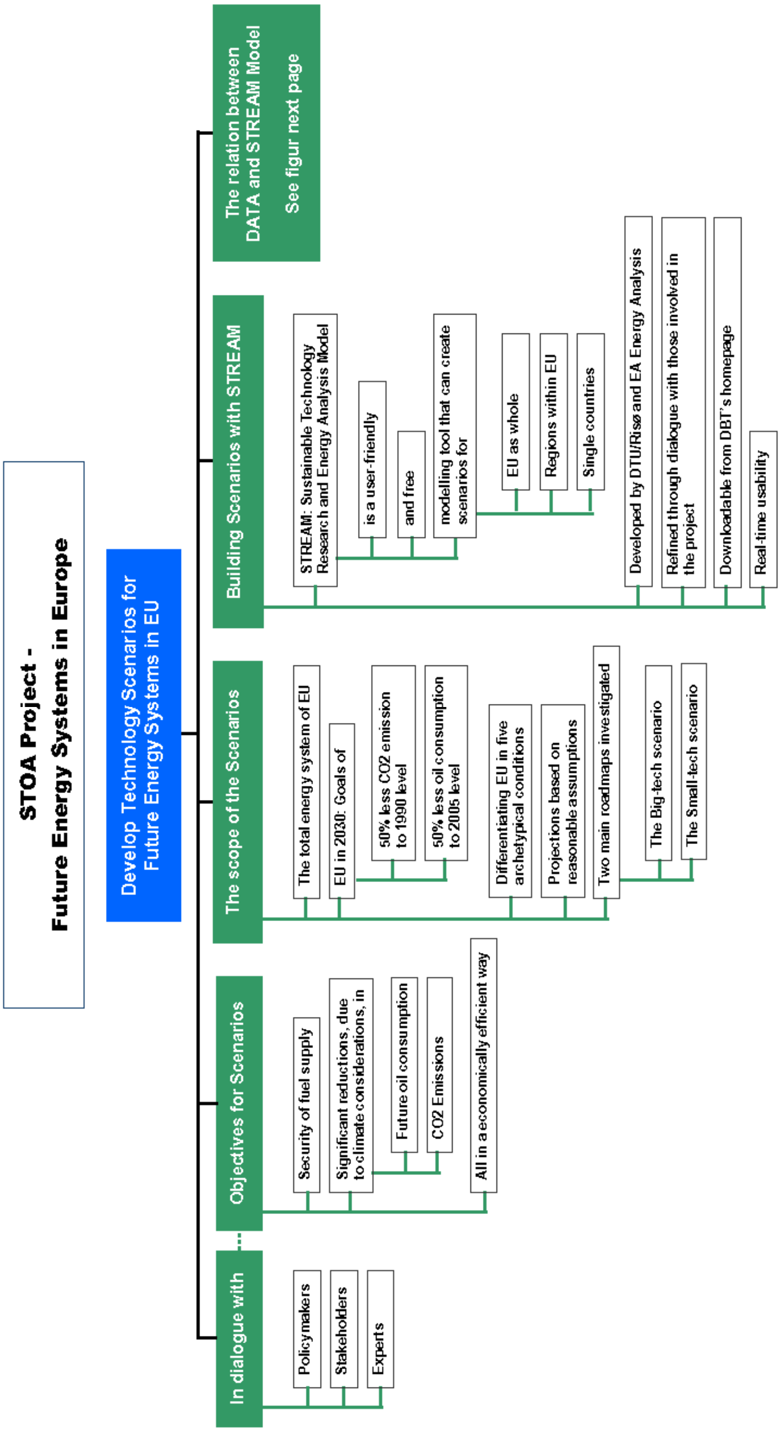
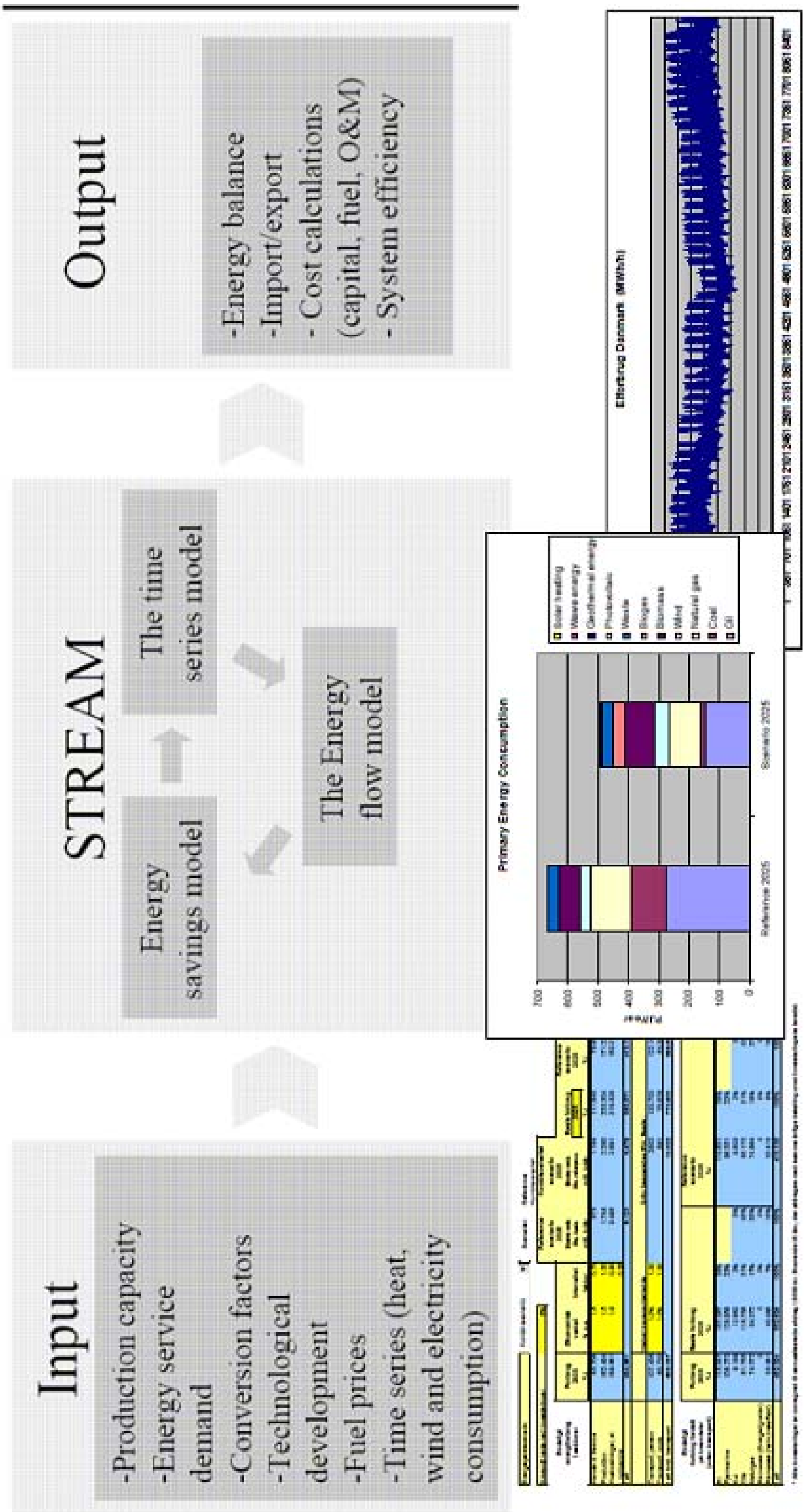


Figure B: Thematical process of the project




Input
-Production capacity
-Energy service demand
-Conversion factors
-Technological development
-Fuel prices
-Time series (heat, wind and electricity consumption)
STREAM
Energy savings model
The time series model
The Energy flow model
Output
-Energy balance
-Import/export
- Cost calculations (capital, fuel, O&M)
- System efficiency
Primary Energy Consumption
Solar heating
Wave energy
Geothermal energy
Photovoltaic
Waste
Biogas
Biomass
Wind
Natural gas
Coal
Oil
Reference 2025
Scenario 2025
Elforbrug Danmark (MWh/h)

3 BACKGROUND

There is common agreement that Europe faces a series of energy challenges in the future that need to be thoroughly discussed. Despite the numerous initiatives elaborated in the past, and new ones already ongoing, energy consumption in Europe is still expected to increase, as are CO_2 emissions at a time where reductions are needed.

Global oil demand is forecasted to grow amidst an uncertain supply situation in the mid-term future. This subject is intrinsically related to energy security among nations and constrained by geopolitical state such as warfare, which not only puts pressure on oil prices, but also carries a net of negative externalities for human welfare.

Likewise, the diversification of natural gas import sources will become important as EU production is likely to drop rapidly in the next 20 years. As such global security risks will increasingly be linked to energy market developments. In the face of this panorama there is a need to change unsustainable energy regimes and agreement on how to choose the right mix of energy technology solutions of the future to end up with sufficient and robust energy systems. The term sufficient is used here in the sense that a reasonable energy demand can be supported by a high level of energy security. Within the EU, both the Commission and Member States are struggling with the formulation of the necessary policies to meet these challenges.

Based on the stated objectives of improving the security of fuel supply, and significantly reducing future oil consumption and CO_2 emissions, the STOA project “Future Energy Systems in Europe” develops a set of technology scenarios for the future energy systems in Europe in 2030. The different characteristics, opportunities and priorities for the energy sector in different parts of Europe are being integrated in the energy scenarios for five archetypes of EU countries representing different conditions in their existing energy sector and different opportunities to meet the objectives because of variances in renewable energy potentials. Hopefully the scenarios, by being sensitive to regional highs and lows in energy potentials, may provide the platform for a debate on the future challenges and opportunities in the energy field in Europe.

3.1 Scope of the project

The STOA project Future Energy Systems in Europe makes use of scenario modelling tools with the intention to illustrate how it is possible to fulfil the goals of improved security of supply and greater care for the environment in an economically efficient way. The scenarios focus on ensuring cost-efficiency, minimising environmental impacts and improving security of fuel supply.

Two objectives for 2030 are established to guide the scenario development:

- Reducing CO_2 emissions by 50 per cent compared to the 1990-level
- Reducing oil consumption by 50 per cent compared to the present 2008 level

Through the scenarios and the project workshops, the STOA project has cast light upon the set of multifaceted considerations needed to develop the energy systems in the Member States and how to meet the objectives in the new climate and energy agreements.

Compared to projections and scenarios previously published by the EU Commission, (see e.g. ref.5 and ref.6) the present project explores more radical changes of the European energy and transport systems.

During the process of scenario development feedback has been received from politicians, energy experts, academics and other stakeholders in order to consolidate the robustness of the scenarios presented.

3.2 Communication

The first phase of the project was concluded with a workshop held in November of 2007 in the European Parliament in Brussels. During this workshop MEPs, as well as experts and stakeholders, provided valuable input and information for the preparation of the STOA scenarios. At a MEP Dinner Debate on April 23, 2008 in Strasbourg an adjusted STOA reduction scenario was presented. The feedback received by the attendees of the meeting regarding the assumptions and results was generally positive. Moreover, a number of specific comments were provided by the MEPs. These have been integrated into the present work and are listed in the summary from the meeting.

At the Dinner Debate Carbon Capture and Storage (CCS) was emphasised as an important technology by several MEPs. As a direct response to this a separate scenario – Big-tech – has been created illustrating the potentials of this technology in combination with nuclear power. Apart from minor adjustments, the Small-tech scenario in this report is similar to the STOA reduction scenario presented at the Dinner Debate held on April 23, 2008.

3.3 Data

When developing scenarios for future energy systems one often found constraint is that actors have differing approaches and use complex models that are not always transparent for an outsider. Therefore, compared to other scenario tools, relatively simple models have been developed for use within this project to give all relevant actors better insight into the analyses. As a means to quantify the scenarios for 2030 the Sustainable Technology Research and Energy Analysis Model - in short called STREAM **-** has been applied**.**

The scenarios are prepared for different geographic archetypes of conditions in the EU in 2030. Each archetype area has distinct features, due to climatic conditions and historical data of the existing energy system, making it relevant to focus on certain solutions.

All data used in the scenarios are publicly available and the scenario tool is available for download on the websites of STOA, the Danish Board of Technology, and Ea Energy Analyses.[7]

The model and scenarios were updated based on the feedback received from the workshop with experts and MEPs held on November of 2007, and the Strasbourg Dinner Debate with MEPs in April of 2008. It is now possible to create scenarios for the whole of Europe, regions or single countries in a quick and efficient way. However, it is important to keep in mind that energy system analysis is a complex matter and thereby limits the ease of use of any software designed to analyse it. Amongst other things, what the STREAM model presents is a familiar interface (Excel spreadsheets), a robust and refined data-set to start with that it is free of charge to use, and a high level of flexibility regarding the possibilities of creating scenarios.

The current modelling is only the first step in the process of continually feeding the STREAM scenario tool with the most adequate data to get to most sensitive scenarios. Because of the STREAM model's composition such a process is possible and relatively easy, therefore STREAM represents a good means to go further into the analysis of the future of European energy systems.

[7] http://www.europarl.europa.eu/stoa/default_en.htm; The Danish Board of Technology: www.tekno.dk , http://ea-energianalyse.dk/index_uk.html

4 PROJECT TIMETABLE

The project consists of two phases. The first phase, focusing on modelling development and data gathering ended with the workshop in November of 2007. In phase II the data that had been gathered in phase I was further qualified and an additional scenario (incorporating a higher implementation level of centralised solutions such as CCS and nuclear power) called 'the Big-tech scenario' (as opposed to the 'Small-tech scenario' which had been the focus of the project earlier, focusing on decentralised RE (Renewable Energy) solutions, was developed.

Phase 1

The first phase of the project was dedicated to the modification of the STREAM modelling tool for EU calculations and gathering of data. Following this, regional scenarios were developed and integrated into a common EU scenario. The results of the first phase were presented at the workshop in November of 2007 at the European parliament in Brussels.

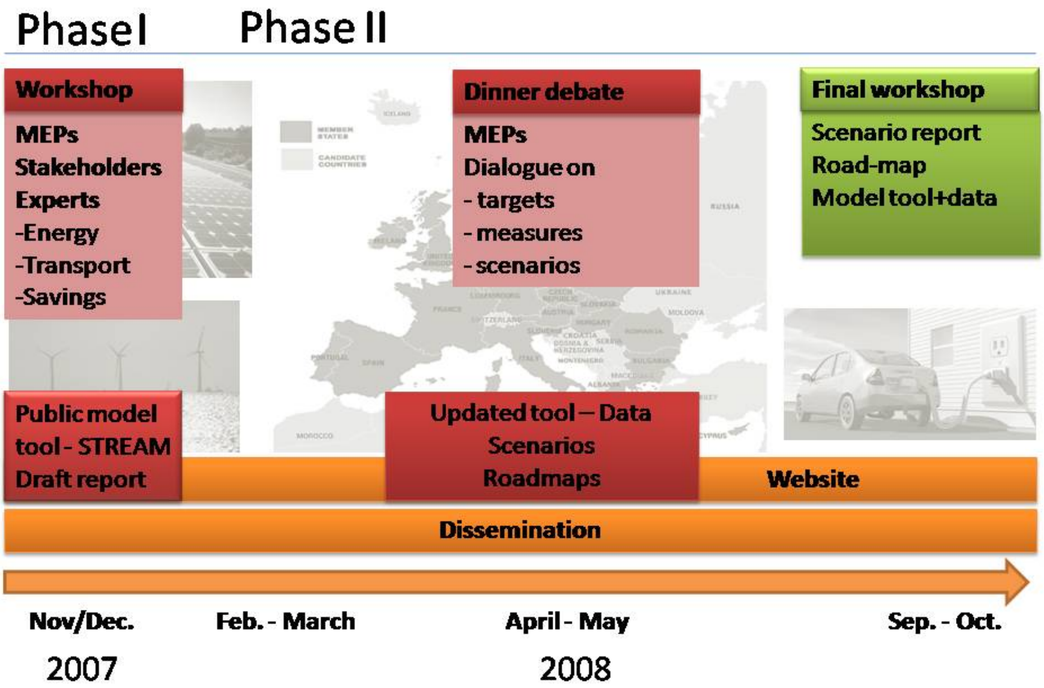
Outcomes of the first phase of the project were

- An interim report describing the scenario results and key assumptions, current state of the project and the main items to be dealt with at the November 2007 workshop.
- The modelling tool STREAM (to be used for possible further studies), including all relevant scenario data. This has been available since December of 2007.
- Valuable input for further model improvements and guidelines for new scenarios

Phase 2

The second phase began with the workshop held in November 2007. During winter and spring of 2008 scenarios were further qualified based on the input from the workshop. Another meeting in the form of a Dinner Debate was held in April 2008 where the developments of this project were presented and interesting discussions were held and feedback was obtained. After this meeting the scenarios were further updated and presented in the European Parliament at a workshop in September 2008. The final report was submitted to STOA in October 2008.

Figure 3: Time schedule



5 METHODOLOGICAL OUTLINE

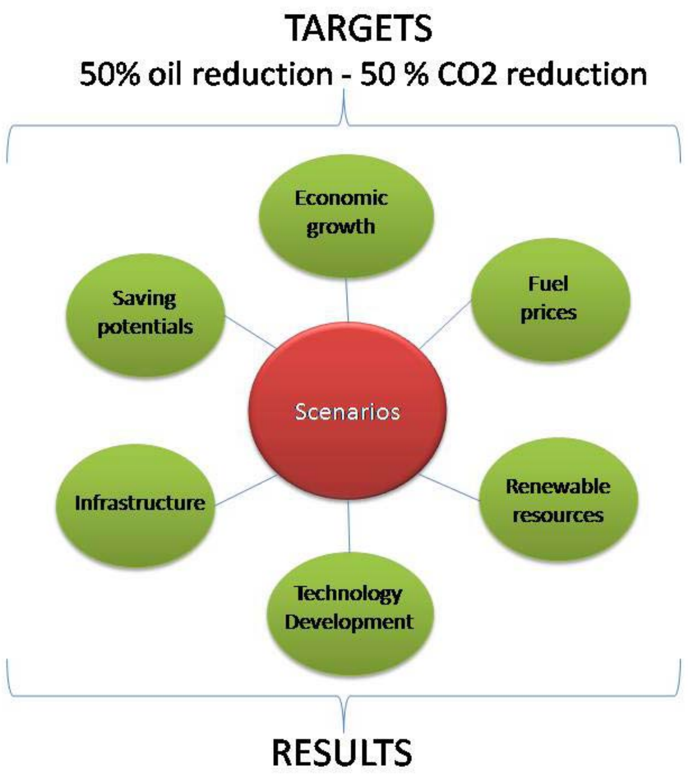
This section outlines the main assumptions used to formulate the scenarios. For the sake of reliability and transparency all conjectures fully refer back to the data sets and calculations from the STREAM model as their basis and all data employed in the STREAM modelling tool are publicly available. The selection of the sources was established through a literature review focused on energy systems at the European level (see list of references). This distinctive feature facilitates an open dialogue with respect to the methodology.

The overall objective of presenting the insights of the data used to develop the scenarios was to receive feedback from politicians, energy experts, academics and other stakeholders to consolidate the robustness of the forecasts presented. This was done to different degrees at all the STOA events, but this will be an ongoing process since 'the best data set' will gradually change over time.

This section focuses on the following six elements:

- Fuel prices
- Energy Savings
- Energy demand
- Infrastructure
- Technology data
- Renewable resources

Figure 4: Modelling considerations



The choice of technologies in the scenarios has been made in collaboration with the MEP´s involved in the project. Cost and performance of the technologies have been important parameters in the selection process. For example, more wind power is included in the Small-tech scenario compared to solar or wave power due to the difference in economics of these technologies.

5.1 Fuel prices

Fuel prices are volatile, in particular oil prices, and therefore price forecasting is subject to open debate. However, a baseline is necessary and fuel prices in this project are based on the projections of the World Energy Outlook 2007.

The prices in World Energy Outlook 2007 to a high degree resemble the prices used in the most recent long-term energy sector projection by the DG Tren (European Energy and Transport - Trends to 2030, Update 2007). Nevertheless, compared to the prices in September 2008 – when the final calculations from this project were made – they are significantly lower.

Therefore an additional analysis is made with higher fuel prices corresponding to the market prices in early September 2008.

Table 2: Fuel prices

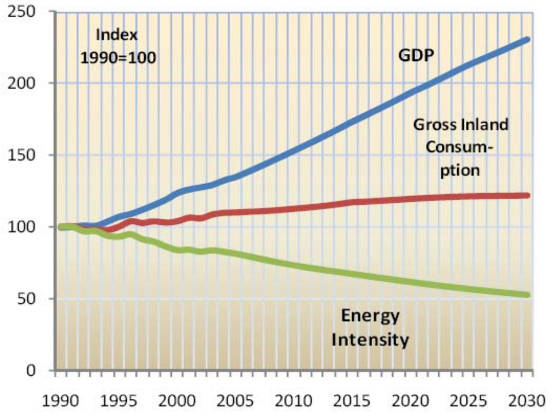
Fuel price projections	Oil (USD/bbl)	Gas ($/MBtu)	Coal ($/ton)
Low (IEA projection 2007*)	62	7.3	61
High (Prices in September 2008)	115	16.0	179

*ref.2. IEA World Energy Outlook 2007. Today's prices are based on the following sources: Oil: Brent crude oil prices, 1 September 2008. Natural gas and coal prices depend significantly on the season; hence we apply forward prices for 2009. Natural gas: TTF forward gas price for the calendar year 2009, Coal: EEX futures based on ARA. In the latest fuel price projection from the IEA (ref.1) from November 2008 the agency foresees that the cost of a barrel of oil will increase to approx. 120 $/bbl in 2030.

5.2 Energy demand based on DG TREN

Energy demand in the reference scenario is based on the projections made by DG TREN. Accordingly, in the scenarios it is assumed that if no new measures are taken to save energy and utilize energy more efficiently, the primary energy demand in the EU-27 will increase at an annual rate of 0.4 per cent between 2005 and 2030 compared to an average annual growth rate of approx. 2.1 per cent for Gross Domestic Product (GDP). This implies that the energy intensity of the EU-27 energy system will improve at a rate of 1.7 per cent in 2005-2030 under baseline assumption. In the Small-tech scenario additional measures are taken to improve energy intensity even more, thus leading to an increasing gap between GDP and gross energy consumption.

Figure 5: Historic and projected developments in GDP, gross energy consumption and energy intensity for EU27 in DG Tren baseline scenario

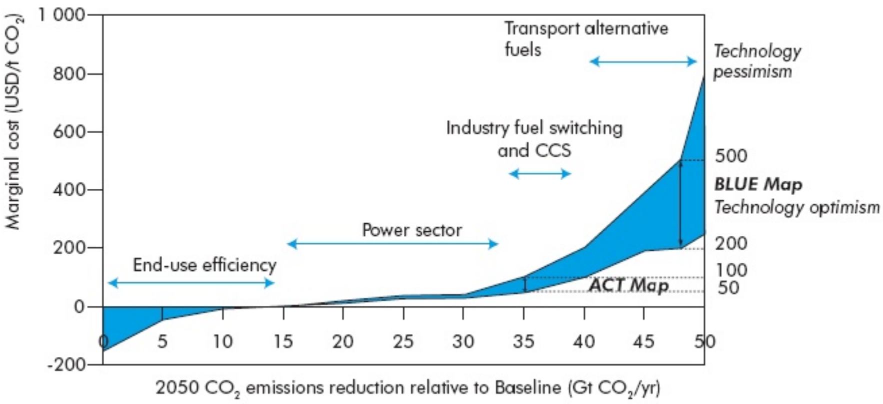


5.3 Energy savings

There is an increasing acceptance at the EU level that energy savings and/or improved energy efficiency at the end-use level is just as important as how we configure our energy supply system. Energy savings are crucial if the EU is to continue to undergo economic growth and at the same time comply with global and EU agreements on climate and environment. Energy savings reduce consumer's energy bill and postpone investments in new power capacity and transmission lines.

A number of studies show that the potentials for energy savings are significant (see textbox) and that a substantial part of the potential can be realised at low or even negative total costs.

Figure 6: Global marginal costs of measures in IEA BLUE Map scenarios [IEA, Energy Technology Perspectives 2008]



As can be seen, more than one third of the CO2 reduction comes from energy savings with negative or neutral marginal costs, displayed in the figure by the blue area below or equal to 0 on the y-axis. We see that it is improvements in 'end-use efficiency' and the 'power sector' that has by far the lowest marginal costs compared to the level of CO_2 emission reduction they provide.

Table 4, provides examples from a recent study by McKinsey &Company where different technologies and sectors have been investigated. Many of the saving opportunities have a short pay-back time or high internal rate of return (IRR). According to McKinsey &Company world growth in final energy demand can be reduced from 2.2 per cent per year to 0.7 per cent by utilizing existing saving opportunities. In the developed regions the change can be from 1.0 per cent per year to -0.3 per cent per year.

However, there is a need for better public available data on energy consumption in different sectors in the different Member States, and it is necessary to treat end-use efficiency and savings equally with supply technologies in energy system analysis of future possibilities.

As a consequence, it has not been possible to obtain detailed data for energy savings on a member state level. Therefore the scenarios are based on the detailed Danish data for saving potentials within different sectors and end-use services. However, the real potentials at the EU level are probably higher since Denmark is a country with relatively low energy intensity compared to most other European countries.

The reference projection of efficiency improvements from 2005 to 2030 used in this project has attempted to follow the DG TREN [ref.4] baseline scenario as closely as possible. The DG TREN baseline and the reference include efficiency improvements of 20-30 per cent (excluding transportation) in the period 2005 to 2030. The scenarios present efficiency improvements of 30-55 per cent (excluding transportation). The costs of energy savings are calculated as extra costs going from the baseline level to the saving level in the scenarios. The costs are based on background reports from the Danish Action Plan for Renewed Energy Conservation (can be found on the Commissions' homepage [ref.20].)[8]. The yearly costs related to improving efficiency from the level in DG TREN baseline to the level used in the scenarios, using an interest rate of 5 per cent, and the assumed lifetime for each technology is 18-25 €/GJ for electricity savings, and 10-16 €/GJ for heat savings. These costs are based on prices used by the Danish government when calculating socio-economic costs related to the Danish Action Plan for Renewed Energy Conservation.

As indicated in the text box, several studies and EU papers support the size of the used saving potential in the Small-tech scenario, and in all studies the cost of implementing such savings is concluded to be a net benefit.

[8] http://ec.europa.eu/energy/demand/legislation/end_use_en.htm

Table 3: Energy saving potentials according to McKinsey &Company [ref.18]

	% saving potential or opportunity	IRR	Description
Heating and cooling	50 – (new buildings) 25 – (replacement)	~10% ~10%	Current technology Improved technology
Lighting	65	100% +	Compact fluorescent lighting
Water heating	65	11%	High efficient electric water heater and solar water heater
Major appliances	40-60	N/A maybe ∞	Increasing appliance efficiency standards at 2-3% per year
Small appliance standby	40	N/A maybe ∞	Reduce standby power req. of televisions, set-top boxes etc.

Energy saving potentials according to different surveys, references included

EURIMA study – The Contribution of Mineral Wool and other Thermal Insulation Materials to Energy Saving and Climate Protection in Europe. By ECOFYS for EURIMA:

- Adding insulation to existing buildings in EU-25 could reduce energy for heating by 42 per cent.

DG TREN – Scenarios on energy efficiency and renewables. By Dr. L. Mantzos and Prof. P. Capros:

- In the “Energy Efficiency” case for EU-25 a 20 per cent relative reduction in energy demand is reached in 2020.

Green Paper on Energy Efficiency or Doing More with Less. Brussels 22.6.2005. COM(2005) 265 final:

- 20 per cent reduction in energy consumption in EU compared to the projections until 2020 is possible on a cost effective basis.

EPC (European Policy Centre) – Gain without pain: towards a more rational use of energy. By Marie-Hélène Fandel and Fabian Zuleeg March 2008:

- Large saving potentials are available but need new policy measures and active use of existing directives, such as the Eco-Design Directive.
- Third- party financing such as ESCOs (Energy Service Companies) should be promoted.
- All public sector organizations should have ambitious targets (including the European Institutions).
- Metering and individual pay by the user is important.

Capgemini – Demand Response: a decisive breakthrough for Europe.

- Electricity savings: 20-50 per cent.

IEA ETP2008

- In the so-called ACT Map scenario, energy consumption in the building sector in 2050 is 32 per cent below the Baseline scenario level and in the BLUE Map scenario it is 41 per cent below the baseline scenario. But 80 per cent reduction in building energy consumption can be achieved by known technology.

IEA 2007 - Tracking Industrial Energy Efficiency and CO2 emissions

- Manufacturing industry can improve its energy efficiency by 18-26 per cent by using best practice commercial technology.

5.4 Flexible power demand

Flexible power demand is just as interesting as peak shaving, stabilisation of the power system and reducing the need for investment in new capacity.

Flexible power demand is an efficient measure for saving investments in power grid and production capacity. If e.g. 5 per cent of EU27 power consumption (equalling electricity use for domestic freezers and refrigerators) could be 100 per cent flexible – meaning that consumption can be moved from critical periods to periods with “surplus” power - it could reduce peak load and thereby the need for power capacity by almost 20 per cent.

All demand cannot be fully flexible because most of the electricity consumption has limits for how long the consumption can be postponed. A freezer can be stopped for several hours without any problems, but a coffee machine or a cooker will be very difficult to shut down during specific hours.

In the Small-tech and Big-tech scenarios it is assumed that there is some flexibility in the power demand in 2030. For electricity used in electric vehicles and for bio-fuel production it is assumed that a part of the consumption is fully flexible and that a part is used in night hours where demand is generally low. As can be seen in the following table, a share of the overall electricity consumption is also assumed to be flexible to a different extent in the two scenarios.

The highest degree of flexibility is assumed in the Small-tech scenario where smart meters and intelligent market setup are expected to facilitate flexible energy consumption according to price signals and systems demands.

Table 4: Flexible electricity consumption in the transport sector

Scenario	Electricity Consumption in the transport sector		
	Flexible	**Night consumption**	**Unflexible**
Big-Tech	40%	30%	30 %
Small-Tech	50%	20%	30 %

Table 5: Flexible electricity consumption (share of total electricity consumption in households, trade/service and industry)

Scenario	Flexible share
Big-Tech	0,5%
Small-Tech	2,0%

5.5 Infrastructure

The scenarios consider the existing energy infrastructure in Europe as a point of departure for the establishment of policy recommendations.

The modelling tool used to develop the scenarios follows the overall energy flows in the energy and transport systems, but it is not capable of identifying bottlenecks in the infrastructure. Hence the demand for new infrastructure for gas, electricity and district heating is not quantified in the scenarios.

However, in the financial calculations estimates of the cost of connecting off-shore wind power to the grid, and the cost of expanding district heating systems have been included. These estimates are based on standard values. Moreover, the costs of transporting CO_2 from power plants to selected deposits – and establishing the needed infrastructure - are included in the operational costs of the CCS power plants. These costs are presented in the following table.

Table 6: Costs assumed for infrastructure

District heating	**Offshore wind power***	**CO_2 storage (incl. transportation)**
30 mill. €/PJ	0.6 mill. €/MWe	9.6 €/ton

* Includes connection to land. The costs of the transformer station and internal electricity infrastructure at the wind farm are included in the costs of the turbines. (PJ: Peta Joule, MWe: MegaWatt electrical)

5.6 Technology Data

Reliable information regarding future costs of different energy and transport technologies are one of the key uncertainties when forecasting cost and performance of future energy systems. Forecasting is complicated not only because of the challenges of predicting technological breakthroughs, but also due to the fact that the choice of future policies may highly influence technological development.

If, for example, the policy framework supports renewable energy technologies these technologies can be expected to flourish through economy of scale and learning-scale processes.

In the present project information on energy supply technologies and electricity generation technologies are based primarily on data from the RECaBS (Renewable Energy Costs and Benefits to Society) project under the IEA Implementing Agreement on Renewable Energy Technology Deployment [ref.21][9] and the catalogue of technology data developed and used by the Danish Energy Agency and transmission system operator (ref.8).

[9] All data is publicly available at www.recabs.org.

The key transport technology data source is the CONCAWE-study [ref.11], a large European Wells-to-Wheel study covering a wide range of fuels and technologies, except EVs (Electric Vehicles) and Plug-in hybrids. Information regarding these, in addition to hydrogen, are mainly based on American studies from Princeton University and University of California [ref.22, ref.9, ref.10, ref.14, ref.25 and ref.16], and data from the Danish Ministry of Transport [ref.13 and ref.24 and ref.12].

- Data on district heating and cooling potentials and costs were obtained from the ECO-heat-cool research project under Euroheat and Power.[10] The complete data for all technologies are available in the spreadsheets of the STREAM model, which is downloadable at the website of STOA and the Danish Board of Technology.[11] Indicative data are shown in the following table regarding technologies for electricity production.

[10] http://www.euroheat.org/ecoheatcool/index.htm

[11] http://www.europarl.europa.eu/stoa/default_en.htm; http://www.tekno.dk/subpage.php3?article=1442&survey=15&language=uk

Table 7: Characteristics of new technologies used in the model

Electricity generation	Capital cost	Typical size	Electrical Efficiency	Technical lifetime	Fixed O&M[12]	Var. O&M
Technologies	€/MW[13]	MW	%	Years	€/MW/year	€/MWh/year
Oil	672.000	20	47%	30	10.738	2
Coal	1.400.000	400	47%	30	18.200	2
Ccgt[14]	460.000	250	58%	25	12.500	2
Wind, offshore (incl. net)	2.500.000	20		20		15
Wind, onshore	1.150.000	5		20		12
Biomass	1.500.000	400	45%	30	28.500	3
Biogas	3.500.000	2	39%	20		28
Waste	5.800.000	13	27%	20	232.000	22
PV (Photovoltaics)	2.400.000	2		30	24.000	0
Nuclear	2.200.000	1.600	33%	40	70.000	0
Geothermal	1.345.000	1	30%	20	0	0
Wave power	1.850.000	25		20	37.000	0
Natural gas w. CCS[15]	1.100.000	400	48%	30	12.500	1
Coal with CCS	2.240.000	400	37%	30	18.200	2
Biomass with CCS	2.400.000	400	33%	30	25.000	3

5.7 Renewable resources

The Small-tech scenario makes use of all of the environmentally sustainable biomass resource in the EU, and the majority of the viable potential for wind. The solar resource, which is mainly constrained by economics, is primarily exploited in Southern Europe and could be further increased beyond 2030.

The data on potential biomass resources for energy purposes is based on the study "How much bioenergy can Europe produce without harming the environment?" prepared by the European Environmental Agency in 2006 [ref.7]. The study found that the biomass resource could reach almost 12,000 PJ by 2030 — about 17 per cent of the total annual energy consumption of the EU-27 today. The study works with calculations of environmentally-compatible bioenergy potentials, and thus to a certain extent includes competing uses of land for biomass versus food production (ref.7, p. 14-15).

[12] O&M: Operation and Maintenance

[13] MW: Mega Watt – MWh: Mega Watt Hours

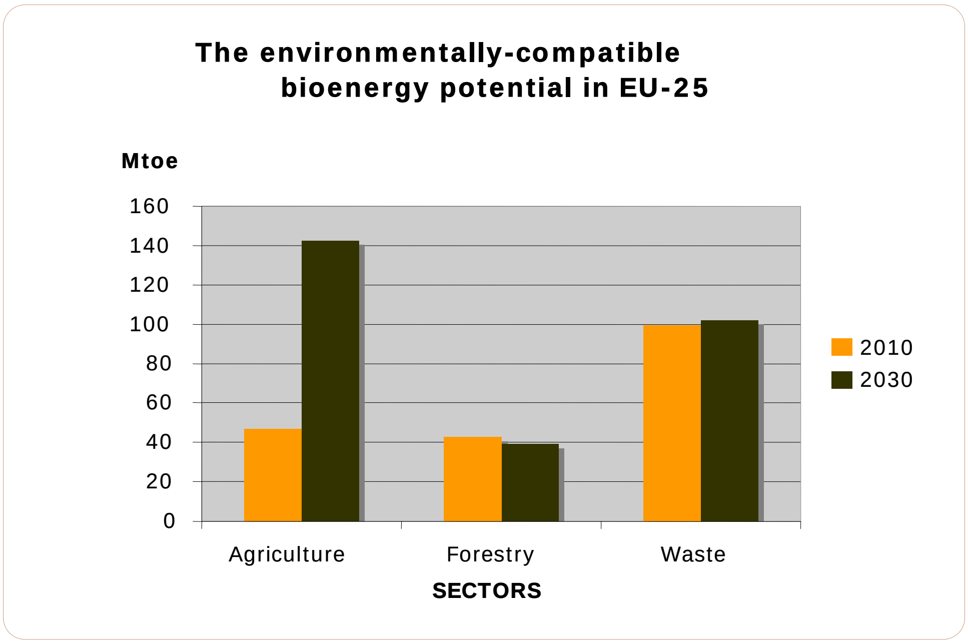
[14] Ccgt: combined cycle gas turbine

[15] CCS: Carbon Capture and Storage

The potential land availability for bioenergy crop production, in the study, was calculated by subtracting the future land requirements for food production from the land requirements for food production from the land requirements in 2000 minus the estimated amount of land that would be needed to respect the environmental criteria and for urbanisation and other non-agricultural activities (ref.7, paraphrase p. 21).

Wind, ocean, solar and geothermal potentials are based on the EU financed project Green-X [ref.4], as well as the technology map of SET plan prepared by the EU Commission. [16]

Figure 7: The environmentally compatible bioenergy potential in EU-25 between 2010 and 2030 by sector in Mtoe (million ton of oil equivalent).



The figures above are based on the study conducted by the EEA in 2006 [ref.7] where a number of environmental criteria for minimising additional environmental pressures from bio-energy production were analysed. Based on these criteria, the environmentally compatible bio-energy potential for the EU-25 was calculated up to 2030.

[16] ec.europa.eu/energy/**technology**/set_plan/doc/2007_**technology_map**_description.pdf

Table 8 compares the Renewable Energy potentials identified in the SET plan with the figures applied in the Small and the Big-tech scenarios. The figures are for the EU-27.

Table 8: Comparison of potentials in the SET plan technology map with the scenarios.

GW_e capacity	SET plan	Small-tech scenario	Big-tech scenario
Wind	168 – 300	234	178
Hydro (incl. large-scale)	131	128	128
Photovoltaics & Concentrated solar power	300 – 665 4	160	28
Ocean*	16	16	0

* For ocean technologies a slightly higher potential has been applied in the STOA scenario compared to SET. This is in accordance with the potentials identified by Green-X. (GWe: GigaWatts Electrical)

Wind energy resources can be evaluated through a wind atlas, which is a meteorological basis for estimating the wind climate and wind energy resources. In Europe wind resources are well documented. The areas with great potential are found in Northern Europe along the North Sea, and at certain locations in Southern Europe (see Figure 8, unfortunately it lacks data for the Eastern part of Europe).

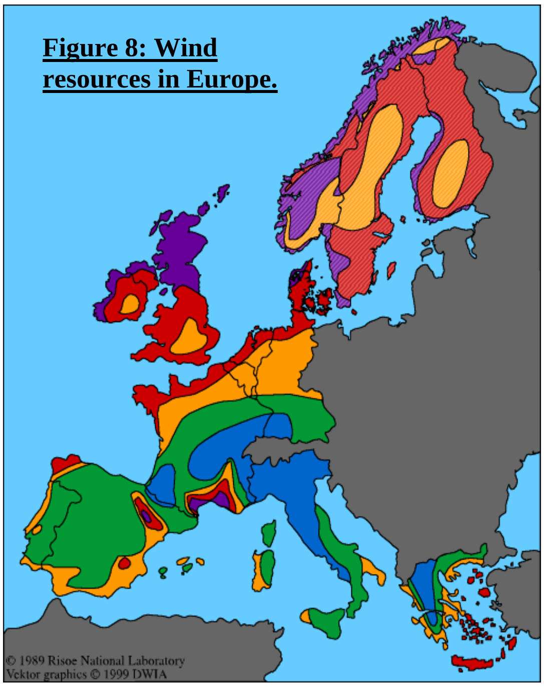


Figure 8: Wind resources in Europe.

Regarding solar energy, the Mediterranean region has the highest energy potential. Good conditions exist in Central and Eastern Europe, and the least favourable conditions are in the Northwest, North Europe and the Baltic states.

Similar considerations have been followed for other technologies (with less share in the energy mix like wave or geothermal energy) using renewable sources based not only on geographical conditions and resources, but also their possible penetration by 2030 as accounted for in the Green-X study [ref.3].

5.8 Modelling tool

Relatively simple models have been developed for use within this project to give all relevant actors a better insight into the analyses. As a means to quantify the scenarios for 2030, the Sustainable Technology Research and Energy Analysis Model (STREAM) is used. This model was originally developed for a project entitled the "Future Danish Energy System" carried out from 2004-2007 by the Danish Board of Technology in conjunction with some of the most important Danish stakeholders in the energy sector [ref.15].

The model is able to provide a quick insight into the different potential energy mixes not only for the whole of Europe, but also for defined regions or countries. The model allows planners, politicians, students and others to be able to create scenarios on demand. Moreover, the databases used can be periodically updated (through Eurostat for example) making this tool and the results more realistic and adaptable. Different potential policies or projections can also be incorporated providing an overview of the proposed scenario. Currently the latest version of the model is available upon request and from the webpage of STOA, The Danish Board of Technology and Ea Energy Analyses[17].

This modelling tool is rather unique due to three key elements:

- First, the model is developed with the purpose of enhancing the complete energy flow; from fuel exploration, conversion and energy use, across all sectors in the society, including the transport sector. Many other models only focus on certain parts of the energy system, for example the dispatching of power plants in the electricity sector and the district heating system.
- Secondly, the model is developed in cooperation between a university, an energy company, a transmission system operator and consultants. This gives the model a high degree of credibility and keeps the focus on problem solving, and thus results in a dialogue with other interests.
- And thirdly, it is a relatively simple model making it possible to conduct new analyses relatively quickly – for example during a meeting. This enhances the knowledge basis for qualified decisions.

The models are based on a bottom-up approach. This means that the user defines the input to the models. For instance, X per cent wind power in the electricity sector or X per cent bio ethanol in the transport sector and on this basis an output is calculated. The model does not perform an economic optimization specifying exactly which set of measures are the most advantageous to combine under the given conditions.

The STREAM model consists of three Excel spreadsheet models:

- **The energy savings model**
    - o This deals with energy savings by means of better efficiency both in the respective energy products and services.
        - Different estimates regarding saving-potentials can be used here to see what consequences they will likely have in the long-term.

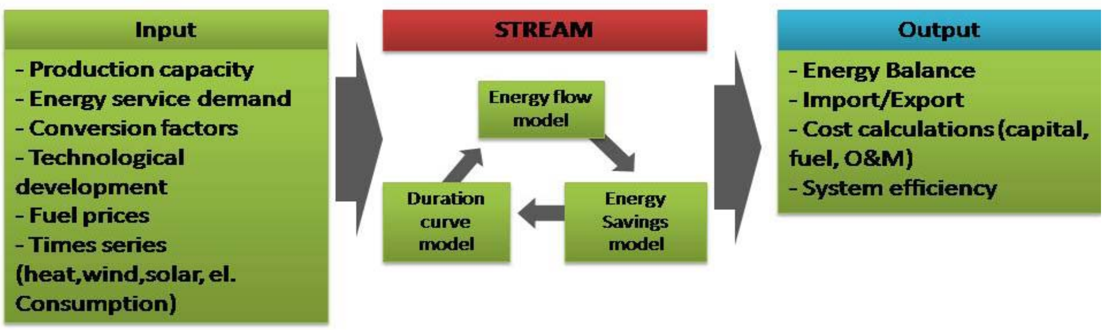
[17] http://www.europarl.europa.eu/stoa/default_en.htm; http://www.tekno.dk/subpage.php3?article=1442&survey=15&language=uk , http://ea-energianalyse.dk/index_uk.html

- **The duration curve model**
  - This takes into account the demand for heat and power and calculates the potential for energy infra-structural changes, factoring in the flexible demand, and generation from fluctuating electricity technologies (wind, solar PV etc,)
    - Here different approaches to the degree of flexibility of the energy system can be experimented with.
- **The energy flow model**
  - Lastly the input and output from the energy savings and duration curve models are put into this model, thereby creating an overview of the total energy consumption, emissions and costs from a total energy systems perspective.
    - In this model an overview is created so that it is possible to see whether the premises that have been used as inputs in the two other models will actually be enough to reach the goals that is required.

Please refer to 'Appendix I' for examples and views of the STREAM model.

Data on European energy systems such as available resources and projected demand for energy services are supplied from a *data aggregation module*, which has been developed specifically for the purpose of the present project. Input data is specified for each country in the EU, but for the purpose of modelling, is aggregated into regions.

Figure 9: The STREAM model



Five geographic regions

For the present project, scenarios have been made for five geographic regions in the EU, which are subsequently aggregated into one common EU scenario:

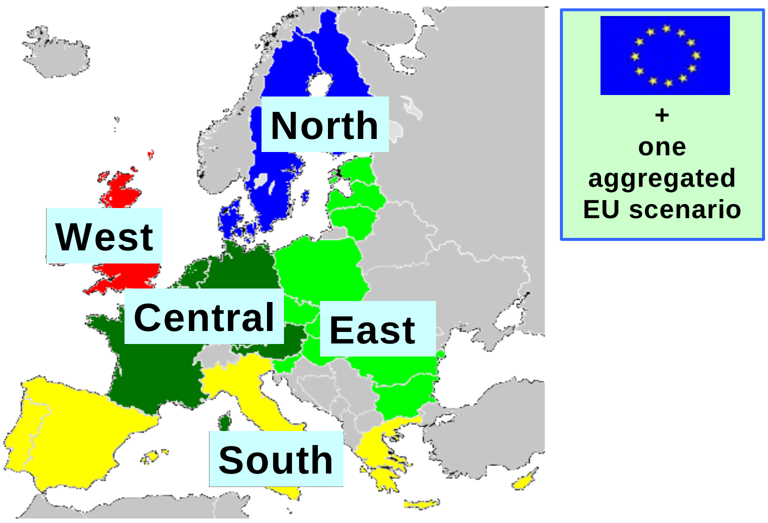
- Central Europe (6): Germany, Belgium, France, Luxembourg, The Netherlands, Austria
- Western Europe (2): Great Britain and Ireland
- Eastern Europe (10): Lithuania, Latvia, Estonia, Poland, Hungary, Czech Republic, Slovakia, Rumania, Bulgaria, Slovenia

- Southern Europe (6): Malta, Cyprus, Greece, Italy, Spain, Portugal
- Northern Europe (3): Denmark, Sweden, Finland

Each regional area has distinct features, due to climatic conditions and/or the history of the existing energy system, making it relevant to focus on certain solutions. For instance, in Southern Europe solar resources are high, as are the needs for cooling, whereas the heating requirements are relatively low in comparison with Northern Europe.

In Central Europe the existing nuclear power plants and domestic coal power resources are important elements that need to be taken into consideration. Eastern Europe has vast biomass resources and energy demand is expected to increase at a relatively high rate. Meanwhile large biomass and wind power potentials exist in the Nordic countries, and their electricity sector is dominated by hydropower and nuclear. Lastly, the Western part of Europe has large wind and off-shore renewable energy resources.

Figure 10: Scenarios were made for five European regions (archetypes) and aggregated into one common EU scenario



5.9 Scenario economics

The economics of the scenarios are calculated as the annuitised value of the entire energy system in the scenario year (2030), i.e. the average annual capital costs as well as costs for fuels, operation and maintenance. The outcome is a simplified welfare-economic calculation, which does not take into consideration possible tax distortion elements, environmental externalities other than greenhouse gases (e.g. NOX, SO2 and particles), and the value of security of supply. This financial calculation makes a relative comparison of scenarios and references possible.

Moreover, two of the important measures in the transport sector are not valued in economic terms.

- *Energy efficient cars.* In both Small-tech and Big-tech assumptions are made that new cars become more fuel efficient compared to the reference projection. However, the cost of this change is not estimated. People may suffer a welfare-economic loss from driving cars with lower performances (less room, less acceleration, no air-condition etc.) and direct extra cost for the construction of the efficient cars (more costly engines, low-weight materials etc). On the other hand, if people are encouraged to buy smaller cars (= better fuel economy) this may lower the direct costs.
- *Transport mode changes.* In the Small-tech scenario it is assumed that the share of passenger transport covered by cars will decline somewhat compared to today. The incentives to bring this change through could for example be road-pricing, improved public transportation, improved conditions for cyclists or health campaigns. The direct costs associated with such measures have not been quantified, nor has the benefits in terms of lower congestion and improved health of commuters.

The calculations are made in fixed 2006 prices, and the discount rate is set at 5 per cent. It should be stressed that it is the annual costs in 2030 that are determined. The annual costs cannot be expected to be constant up to 2030.

Fuel costs are generally reduced in the reduction scenarios whereas investment costs increase. Also, operational costs increase in all reduction scenarios, partly due to the fact that it is more demanding to handle biomass, biogas and waste than fossil fuels. On the whole, large uncertainties are connected with estimating long-term costs of operating an energy system. Not only might the investment costs of the technologies change significantly over more than 20 years, but fuel costs may depart considerably from the assumptions made in this report.

It should be stressed that the economic analyses are static in the sense that the total fuel consumption is assumed to be unchanged regardless of the fuel prices examined. For example, the dispatching of power plants does not change according to fuel prices, and consumers do not reduce their demand for transportation at higher fuel prices.

As previously mentioned, security of supply (e.g. in the form of failing fuel supplies) and other environmental and health costs (e.g. air pollution) are not valued in this study. Compared to the reference, the consumption of fossil fuels is brought down in all reduction scenarios, and in this connection, a gain in the form of lower environmental and health costs as well as a more reliable supply may therefore be expected. On the other hand, the report has not assessed how the additional investments in the scenarios should be financed and how economic incentives should be structured. There may be significant transactions costs related to making players in the energy markets (including energy consumers) pick the solutions envisaged in the scenarios. Moreover, publicly financed economic incentives may lead to distortion losses, which have not been quantified. Finally, the costs of investments may prove to be higher or lower than estimated.

6 SCENARIO ASSUMPTIONS

This chapter presents key assumptions from the various regional archetype-scenarios as well as for the aggregated EU-27 reduction scenario.

From the perspective of the modeler and the analyst the installment of specific technologies at specific quantities in a scenario represents an *assumption,* which therefore is the correct term to be used. From a policy makers point of view these elements of the scenarios may be seen as potential *measures* for policy-making if the scenario is seen as attractive.

The following issues will be addressed:

- Assumptions in the transport sector
- End use and energy savings (industry, tertiary, residential)
- Electricity supply measures

6.1 Assumptions in the transport sector

In 2005 the transport sector accounted for 30 per cent of the total energy consumption and contributed heavily to EU's Green House Gas emissions (GHG). Trends show that these figures are to increase significantly in the future. Due to the heavy dependency of oil, securing energy supplies is expected to become an important consideration for the transport sector in the future.

The target of 50 per cent oil reduction in 2030 compared to 2005 poses a big challenge to the transport sector, largely because it is currently highly dependent on oil in the form of gasoline, diesel and jet fuel today.

In the Small-tech scenario, the key measures to reduce oil consumption are improved efficiency of vehicles for passengers and transport of goods, and the introduction of electricity in the car and truck fleets. In 2030, the average conventional car will emit approx. 100 g CO_2 per km.

Electric vehicles and plug-in hybrid electric vehicles may offer multiple benefits by improving fuel efficiency as well as the utilisation of wind energy by using electricity in a more flexible way (e.g. by charging at certain times or serving as "batteries" for the electricity system). Similarly, flexible consumption can improve the economy of systems with a high-share of base-load capacity such as nuclear power and CCS. In both reduction scenarios, the share of electric cars varies between 15 - 25 per cent depending on the location. The highest shares are anticipated in the regions with the highest level of wind power penetration.

In the Small-tech scenario, where energy conservation plays a key role, biofuels are not a crucial measure because it makes more sense – from an energy resource point of view – to use the limited biomass resources for other purposes such as combined heat and power generation. This is because the production of second generation biofuels requires significant amounts of process energy. Hence only approx. 5 per cent of transport work is covered by biofuels in this scenario. In the Big-tech scenario where the lower level of energy savings makes it more difficult to cope with the 50 per cent oil reduction target, biofuels are introduced at increasing levels in the transport sector (approx. 15 per cent). By way of comparison, the EU biofuels target for 2020 is 10 per cent

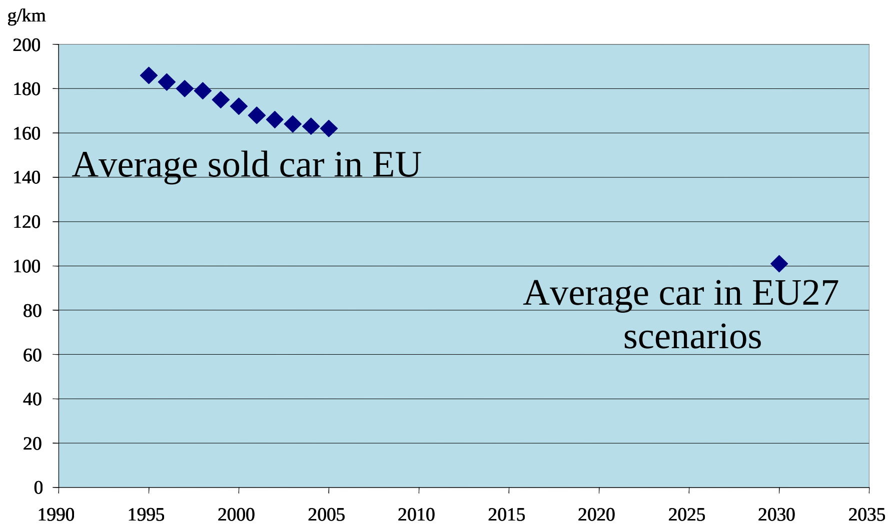
Natural gas is assumed to be used by 20 per cent of the busses in the Big-tech scenario and, in addition, natural gas is used to propel 10 per cent of all transport work by trucks and vans.

A certain degree of modal change from car to train, bus to bike and from lorries to train and sea transport is also assumed to take place in both reduction scenarios. However this change accounts for a minor share.

Improved efficiency

In both the Small-tech and the Big-tech scenarios energy efficiency measures in the transport sector make the most important contributions to achieve the reduction of oil consumption by 50 per cent compared to the present level and reducing CO_2 emissions by 50 per cent compared to the 1990-level in the Small-tech and the Big-tech scenario.

Figure 11: Historic development in the efficiency of new cars sold in the EU compared with the assumption for the average car in the scenarios. The same improvement in efficiency is assumed in the Small-tech and Big-tech scenario

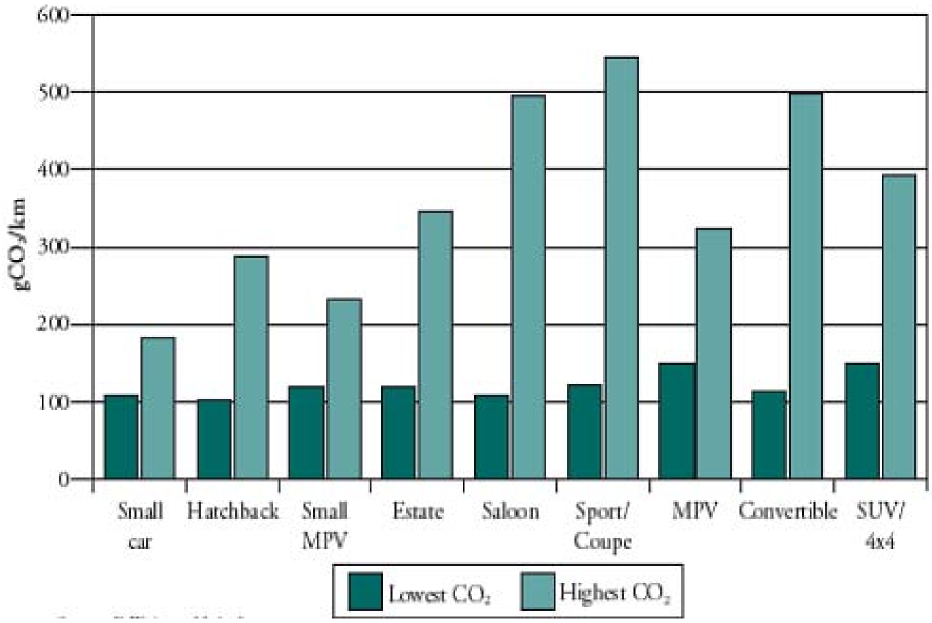


The average sold car in EU produced between 190 and 160 gram CO_2 per kilometre during the years of 1995 and 2006. The European Commission has established a proposal that requires a reduction of the average emissions of CO_2 from new passenger cars in the EU from around 160 grams per kilometre to 130 grams per kilometre in 2012. That will denote a reduction of CO_2 emissions reaching levels of 19 per cent.

In the scenarios a reduction down to approx. 100 gram of CO_2 per kilometre is assumed to be obtained by year 2030 for conventional cars propelled by gasoline or diesel due to improved efficiency of the motor, aerodynamics, lighter materials etc.

Figure 12 shows the emissions from new cars in 2006 divided into the different classes. There appears to be a very large difference between the CO_2-emissions within the different classes. For all classes it is possible to find vehicles emitting less than 150 g CO_2/km. Simply by choosing the most efficient cars, that are already on the market today, it should be possible to come very close to the efficiency target of the STOA scenarios.

Figure 12: Emissions from different classes of new cars in 2006



(MPV: Multi Purpose Vehicle, SUV: sport utility vehicle) (ref.19)

New fuels and technologies

In the both reduction scenarios, the share of electric cars varies between 15 and 25 per cent depending on the location. For example in the case of cars, a share of 15 per cent of electric vehicles has been considered for west, east and south region, for central and north a higher share of 20 per cent and 25 per cent respectively is taken into account due to the large share of wind energy which provides great incentives to introduce electricity in the transport sector as means of storage.

Table 9: Electric vehicles share on transport sector

Region	Cars	Trucks/Cargo
North	25%	20%
Central	20%	15%
South	15%	15%
West	20%	15%
East	15%	20%

Hydrogen based cars have not been included as an option in the scenarios. The main reason for this is that the energy losses associated with the production and conversion of hydrogen are expected to be significantly greater than for electric vehicles.

Modal change

Some degree of modal change from car to train, bus and bike and from lorries to train and sea transport is also assumed to take place in the scenarios.

Figure 13: Example of modal change for the North region

Share of Transport work		Ref_North	Scenario_North	
Person	2005	2030	2030	2005 Utilisation
mio.person km	307.700	397.000	397.000	
Car	71%	70%	60%	39%
Bus	8%	6%	10%	28%
Train	7%	6%	12%	40%
Aviation and ferries	14%	17%	13%	50%
Bike, ICT etc.	0%	0%	5%	100%
	100%	100%	100%	
		Ref_North	Scenario_North	
Goods	2005	2030	2030	2030 Utilisation
mio.tonnes km	140.800	185.400	185.400	
Trucks and cargo vans	70%	73%	65%	30%
Train*	23%	20%	23%	50%
Ship*	6%	7%	12%	40%
Air transport		0%	0%	80%
	100%	100%	100%	

The Figures above show, by example of the Northern Region, what degree of modal change is assumed. We see that about 10 per cent of car transport is assumed to distribute on bus and trains and other more energy efficient transportation means.

To implement modal change, which is a crucial measure in increasing energy efficiency in the transportation system, a range of policy measures are required, but it is out of the scope of the project to analyse this.

Information and communication technologies

Information and communication technologies (ICT) have capabilities to reduce energy consumption and CO_2 emissions. Perhaps the most obvious way is through substitution of physical transport through video and teleconferences, telecommuting and tele-education.

One can also interpret the potentials of ICT in a broader sense with ICT gradually becoming an integrated part of everyday appliances such as washing machines, refrigerators and office machines etc. Though we consume energy when using ICT, the potentials of ICT to deliver energy and transport services in a more intelligent way, for example through dematerialization, are substantial (ref.17). One example is intelligent heating of houses; another is the replacement of traditional answering machines with virtual ones.

In the Small-tech scenario, ICT is envisioned to play a role in reducing energy consumption by consumers, in developing a smart-grid to incorporate high shares of renewables and in reducing the transport demand through web-conferences and tele-commuting. It has been assumed that approx. 3 per cent of the demand for car transportation can be met by ICT and 10 per cent of passenger transportation by flight.

In November 2007 the European Commission presented the **SET-Plan**. The aim of the SET-Plan is to **accelerate the market introduction and take up of low-carbon and efficient energy technologies**. In the Technology Map of the SET-Plan,

*"...It is stressed that the assessment is **not made at the energy system level**. Consequently, the impacts of the various technologies cannot be added up since it is not feasible that all technologies achieve the envisaged maximum potentials simultaneously. In addition to physical and technical constraints of the energy system, social and consumer acceptance is an important barrier for the deployment of a number of technologies. ... The time horizon considered for the assessment is 2030".*

The present project attempts to link the aims of the SET-Plan with an actual projection of the energy status for EU27 in year 2030 incorporating the potentials identified in the SET plan. Thereby it is possible to show the impact (actual and economical) of utilizing all the different technologies to achieve given targets for the year 2030.

6.2 End use and energy savings (industry, tertiary, residential)

Energy savings and improvement of the energy efficiency are crucial elements in the Small-tech scenario and require efforts in relation to buildings, industry and appliances. In the Small-tech scenario, additional savings in the order of 10-20 per cent of electricity demand and 6-10 per cent of the heating demand are assumed compared to the EU Commission baseline for 2030. The level of energy services delivered to consumers is assumed to be the same in the Small-tech scenario as in the baseline. In other words, the energy savings in the scenarios for 2030 are obtained by improving the efficiency of appliances and through better insulation of houses etc. – not by lowering the service level.

The increased energy efficiency at end-use level in the Small-tech scenario reduces the gross energy demand by around 18,000 PJ or by 25 per cen.t2,500 PJ electricity is saved each year replacing almost 200 large power plants at 600 MW capacity.

A number of studies have documented that there are technical and economic saving potentials at least in the same order of magnitude as the potentials included in the Small-tech scenario. However, the big challenge is to find the proper measures to harvest these potentials. It is a critical assumption in the Small-tech scenario that this is, in fact, possible. This will require ambitious continued policy efforts both at the EU, national, and local levels.

The Big-tech scenario assumes the same level of improvements in energy efficiency as in the Commission's baseline.

Energy demand from the four sectors (Tertiary, Industry, Residential and Transport) is based on the expected economic growth in each sector in each country. The economic growth in the scenarios follows the growth rates used in DG TREN. A so-called "frozen efficiency" energy demand for each sector is calculated and the saving measures are then added.

Table 11 illustrates the level of savings included in DG TREN and our reference and then the additional savings included in the Small-tech scenario.

Table 10: Efficiency improvements in the reference and in the Small-tech scenario divided on sectors

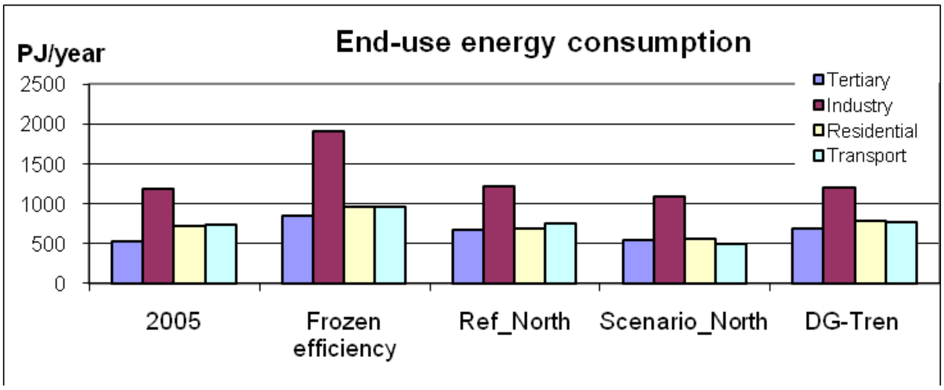
Per centage saving compared to today's level	Energy form	Efficiency improvement in reference*/Big-tech scenario	Additional savings in Small-tech scenario
Tertiary	Electricity	20-30	**10-20**
	Heating	20-30	**6-10**
Industry	Energy	20-30	**10-16**
Residential	Electricity	20-35	**10-20**
	Heating	20-40	**7-15**

* DG TREN baseline scenarios.

In the Energy saving model the sectors are further divided into different industries and end use services. The energy savings are implemented at the level of different energy use in the different industries and households.

Figure 14 is an example of the aggregated results from the Energy saving model. This example is the central region of the EU-27. The "frozen efficiency" projection shows the development in energy demand if efficiency was not improved compared to today's level. The reference scenario is very close to the DG TREN baseline in terms of energy demand, while the Small-tech scenario with the additional saving measures has a reduced demand.

Figure 14: Example of the calculated end use energy demand in the North region



Costs related to improving efficiency from the level in DG TREN baseline to the level used in the scenarios, using an interest rate at 6 per cent and the assumed lifetime for each technology, is 18-25 €/GJ for electricity savings, and 10-16 €/GJ for heat savings (GJ: Giga Joule). These costs are based on prices used by the Danish government when calculating socio-economic costs related to the Danish Action Plan for Renewed Energy Conservation.

6.2 Substitution of oil, gas and coal

One of the main measures assumed in the scenarios is the substitution of conventional fossil fuels used, such as coal, oil and natural gas with increased district heating/cooling usage, biomass, solar thermal and other sustainable technologies. These are technologies that can be applied in all the regions (with different potential from region to region).

6.3 District heating and cooling

Currently, district heating combined with mixed heat and power plants are widely used in the Eastern and Northern European countries. From an energy resource point of view, there are major benefits to be gained from extending the district heating infrastructure in other regions of Europe as well. In combination with mixed heat and power generation, district heating may increase the fuel efficiency of power plants from 40-50 per cent (electricity only) to approx. 90 per cent (electricity and heat).

Figure 15: Combined Heat and Power (CHP)

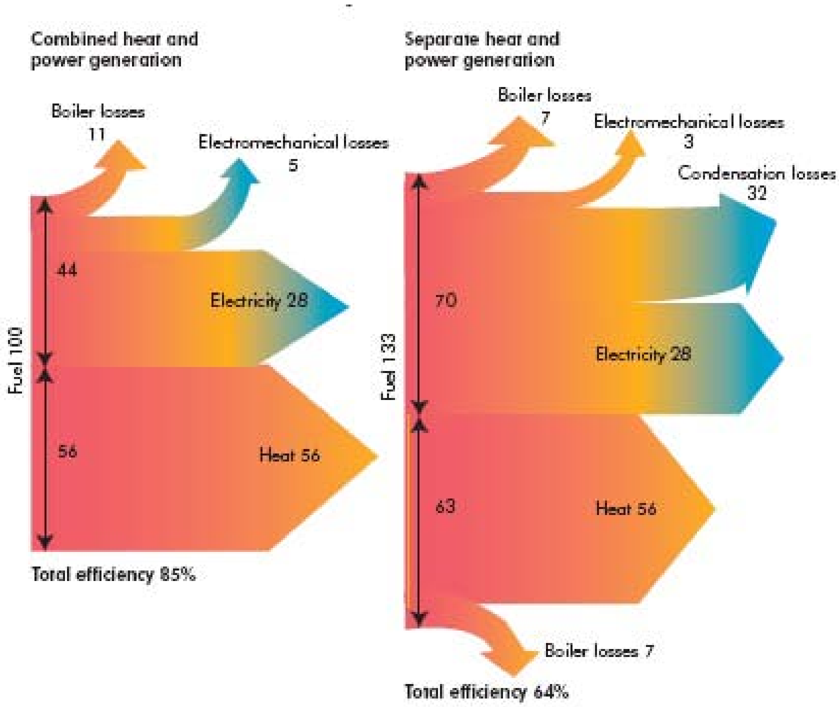


Illustration of fuel consumption when producing power and heat together at a CHP plant and when producing heat and power separately. The amount of electricity and heat generated is the same in the two situations, but with 33 per cent higher fuel consumption in the case of separate heat and power generation. The illustration is quoted from IEA, Energy Technology Perspectives 2008.

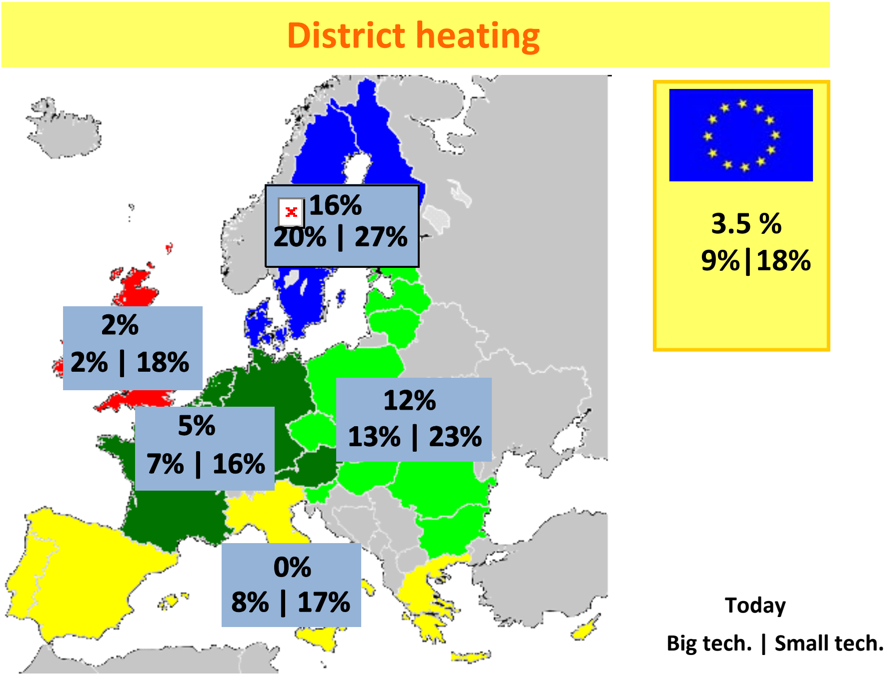
The surplus heat from the power plants can be used for heat purposes, and if relevant, for cooling as well. District heating systems can also provide a valuable storage medium for wind power through the use of electric boilers and heat pumps. Finally, district heating gives consumers a high level of security of fuel supply as multiple fuels may be used for the production, including municipal waste, geothermal heat and solar heat.

District heating in combination with combined heat and power plays a key role in the Small-tech scenario where generation resources are assumed to be increasingly distributed. In the Small-tech scenario, the share of district heating and cooling in final energy demand (excluding transport) increases from 4 per cent today to 18 per cent.

Increasing the share of district heating and cooling will require significant regulation and planning at the national level, and among local authorities and cities in the European Union.

Due to lack of data district cooling has not been included in the modelling.

Figure 16: District heating as share of final energy demand in industry, residential sector and tertiary sector. (Today = > Scenario)



This model shows the share of district heating relative to the final energy demand in industry, residential sector and tertiary sector across the five regions. The first number is today's percentage, bottom left is the Big-tech scenario and bottom right is the percentage for the Small-tech scenario.

6.4 Nuclear power

In the reference projection for 2030, the contribution of nuclear power is expected to follow the baseline from the European Commission, which considers the different policies towards nuclear power across Europe. This reference, which includes a phase-out in Germany, leads to slightly decreasing nuclear capacity towards 2030 for the EU27 as a whole.

In the Small-tech scenario, expansion with nuclear power is not used as a dedicated measure, nor are nuclear power plants expected to be decommissioned beyond what is assumed in the reference projection.

In Big-tech, nuclear power is a measure to achieve CO_2 reductions and displace fossil fuels for power generation. Compared to today, nuclear power capacity is increased from approx. 135 GW to 175 GW. This increase is assumed to take place in all regions across Europe, but not in member states currently opposed to nuclear power. By way of comparison, the SET-plan technology map points to a potential penetration for nuclear in the range of 127-200 GW in 2030.

The choice of reactor design is not considered in the scenarios. The SET plan underlines the need to develop a new generation of fast-breeder reactors in order to exploit the limited uranium resource more efficiently.

The cost of nuclear power – direct costs as well as externalities - is a subject of controversy. For the economic calculations in this project, it is assumed that new nuclear power plants may be installed at an overnight cost of 2.2 Mill. €/MW. Possible external costs and the costs of decommissioning retired power plants and managing radioactive waste have not been considered in the project.

6.5 Carbon Capture and Storage

In the Big-tech scenario, CCS is an important instrument for reducing CO_2 emissions from power generation. In 2030, some 145 GW of power generation capacity is assumed to be equipped with CCS, capturing and storing 930 Mt of CO_2 underground in the EU annually. This is based on an assumption that all large thermal power plants commissioned beyond 2020 are equipped with CCS. In addition, it is anticipated that all coal power plants commissioned in the period 2010-2020 are prepared for CCS, and that a considerable share of these power plants are retrofitted in the subsequent decade.

By way of comparison, the SET plan indicates a potential of 90-190 GW of CCS capacity in 2030.

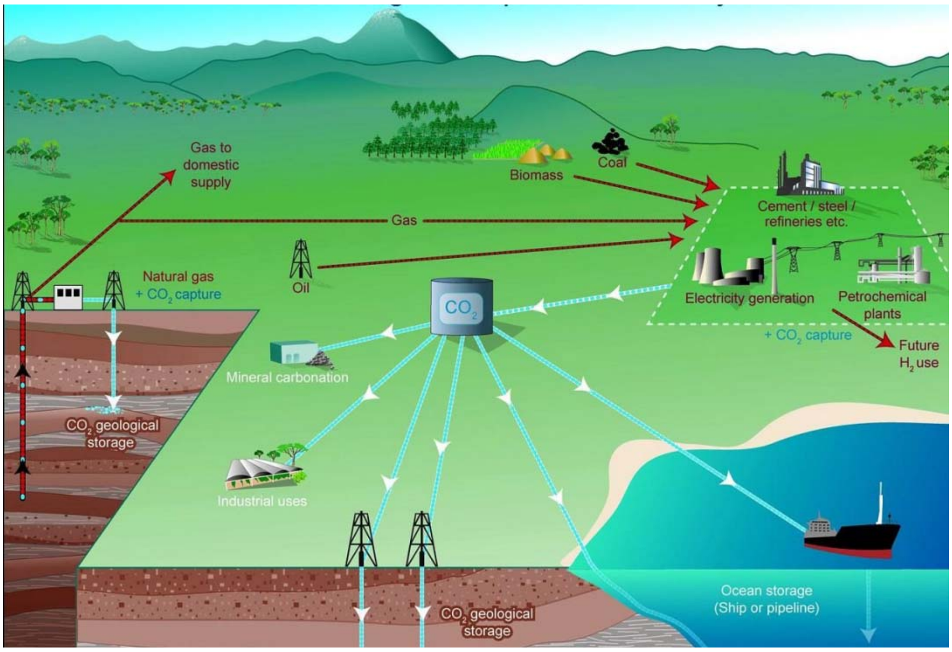
The CO_2 capture technologies in the Big-tech scenario are installed mainly at coal-fired power plants, but also to a certain degree at gas-fired and biomass co-fired plants. The latter will thus contribute to a net reduction of CO_2 emissions.

Although CCS holds big promises, a number of barriers related to CO_2 storage need to be addressed before this technology can be used on a large scale in the future. Liability and environmental issues in case of leakage will require a carefully regulated legal framework that will guarantee a safe implementation in the long-term. Applications in the separate modules consisting of a CCS system have been demonstrated, but the demonstration of a large-scale fully integrated power plant has not yet taken place.

Moreover, CCS technologies have high investment costs and significant energy consumption for capturing $CO_{2.}$ The SET-plan estimates that the loss in electric efficiency would be in the range of 12-15 percentage points for the first generation of CCS plants, decreasing to 8 percentage points for new plants commissioned in 2030. This study uses a loss of 10 percentage points as an estimate for the average CCS plant in 2030.

The potential for using the CO_2 captured at CCS plants as a means to enhance oil recovery from oil fields – for example in the North Sea – have not been explored within the present project.

Figure 17: A schematic diagram of a possible CSS system [ref.18]



6.6 Exploiting the potential for Renewable Energy (RE)

In the base year of 2005, renewable energy sources contributed approx. 7 per cent of the gross energy consumption. In the reference projection, this figure increases to approx. 14 per cent as a result of increasing fossil fuel prices and existing support schemes. In the Small-tech scenario, renewable energy is an important measure and its utilisation increases to 38 per cent of the gross energy demand. In the Big-tech scenario the share of renewables is 22 per cent.

Both the Small-tech and the Big-tech scenario make use of all the environmentally sustainable *solid* biomass resource in the EU. In addition, the biogas and the municipal waste resources are fully utilised in the Small-tech scenario, mainly at decentralised combined heat and power plants.

Wind and solar power are important sources of electricity generation in the Small-tech scenario where the majority of the expected viable potential for wind is utilised.

The utilisation of solar energy, which is mainly constrained by economics, primarily takes place in Southern Europe and could be further increased beyond 2030. Currently, some 5 GW of solar power capacity is installed in Europe and growth rates in recent years have been around 50 per cent per year. In the Small-tech scenario, the solar power capacity increases to approx. 160 GW corresponding to an annual growth rate of 15 – 20 per cent from today to 2030.

Ocean technologies, such as wave power, are also anticipated to play a role in the Small-tech scenario even though their contribution to the general electricity supply is limited.

In the Big-tech scenario a more moderate development in wind power, and particular solar power, is anticipated. No development of ocean power technologies is assumed in the Big-tech scenario.

The development of the investment costs of solar power technologies are critical factors in their actual implementation in the Small-tech scenario.

For the economic calculations it is assumed that the cost of solar power plants and ocean power will improve considerably compared to today. It should be stressed that there is a significant degree of uncertainty as to whether these cost reduction potentials will actually materialise.

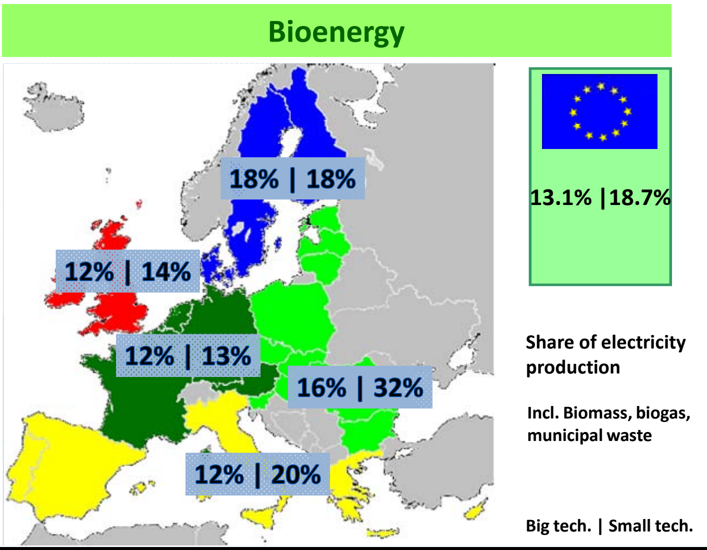
The following sections describe in greater detail how biomass, wind, solar and ocean technologies are put into play in the scenarios.

Biomass

Biomass used for energy purposes in the Small-tech scenario reaches a share of 19 per cent at the EU-27 level with its most dominant role in the Eastern region where bioenergy reaches up to 33 per cent of the electricity production.

The resources exploited are based on an analysis from the European Environment Agency, EEA (ref.7), on biomass, and are those that can be utilised in an environmental friendly and sustainable way. The biomass used for electricity generation is almost exclusively used at combined heat and power plants.

Figure 18: Bioenergy power share of electricity production



In the scenarios, as bioenergy we consider the use of biomass such as wood waste, agricultural residuals including biogas (which is used at Combined Heat and Power (CHP) plants) and municipal waste. In fact, municipal waste is a very important resource in the scenarios covering 8-9 per cent of electricity production.

Wind power

Regarding wind power, the scenarios show a great potential in four regions of Europe, leaving the Eastern region with a low potential of 6 per cent in both reduction scenarios. The Western region has the greatest share in the Small-tech scenario with 23 per cent of the total electricity production, followed by Central and North region with 20 per cent. The smallest share exists in Eastern Europe mainly due to the limited wind resources. These variables are due to the potential of wind resources in the different regions. The total share of electricity production in the EU-27 becomes 16 per cent in 2030 in the Small-tech scenario and 9 per cent in the Big-tech scenario. These percentages may be increased further beyond 2030 if the necessary infrastructure is prepared to support it.

Figure 19: Wind power share of electricity production

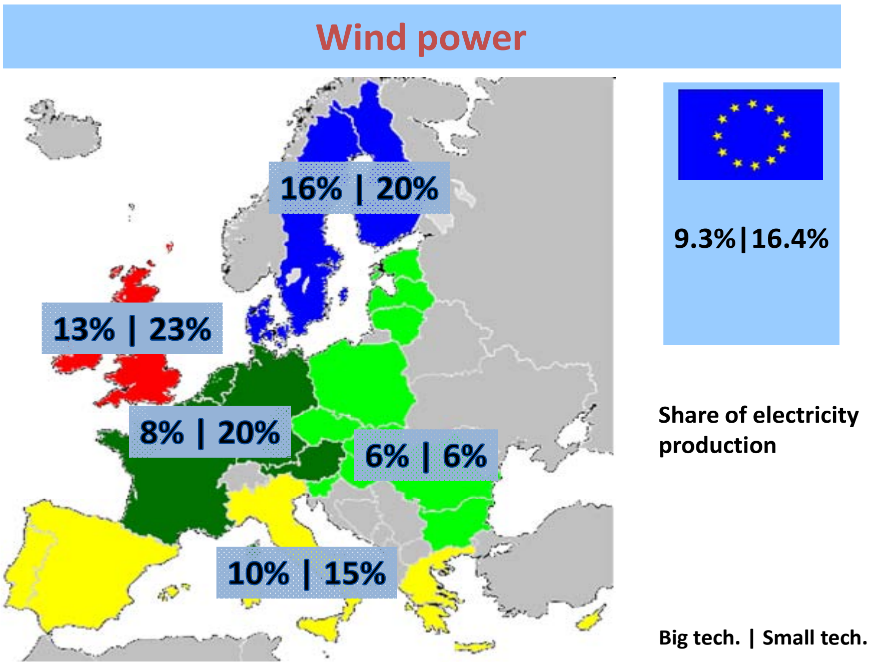
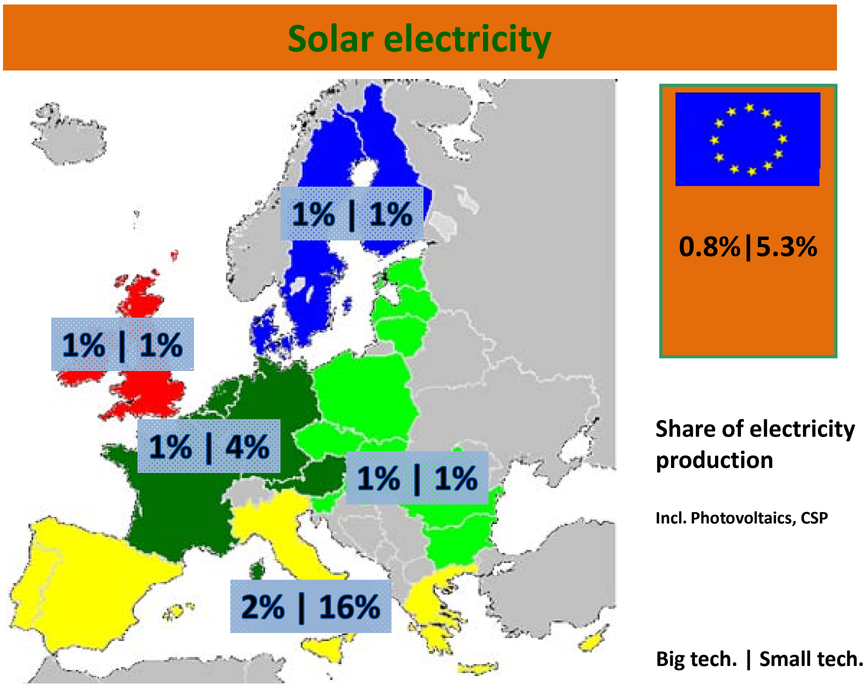


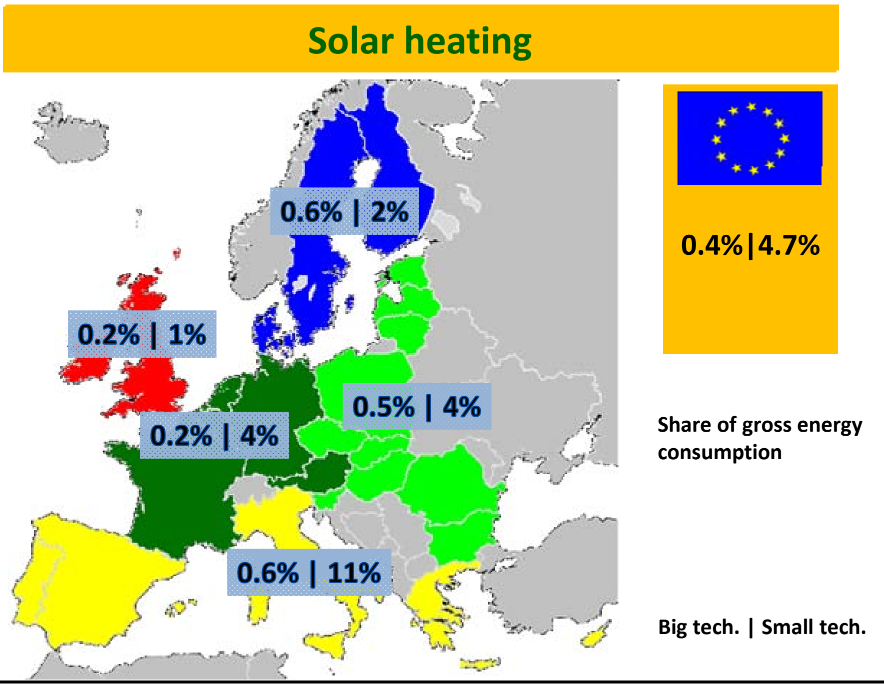
Figure 20: Solar electricity incl. PV and CSP Photovoltaic



Solar power (PV and CSP)

Solar power provides up to 5,3 per cent of the total EU-27 electricity production in the Small-tech scenario with the highest expected share in the Southern region. Photovoltaics (PV) have been considered as the main technology regarding solar electricity, although part of the capacity is composed of production from Concentrated Solar Power (CSP).

Figure 21: Solar thermal as share of gross energy consumption



Solar thermal

Solar thermal technologies are readily available and could be a low-cost and effective solution that in the southern region could provide up to 100 per cent of the demand for heated water. Moreover, they can be deployed in regions with different climatic conditions and can be used in all sectors where there is low temperature heat demand. In that respect, solar thermal has been projected to cover almost 5 per cent of the overall gross energy consumption in the scenarios.

In the following table an example for the different fuel shares for heat supply in the South Region is shown.

Table 12: Example of model input. Shares of fuels for heating supply in the residential sector in the South

Fuel consumption	2005 TJ	2005 %	Frozen efficiency TJ	Frozen efficiency %	Ref_South TJ	Ref_South %	Scenario_South TJ	Scenario_South %
Electricity	**567808**	**26%**	**901852**	**27%**	**789801**	**30%**	**532432**	**25%**
- Appliances	412208		671712		539471		416208	
- Space heating	155599	9%	230139	9%	236025	11,00%	87168	5,00%
District heat	12875	1%	19043	1%	386223	18,00%	435842	25,00%
Coal	4965	0%	7343	0%	0	0,00%	0	0,00%
Oil	533309	29%	788792	29%	257482	12,00%	52301	3,00%
Natural gas	890216	49%	1316675	49%	965557	45,00%	383541	22,00%
Biomass	216429	12%	320110	12%	257482	12,00%	174337	10,00%
Solar Heating		0%		0%	0	0,00%	523010	30,00%
Heat pumps	0	0%	0	0%	42914	2,00%	87168	5,00%
Total	**2225602**	**100%**	**3353815**	**100%**	**2656544**	**100%**	**2101462**	**100%**
		Total heat supplied to buildings:			2145682		1743367	

The column on the far right refers to the Small-tech scenario, where we can see that 30 per cent the fuel share for heat supply is delivered by means of solar heating and another 5 per cent by heat pumps. This makes possible for example a dramatic reduction of natural gas consumption to only 22 per cent (down from 45-49 per cent) of the electricity supply

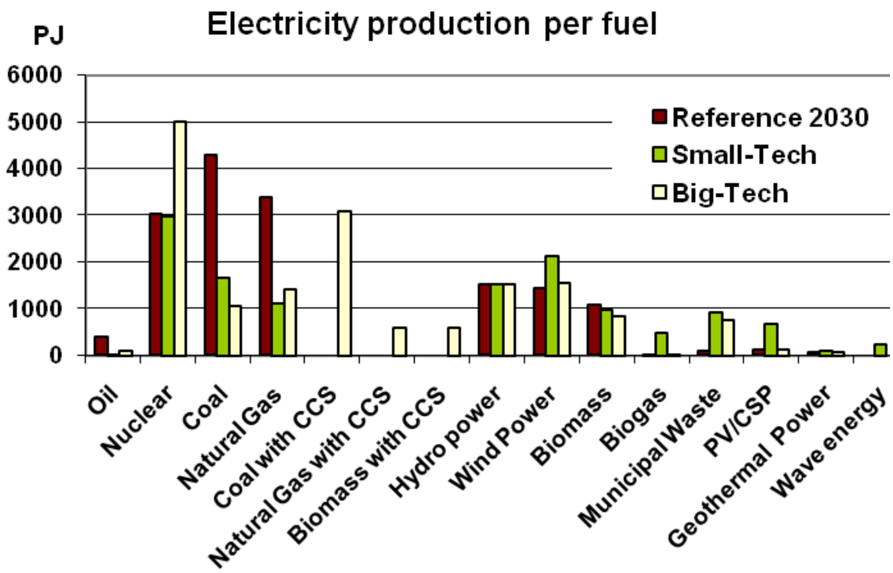
Ocean and geothermal energy

Finally, there is ocean energy, which due to its great potential for a large part of Europe, its share has been distributed between West, North, Central and South region reaching installed capacities of 16 GW in our scenarios for year 2030. Geothermal production is mainly distributed between the East and South Regions contributing both in electricity (3.8 GW installed capacity) and thermal production. However, great potential have been presented and geothermal may actually provide an even higher share.

6.8 Electricity generation

Figure 22 provides an overview of the total electricity production in the scenarios for 2030 compared with the reference projection. The differences between the two scenarios as described above can be observed. The Small-tech scenario relies on a wider variety of renewable sources, while the Big-tech relies heavily on nuclear and CCS technology for coal, natural gas and biomass fuelled power plants.

Figure 22: Electricity production by technology in the reference for 2030 and the scenarios for 2030

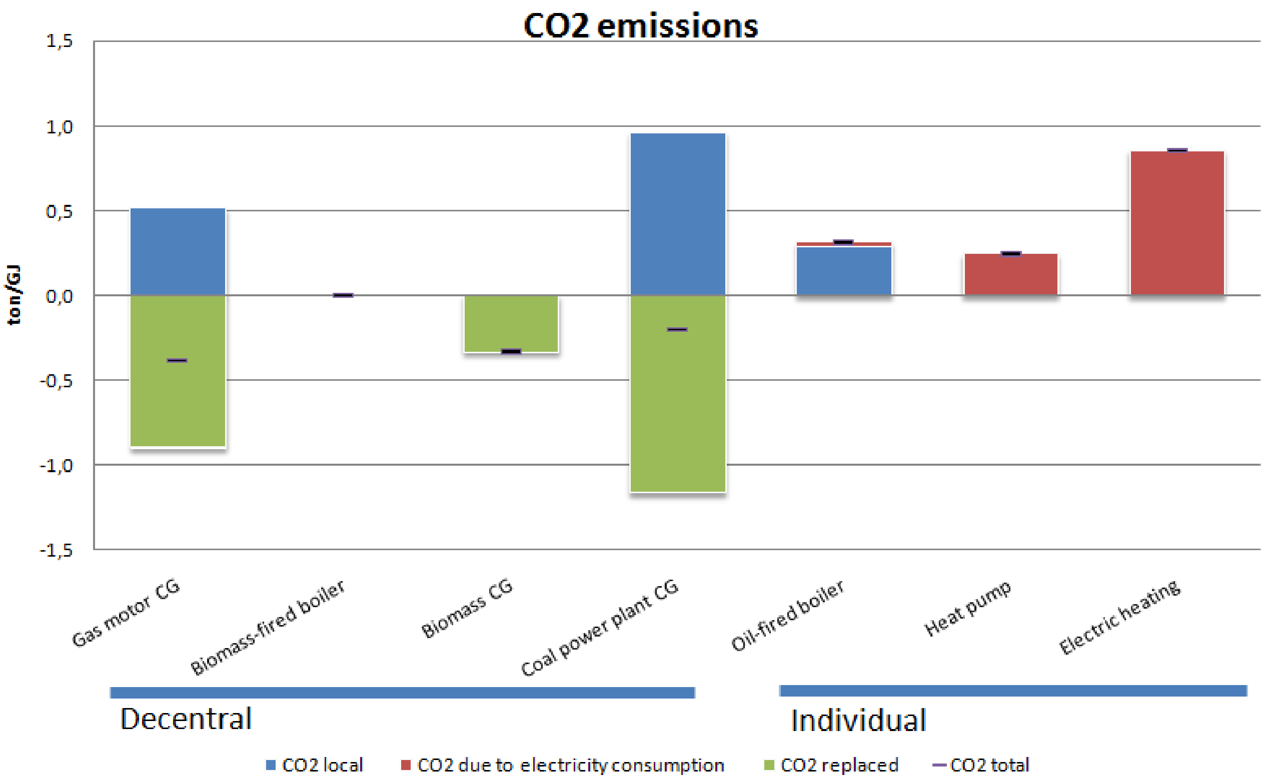


6.9 Space heating

Which technologies for space heating cause the least CO_2 emissions? This was one of the issues addressed by the Swedish Professor Björn Karlsson from Linköping University at the project workshop in Brussels 16 September 2008. When it comes to comparing the environmental aspects and CO_2 emissions of different technologies for heat production, it is not sufficient to analyse the immediate local consequences. One has to look at consequences in an energy systems perspective. Electric heaters cause no emissions locally, but the global footprint is significant because of the emissions related to the production of electricity. In Sweden, where hydro and nuclear power are dominating, reducing the national electricity consumption would allow the country to export a similar amount of electricity to neighbouring countries replacing gas and coal based power. Similarly, generating heat from a local CHP plant (e.g. at a biomass fired cogeneration plant) would replace the need for generation of electricity for heating elsewhere in the energy system and thereby reduce overall emissions.

Figure 23 shows the impacts on CO_2 emissions due to the production of 1 GJ heat from different space heating systems. Local emission is shown in terms of blue columns. The green and red columns show the effect of saved and additional CO_2 emissions elsewhere in the system, originating from replaced or additional electricity production respectively. The total CO_2 emissions show a clear advantage of the cogeneration plants, while electric heating means major CO_2 emissions due to the marginal power plant which is assumed to be a coal fired power plant in this analysis.

Figure 23: CO_2 emission for heat generation based on different technologies. CG = cogeneration of heat and power



6.10 Infrastructure

The massive expansion of wind power – and to some extent solar power – assumed in the Small tech-scenario will benefit significantly from increased transmission between EU countries. This will increase the value of wind and solar power to the energy system and help provide balancing power. To ensure a coherent expansion of the electricity infrastructure – particularly for integration of offshore wind power – it will be necessary to coordinate the plans for transmission capacity between member countries as foreseen in the SET plan.

At the local level a large-scale effort is required to increase the access of consumers to district heating. District heating systems have relatively high initial costs and require a substantial planning and organizational effort at the local level. If these challenges are not dealt with, the development of CHP based district heating may be impeded.

In the Big-tech scenario, a new infrastructure for the transportation of captured CO_2 is required. According to the EU Commission, broadly speaking, there is enough storage capacity for each member state to store its own emissions, provided that the optimistic estimates that have been made regarding aquifer storage potential are borne out. If the substantial storage under the North Sea is to be utilised for CO_2 capture in combination with enhanced oil recovery, this will probably call for trans-national cooperation on infrastructure projects.

In the economic calculations, a cost element of 10 €/ton for transportation and sequestration is included for all CO_2 captured at CCS plants. Possible revenues related to enhanced oil recovery have not been included.

7 SMALL OR BIG... OR A COMBINATION

The project explores two essentially different developments of the European energy systems through a so-called *Small-tech scenario* and a *Big-tech scenario*. Both scenarios aim at achieving the aforementioned goals for 2030; reducing CO_2 emissions by 50 per cent compared to the 1990 level, and reducing oil consumption by 50 per cent compared to the present level.

7.1 Small...

The Small-tech scenario focuses on distributed energy generation, energy savings and efficient utilisation of energy through smarter devices and combined heat and power generation. In this scenario, so-called smart grids and better communication between all elements in the energy supply chain allow for the integration of a high share of non-dispatchable generation such as wind and solar power. Besides small-scale technologies, the solutions in this scenario include measures such as large off-shore wind farms and large combined heat and power plants in the big cities.

7.2 ... or Big

The Big-tech scenario explores the opportunities of more centralised solutions. In Big-tech, almost all new coal and, to a smaller extent, natural gas power plants established from 2020 and onwards are equipped with carbon capture technologies (CCS), and the generation from nuclear power increases by 40 per cent compared to today. Moreover, it is assumed that new large coal power plants commissioned in the period 2010-2020 are prepared to be retrofitted with CCS.

The level of carbon capture and nuclear power introduced in this scenario complies with the upper limits of the potentials identified in the Commission's technology map underlying the SET plan. All the sustainable biomass resource, as assessed by the European Environment Agency, [ref.7] is used in the scenario – mainly for co-firing at large power plants and for heating and process energy at industrial consumers. Energy savings and energy efficiency measures are important in the scenario as well, but solutions are focused mainly on the supply side.

7.3 ...or perhaps a combination

The scenarios illustrate two different developments of the future European energy system – which some might find extreme. Therefore, it is important to note that the measures in each of the scenarios are not mutually exclusive. For example, CCS technologies could be applied in the Small-tech scenario to reduce emissions even further, or more energy savings could be harvested in the Big-tech scenario to reduce the demand for energy. Another scenario combining elements of the two may lead to even greater reductions, or provide added certainty of achieving the existing targets.

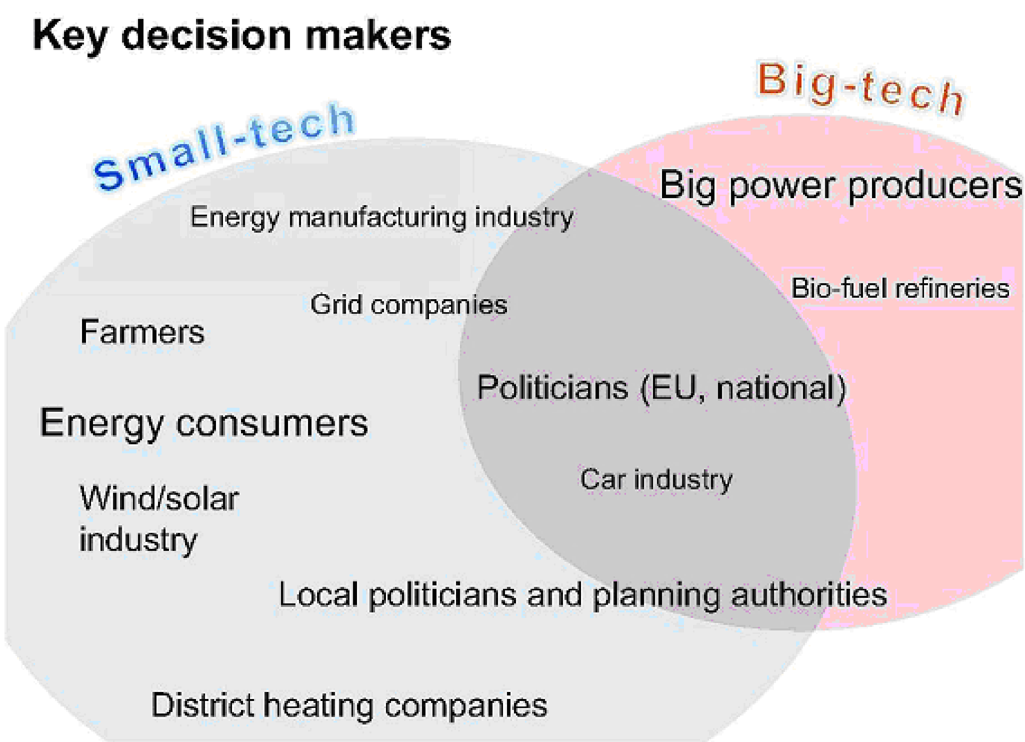
Another option would be that some member states actively pursue the Small-tech scenario, while others pursue the Big-tech scenario.

7.4 Requirements for transformation

The small versus big-tech approach is interesting, because the requirements for the transformation of the energy sector are very different indeed.

For the Small-tech scenario to become reality, it is required that all levels in the energy supply chain take action. Industries and communication technology suppliers will have to produce more energy efficient appliances, building owners are to renovate existing buildings to cope with more stringent building codes, grid owners must rethink their system architecture, and the suppliers of energy will have to gradually change sources from large power plants to renewable, and to distributed units located closer to the consumers. So the distinction between Small-tech or Big-tech also encompasses the distinction between decentralised and centralised energy system solutions.

Figure 24: Key decision makers in the different scenarios



In this case, European citizens have an important role as active consumers of energy, changing energy behaviour according to price signals and investing in energy efficient appliances and equipment. Energy taxation and dynamic labelling and norms for appliances could become crucial measures for achieving this response.

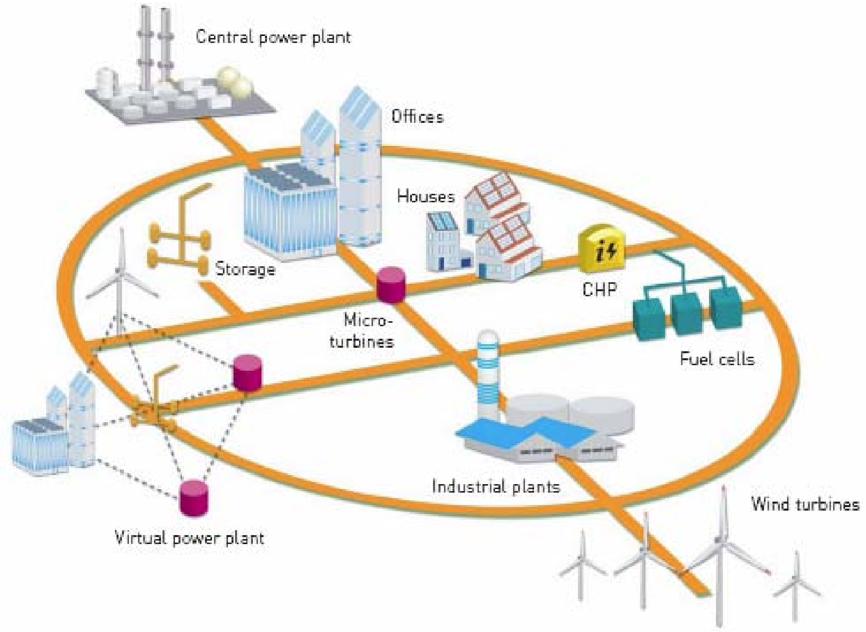
When pursuing the Big-tech scenario, the existing structure of the supply system can remain essentially unchanged, since the main actors will be the large suppliers of electricity. Thus, the implementation of the Big-tech scenario depends on relatively few decision makers. However, the Big-tech scenario is also dependent on the commercialisation of the CCS technology and on public support for more nuclear power.

7.5 The transport challenge

The transport sector has to undergo fundamental changes in both scenarios in order to achieve the ambitious oil reductions. In the Small-tech scenario, electric vehicles and plug-in hybrids displace oil consumption, and information and communication technologies are actively employed to decrease the demand for "physical" transportation. In the Big-tech scenario, 2nd generation biofuels and natural gas become important means, in addition to the electrification of the transport sector. Moreover, it is of great importance that both scenarios assume that the significant technical potentials for improving the fuel economy of conventional vehicles are partly realised.

In the Small-tech scenario, the electricity stores in vehicles and plug-in hybrids are essential for balancing generation from intermittent energy sources such as solar and wind power.

Figure 25: Small-tech Scenario Model



The Small-tech scenario represents a development that differs from the current system setup where, predictably, the power flows in one direction from the central power stations, through high voltage transmission systems, to supply power to consumers located in medium and low-voltage local distribution systems. In Small-tech, generation is distributed to enjoy the benefits of combined heat and power generation and to make use of the dispersed renewable energy sources. Electric vehicles and plug-in hybrids are used to balance wind power by means of information and communication technologies and efficient markets [illustration from "European Technology Platform SmartGrids Vision and Strategy for Europe's Electricity Networks of the Future, EC 2006 [ref.22]

8 RESULTS

To illustrate the consequences of the two scenarios, the key indicators – the development in gross energy consumption and the emission of CO_2 – are compared with historic data as well as with a reference for 2030 resembling the most recent projection from the European Commission [ref.4].

8.1 Energy consumption and CO_2 emissions

The 2030 projection from the Commission predicts a slight increase in gross energy consumption as well as in CO_2 emissions in 2030 compared to 2005. The baseline projection considers actually implemented polices, but not policy targets such as the EU's 20-20-20 targets for 2020. The share of renewable energy is doubled and as a result of stringent policies, gross energy consumption is almost stabilised despite economic growth.

In the Small-tech scenario, it is anticipated that the gross energy consumption will be reduced by almost 20 per cent in 2030 compared to 2005. This is mainly due to the even higher level of energy saving measures and to the increased deployment of combined heat and power generation that reduces conversion losses for electricity and heat generation.

In the Big-tech scenario, gross energy consumption increases by 7 per cent compared to today. This increase, which is slightly higher than in the reference projection, is mainly due to increased utilisation of carbon capture and storage technologies that are expected to require a considerable expenditure of energy, particularly for the capture and transportation of CO_2.

The 50 per cent CO_2 and the 50 per cent oil reduction targets are met in the Small-tech scenario and almost fulfilled in the Big-tech scenario. The reason why the Big-tech scenario is unable to fully comply with the targets is that it mainly focuses on supply-side measures in the electricity sector. In spite of existing power plants being replaced with new nuclear power plants and CCS at forced pace in the Big-tech scenario, there are still significant CO_2 emissions from industry and households that are not dealt with in the scenario.

Figure 26: Gross energy consumption in 2005 and projections for 2030 (excluding fuels for non-energy purposes)

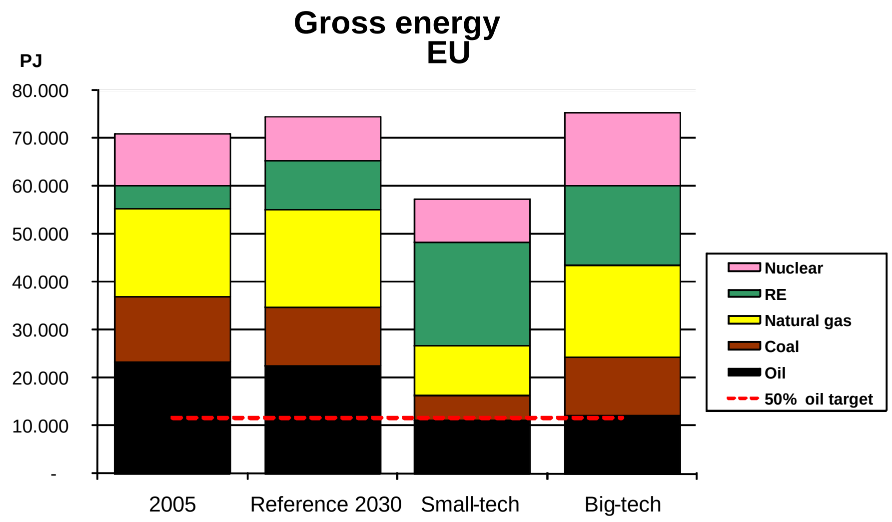
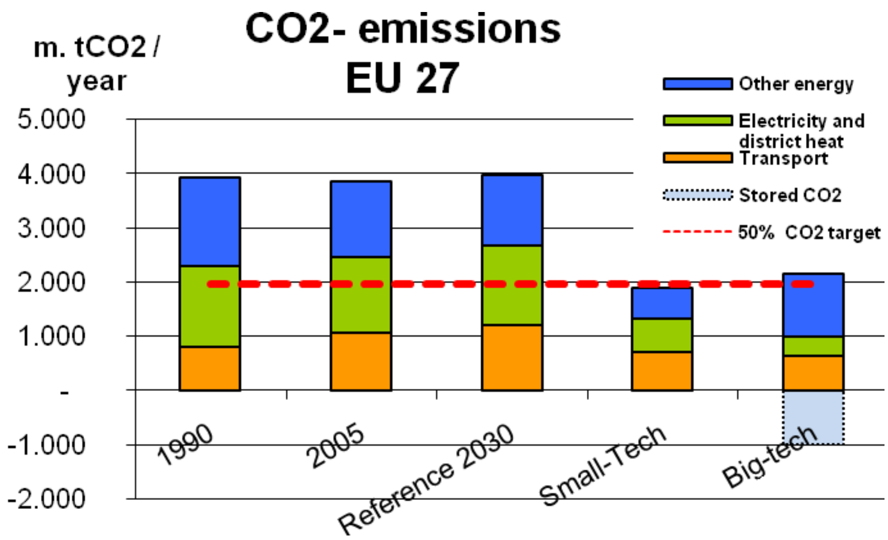


Figure 27: CO_2 emissions



CO_2 emissions from the energy sector in 1990, 2005 and projections for 2030. “Other energy” includes oil, gas and coal used in households, industry and the trade/service sector. Stored CO_2 emissions have been deducted from the emissions from “Electricity and district heating”.

8.2 Security of fuel supply

One way of assessing the impact on the security of fuel supply is to compare the projected production of oil, natural gas and coal in 2030 with the projected consumption in the scenarios. As it is evident in Figure 28, the actual production of oil, natural gas and coal within the EU27 is anticipated to decrease considerably in the next 25 years.

Both reduction scenarios comply with the target of halving oil consumption compared to today. However, the oil production in the EU27 will still only be able to cover approx. 7 per cent of the oil demand, since oil production is expected to be only a third of the current production in 2030.

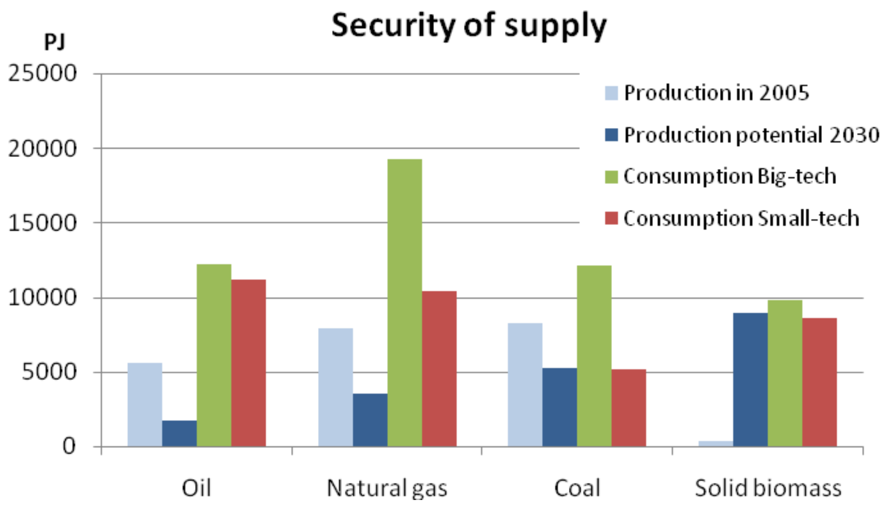
In the Big-tech scenario, the dependence upon imported gas is 80 per cent as opposed to 66 per cent in the Small-tech scenario. This difference is related to the higher level of energy savings and renewable energy in the Small-tech scenario. Indigenous coal production and consumption balance in the Small-tech scenario, whereas about half of the consumed coal has to be imported in the Big-tech scenario.

Solid biomass is also included in the fuel balance as bio-fuels are increasingly traded internationally. On a EU level, the potential biomass resource matches consumption in both reduction scenarios. Within Europe, solid biomass is assumed to be transported within, e.g. from Eastern to Western Europe.

Changes in consumption patterns will also affect market prices and therefore production patterns. For example, higher consumption of coal in the Big-tech scenario is likely to lead to somewhat higher coal prices, and, in return, to increased production of coal sourced within the EU. However it has not been possible to take this relation into account in this analysis.

A proper assessment of the security of fuel supply should also address the reliability and diversity of supply sources, as well as the flexibility of energy consumers and power generators to turn to other fuels in situations of shortage or high fuel prices. In the Big-tech scenario, multi-fuel CCS plants capable of using a diversity of fuels such as coal, natural gas, oil and solid biomass (wood, straw), and municipal waste could possibly provide a way of improving the security of fuel supply.

Figure 28: Security of Supply



Forecasted production of oil, natural gas and coal in EU27 in 2030 compared with the consumption in the two reduction scenarios Small-tech and Big-tech. The figures for solid biomass do not include municipal waste.

8.3 Economic consequences

The economic consequences are calculated as annuitized value of the entire energy system in the scenario year (2030), i.e. capital costs plus costs for fuels, operation and maintenance. To monetize the benefits of reducing CO_2 emissions, a carbon price of 45 €/ton is applied in 2030, based on a forecast from the European Investment Bank (EIB) [ref.24].

The outcome is a simplified welfare-economic calculation that does not include possible tax distortion elements, other environmental externalities than CO_2 (e.g. NOX, SO_2 and particles) and the value of security of supply. Also, socio-economic benefits, such as employment, are not included. This economic calculation makes a relative comparison of scenarios and references possible.

The costs of the scenarios have been estimated with two sets of fuel prices. One based on an oil price just above 60 USD/bbl in 2030 – corresponding to the forecast of WEO published November 2007 [ref.23]. The other corresponds to the high prices of oil, gas and coal that could be observed in the market early in September 2008, when the calculations in the project were finalised. For solid biomass a generic cost of just above 5 €/GJ is applied in both cases.

Table 13: Fuel Price Projections

Fuel price projections	Oil (USD/bbl)	Gas ($/MBtu)	Coal ($/ton)
Low (IEA projection 2007*)	**62**	7.3	61
High (Prices in September 2008)	**115**	16	179

* ref.2. IEA World Energy Outlook 2007. September 2008 prices are based on the following sources: Oil: Brent crude oil prices, 1 September 2008. Natural gas and coal prices depend significantly on the season; hence we apply forward prices for 2009. Natural gas: TTF forward gas price for the calendar year 2009, Coal: EEX futures based on ARA.

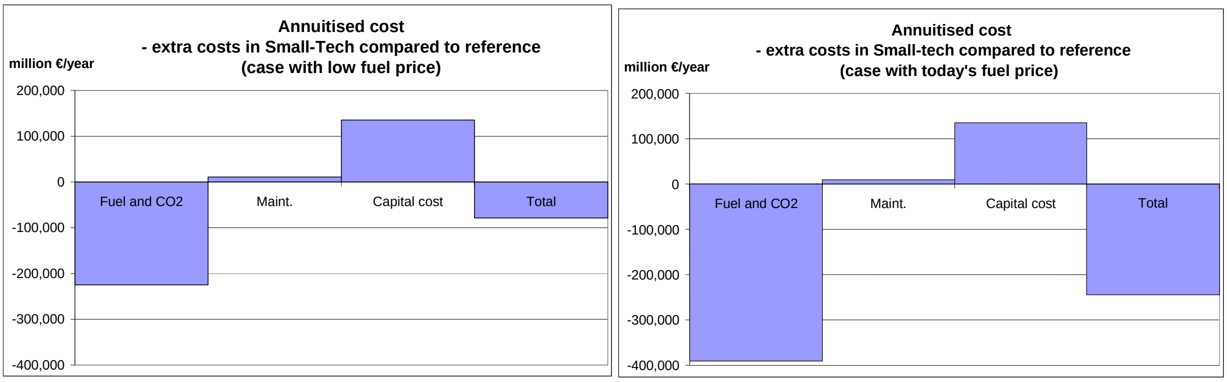
Compared to the reference projection fuel costs are reduced whereas investment costs increase in the Small-tech scenario and Big-tech scenario. The largest fuel cost savings take place in the Small-tech scenario due to the higher level of energy savings, more combined heat and power and fuel-free renewable technologies like wind and solar power. In Big-tech, the fuel cost savings provided by nuclear power and efficiency measures in the transport are to some extent offset by the increasing fuel consumption of CCS plants.

Operation costs increase in the Small-tech scenario, as it is, for instance, more demanding to handle biomass, biogas and municipal waste than fossil fuels.

8.4 Small-tech

Compared to the reference projection, the higher capital costs in the Small-tech scenario are more than outweighed by the saved fuel costs, as can be seen in Figure 29. This is the outcome in the case of “low” as well as “high” fuel prices.

Figure 29: Annuitised costs for Small-tech Scenario



Annuitised costs for the Small-tech scenario compared to the reference scenario in two cases with different fuel prices (“low” fuel price and “today’s (2007)” fuel price).

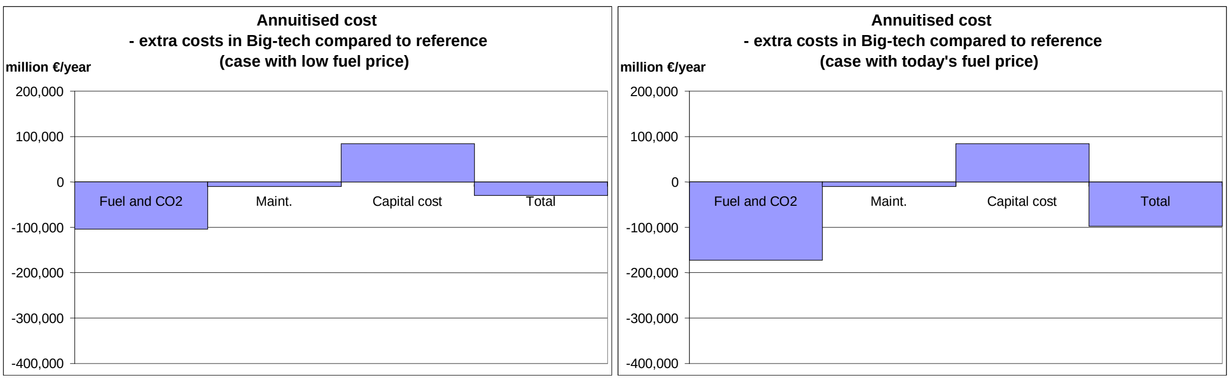
With the high fuel prices, the saving in the Small-tech scenario compared to the reference projection is around 240 b€/year; equalling 1.2 per cent of expected EU27 GDP in 2030 or 600 € per citizen per year.

With low fuel prices, the savings in the Small-tech scenario are around 80 b€/year; or half a per cent of GDP in 2030, and around 195 € per European citizen per year.

8.5 Big-tech

In the Big-tech scenario, the increased investment costs are also outweighed by the reduced fuel cost, due to a shift from oil towards biomass and nuclear power.

Figure 30: Annuitised costs for the Big-tech scenario



Annuitised costs for the Big-tech scenario compared to the reference scenario in two cases with different fuel prices (“low” fuel price and “today’s” fuel price).

With the high fuel prices, the annual saving in the Big-tech scenario compared to the reference projection is around 95 b€/year; around 0.5 per cent of EU27 GDP in 2030 or 240 € per European citizen per year.

With low fuel prices, the savings in the Big-tech scenario is around 30 b€/year; or 0.1-0.2 per cent of GDP in 2030 and around 70 € per European citizen per year.

The main conclusion from this economic comparison between the scenarios and the reference projection is that it is not necessarily more costly to reduce CO_2 emissions and oil dependency than to continue along the road stipulated in the reference scenario.

In order to realise these scenarios, however, investments in the energy sector need to be increased considerably. In the Small-tech scenario, there is a need for additional investments of around 135 b€/year and in the Big-tech scenario around 85 b€/year when reaching 2030.

8.6 Critical assumptions

On the whole, estimating the long-term costs of operating an energy system involves major uncertainties. Not only may fuel costs diverge considerably from the baseline assumptions made in this report - the investment costs of some technologies may also turn out to be significantly different from the assumptions of this report. Therefore, the output of the economic calculations should be treated with great caution.

For the present calculations, estimates of the costs of future power plants were used as predicted in 2006. Since then, the costs of power plants have increased somewhat and the investment costs in the scenarios may therefore be underestimated to some extent. Moreover, it should be stressed that there is significant uncertainty related to estimating the long-term costs of technologies such as CCS or wave power, which are currently in the demonstration phase. This also applies to solar PV, which is a commercially available technology today, but with expectations of considerable cost reductions in the long-term.

Similarly, if investments in energy savings are underestimated, this will have an impact on the economics of the Small-tech scenario. However, there is quite a margin in the Small-tech scenario, with today's fuel prices, the investment costs of energy savings could be five times higher and the scenario would still produce a net benefit. If the low fuel prices are used, the costs of energy savings could be 2.5 times higher and still result in a net benefit for the Small-tech scenario.

9 THE WAY FORWARD

The scenarios developed within the present project show that there are technical and economic potentials for reaching the ambitious goals for 2030 of the present project:

- A reduction of CO_2 emissions by 50 per cent compared to the 1990 level and
- A reduction of oil consumption by 50 per cent compared to the present level

This requires that the potentials for energy savings and energy efficiency measures are harvested, that essential changes take place in the transport sector and that the supply of energy changes towards low or no carbon technologies such as renewables, nuclear power and Carbon Capture and Storage (CCS).

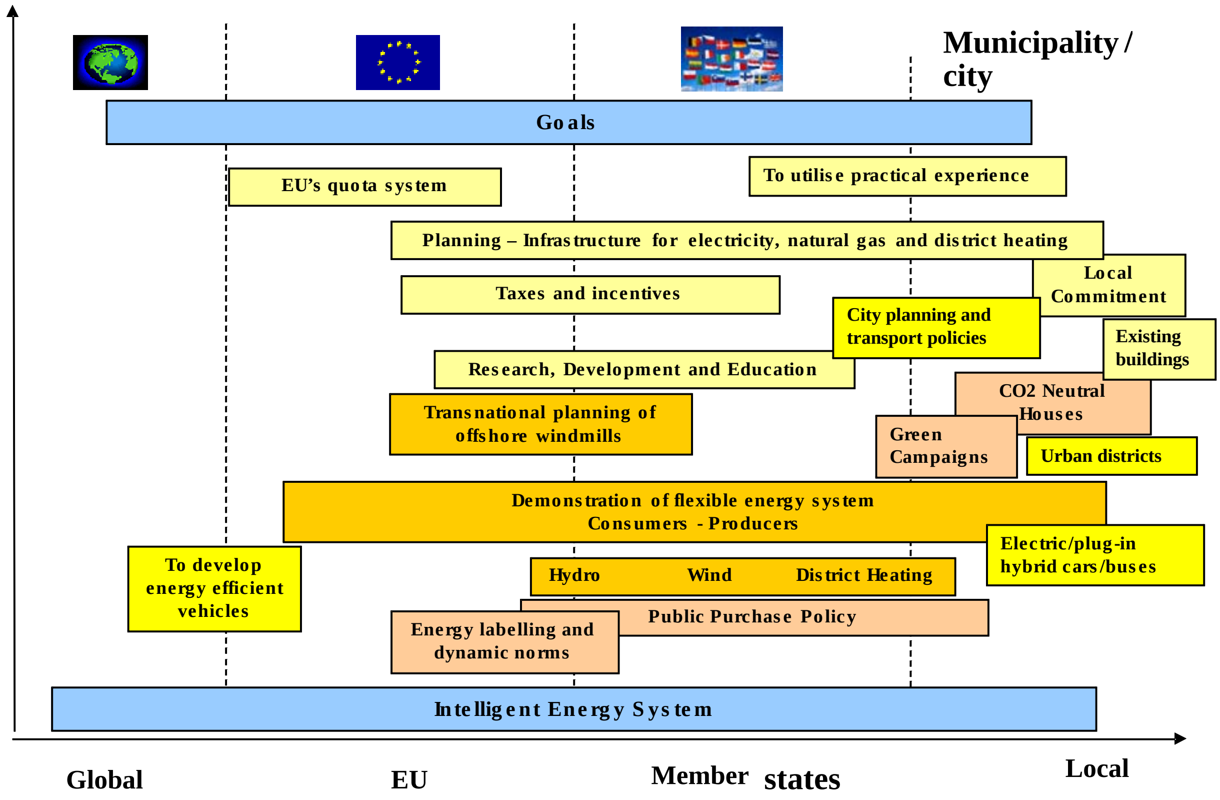
The project explores two essentially different developments of the European energy systems through the Small-and Big-tech scenarios - the first focusing on distributed energy generation, renewable energy and energy savings, and the other on the opportunities of CCS and nuclear power technologies.

The scenarios focus on the technical and financial perspectives of the various technologies. Which policy measures could or should be applied to reach the desired outcome have not been analysed in detail. Consequently, the effects of trade in CO_2 quotas, certificate systems, taxes and similar measures have not been examined separately in the work with the scenarios.

Most of the technologies applied in the scenarios are already commercially available, but research, development and demonstration efforts are urgently needed to further develop electric vehicles, CCS technologies, and certain renewable energy technologies, such as solar and wave power. Therefore, it is important to *keep all doors open*: having the possibility of combining measures from the two scenarios provides greater certainty that the long-term objectives can be achieved. The measures in each of the scenarios are not mutually exclusive.

In order to realise the scenarios – or elements of these – efforts will be needed at the local level, among the member states, and from the European Union (see Figure 31).

Figure 31: Model of relationship between municipalities, the energy system and the energy goals



Reaching the goals of the STOA scenarios will require measures at different jurisdictional levels: the EU, among member states and locally.

Long-term targets for the energy and transport sectors are needed, as well as framework conditions and measures that may contribute to pushing development in the desired direction. Energy savings is a very important measure for securing future energy supply and reducing CO_2 emissions. As can be seen in Figure 31, the legal framework concerning energy savings is present at many levels. At the EU level, ambitious efficiency measures, labelling, and norms for appliances and buildings are to be developed further. But securing the implementation of these norms, especially for buildings, also relies on national and local commitment.

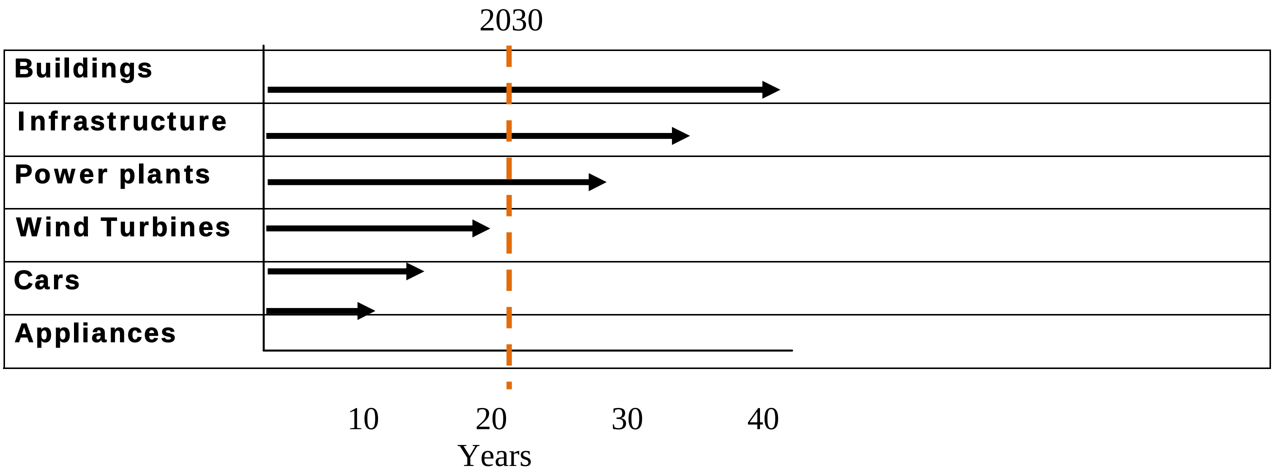
It should also be noticed that some efforts are more urgent than others. It is imperative to take actions regarding transportation, especially car technologies, as well as building technologies because of their slow turnover but vast impact. In the EU, less than 0.5 per cent of the buildings are demolished every year and less than 1 per cent renovated. An average car has a lifespan of around 12-14 years meaning that the cars we are buying today are probably still on the roads in 2020 (see Figure 32).

Even though there are great heat/cooling saving potentials in buildings, and even if we accelerate the process, it will take up to 50 years to update all buildings and thereby harvest the saving potentials. Electrical appliances have a much quicker turnover, and therefore an action taken within this field can have full effect before 2030.

Along with framing the general policies for the energy and transport sectors, the European Union has an important role to play through coordinating trans-national infrastructure projects. The integration of large amounts of wind power calls for greater coordination of electricity infrastructure projects, and introduction of large-scale CCS may require a trans-national pipeline infrastructure for the transportation of captured CO_2.

Locally, municipalities and cities are important stakeholders, for example with respect to shaping transport policies, facilitating district heating infrastructure and setting standards for energy consumption in buildings. Furthermore, through procurement policies and renovation of public buildings the local authorities have a great opportunity to promote best practice.

Figure 32: The technical lifetime of energy and transport technologies



Policy Options

Saving energy is less expensive than producing energy. A number of studies indicate that there is a large potential for cost-effective energy savings in Europe. A continued and amplified effort is required at all policy levels to realize this potential. Since electrical appliances have a quick turnover, actions taken in this field will have a great short term effect. On the other hand measures to improve insulation in buildings are often most effective when they can be part of a renovation and since buildings have long renovation intervals action taken here will have a longer time horizon.

Today, vast amounts of energy are lost at thermal power plants across Europe, because the surplus heat from electricity generation is not used for energy purposes. A targeted effort is required to stimulate the development of **district heating and district cooling grids** to facilitate the utilization of waste heat. This calls for a changed power plant infrastructure with more small units located closer to the consumers of heat and cooling.

Large-scale integration of **variable renewable energy sources** like wind power, solar power and wave power will make new requirements to the way electricity systems are designed and operated. Flexible markets are needed, where consumers, through tariffs and price signals are encouraged to respond to the variations in energy prices – and where interconnectors between different systems are fully utilized to enjoy cross-border trading and to smooth out variations from renewable energy generators. **Strengthening and coordinating the European electricity infrastructure** will become a key measure in the future to allow for a high share of variable renewable energy sources.

Three levels of transformation are needed in the transport sector. Firstly, the **fuel efficiency** of conventional cars has to be improved considerably. Technically, an improvement by at least a factor of two is possible. Secondly, to reduce the dependency of oil and further increase the energy efficiency of cars, it will become essential to introduce **electric vehicles** in large scale in the transport sector. Alternatives are hydrogen based vehicles and biofuels, but the conversion and transformation losses for these technologies are considerable higher than for electric cars. Thirdly, measures have to be taken to encourage **modal-change** (car/flight/lorry => train/light-rail/bike,) and new ways to improve the mobility in society, without increasing the demand for physical transportation – for example by increasing to use of **Information and Communication Technologies**.

The sustainable European **biomass** for energy purposes will become a most wanted resource in a carbon constrained future. To obtain as high a replacement of fossil fuels as possible, from a energy system perspective, it is recommended to use the biomass mainly for power and heat generation, because of the process energy required to produce biofuels for the transportation sector.

Municipal waste is an overlooked energy resource in many European countries. By utilizing municipal waste in new effective **combined heat and power** plants it can deliver a significant share of the demand for heating and electricity.

A continued effort is required to researching and developing technologies like **wave and solar power**, which are not today competitive for large-scale electricity generation. Demonstration of **Carbon Capture and Storage** and safe **nuclear power** is also recommended though it should be acknowledged that due do the reliance on fossil fuels CCS may only be a transitional solution to the long-term challenges faced by the energy sector.

10 LIST OF REFERENCES

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Appendix: The STREAM Model

A short introduction to the STREAM Model

In the following a short introduction to the STREAM model will be given so that the reader may get an idea of what the model consists and whether it will be useful to download and utilize.

The first thing that should be clear is that all of the workings of the model are based on excel spreadsheets.

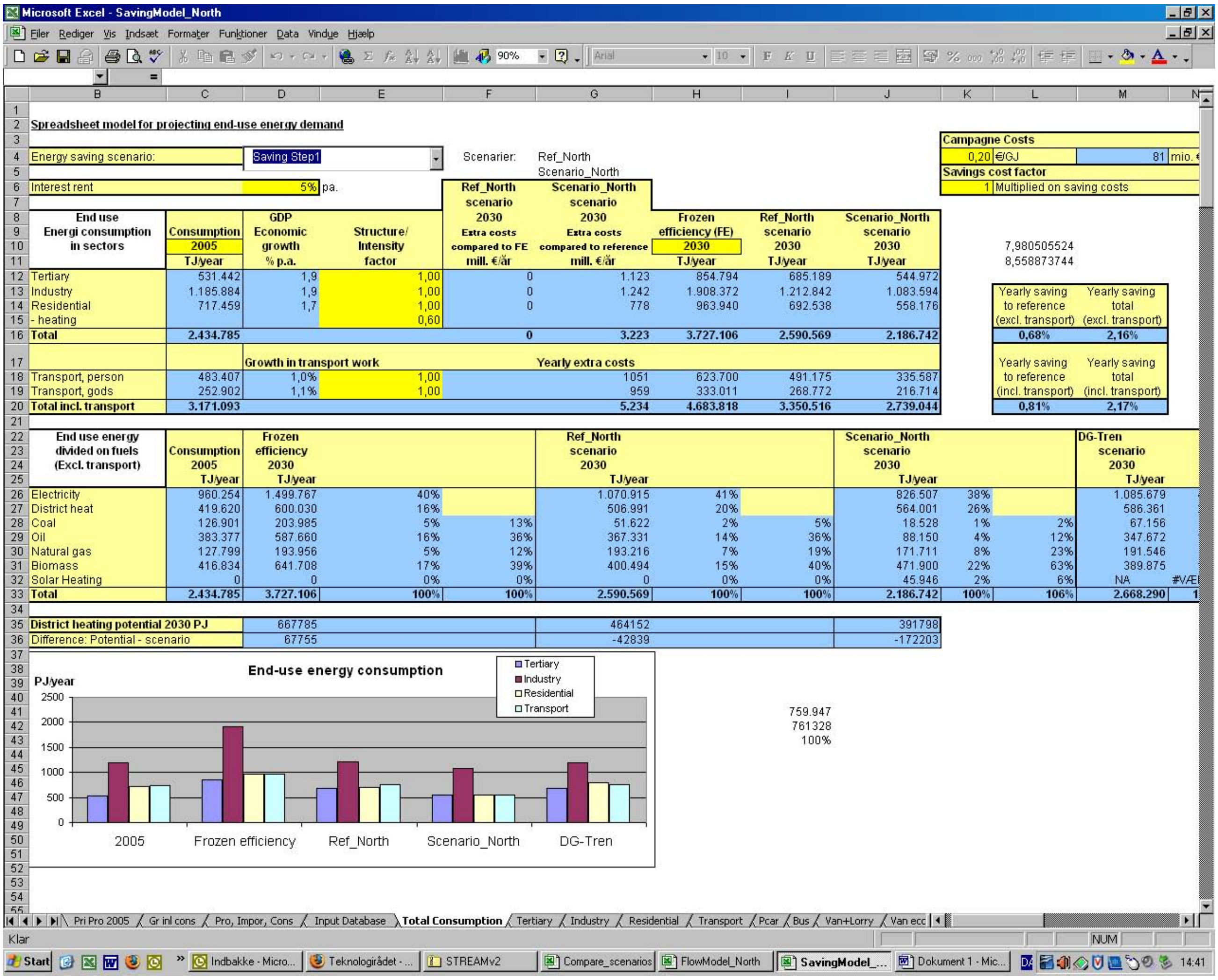
The second thing is that all data and all equations are transparent because of this format.

Also it is possible to edit whatever parameters one would like to alter.

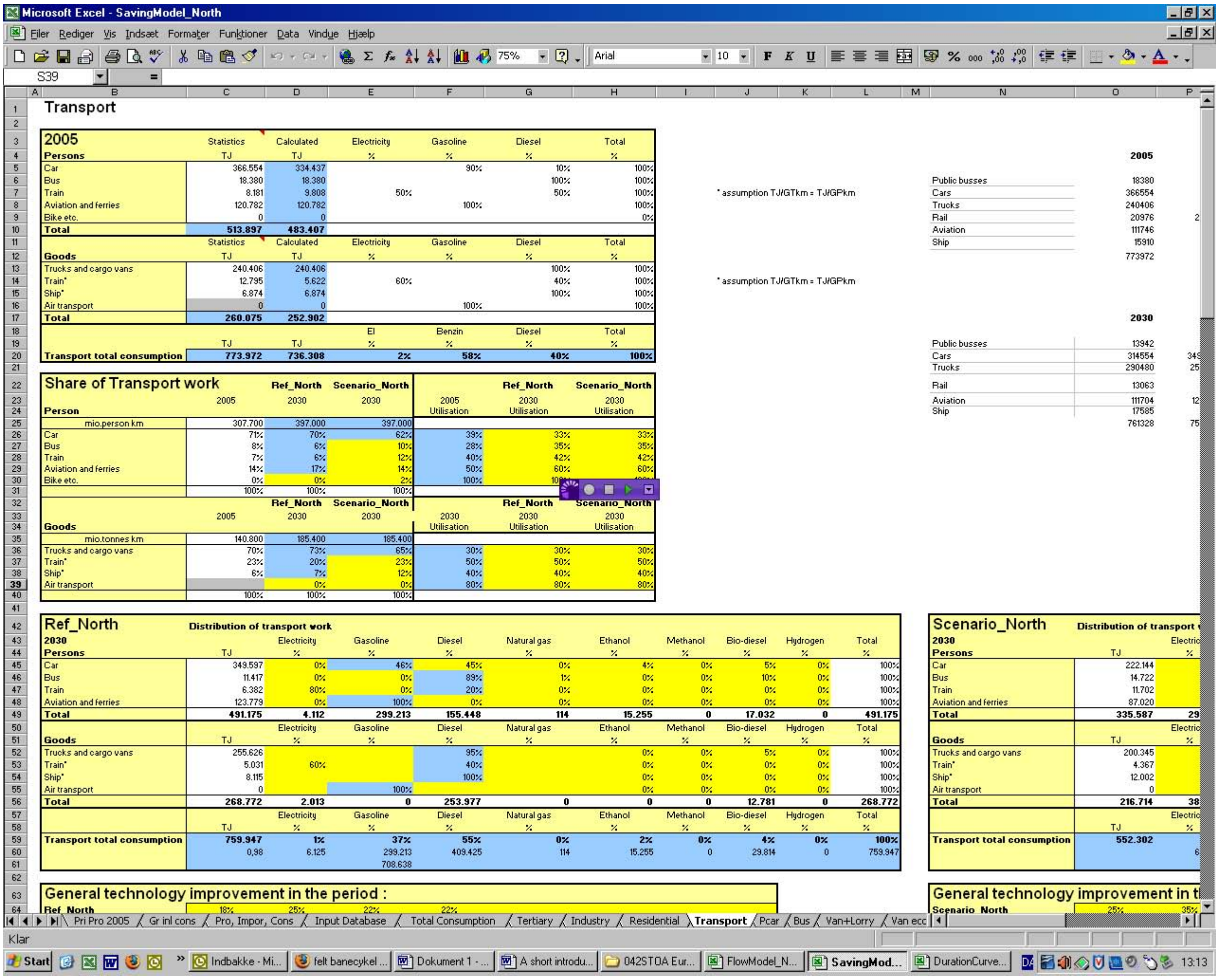
Lastly all the screenshots are not complete views of the spreadsheets but only partial illustrations from the STREAM model of the above three points.

The Savings model

The next screen shows us the Savings model that is one part of the STREAM model. The Savings model deals with energy savings by means of better efficiency both in the respective energy products and services. This section deals with the northern region.

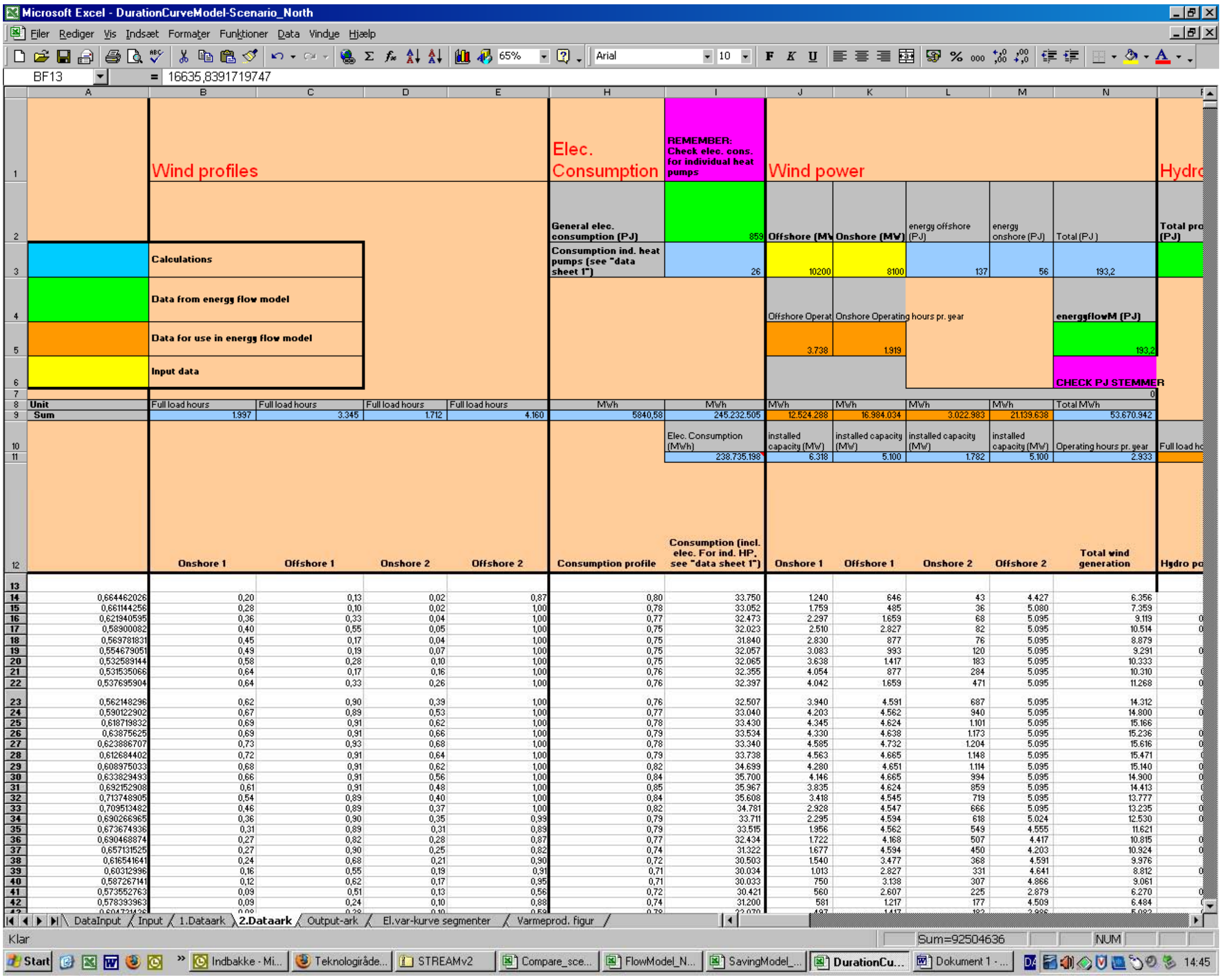


This screen is also from the Savings model and deals with the transport sector amongst other things – again the example is taken from the northern region.



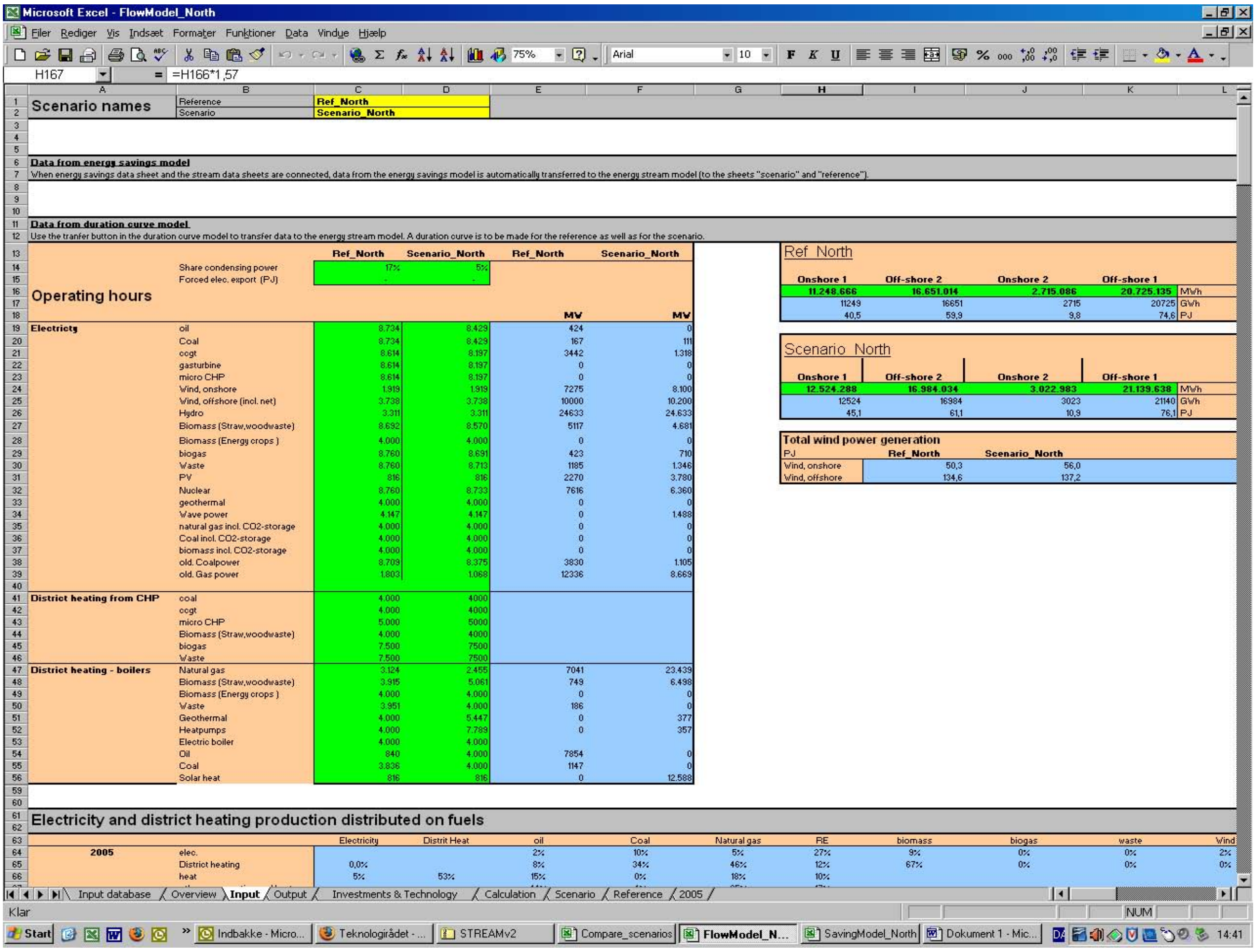
The Duration-Curve model

Now we move on to the Duration-Curve model – this part of the model takes into account the demand for heat and power and calculates the potential for energy infra-structural changes, factoring in the flexible demand, and generation from fluctuating electricity technologies (wind, solar PV etc,)

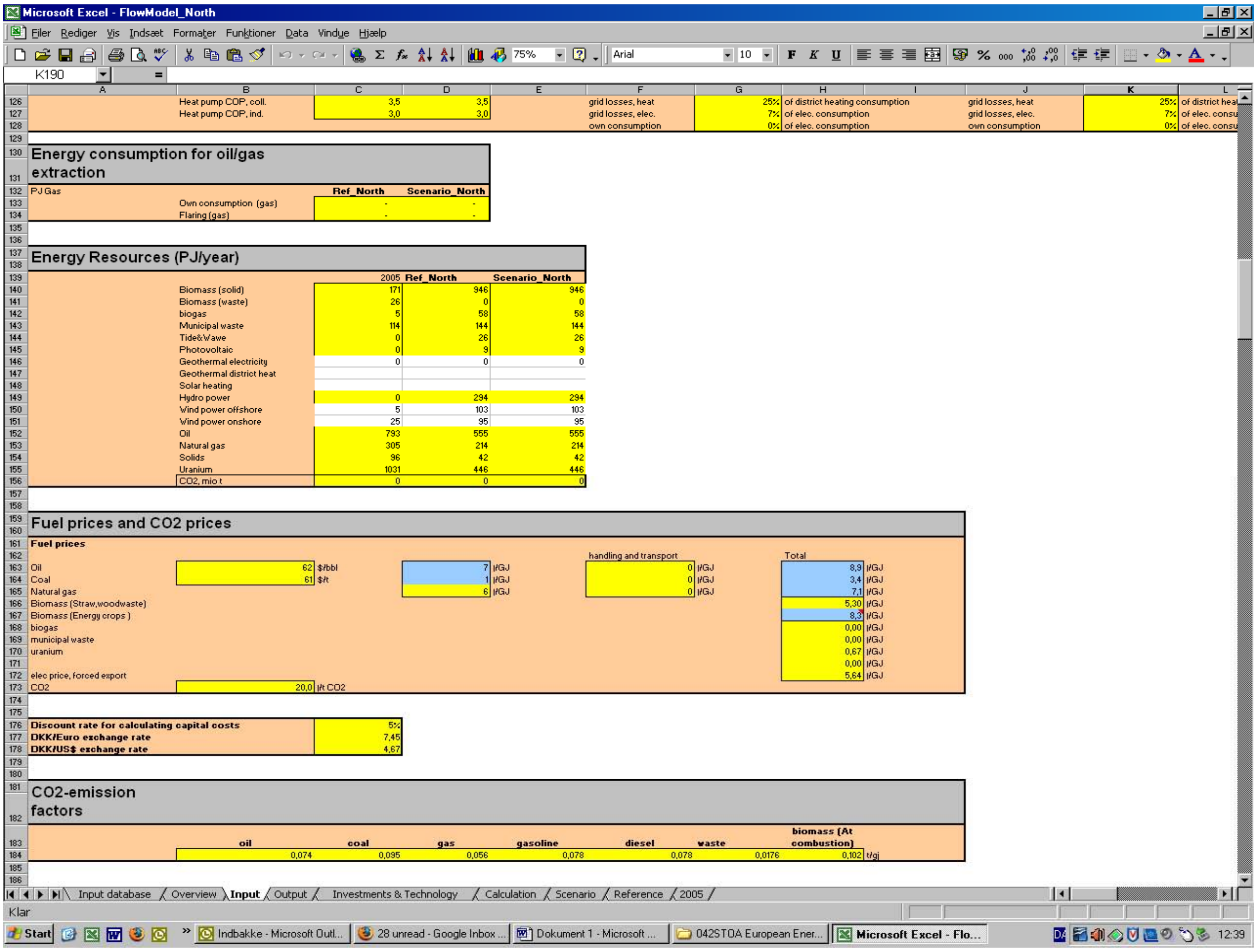


The Flow model

The next two screens are from the Flow model, which deals with energy system considerations and economic assumptions, in this case again for the northern region. Here the input and output from the energy savings and Duration Curve models are put into this model, thereby creating an overview of the total energy consumption, emissions and costs from a total energy system perspective.



The next screens show that the STEAM model makes it possible to create scenarios based on different fuel prices.



To compare scenarios

Finally the STREAM model can compare the different scenarios that the project deals with for example the DG TREN and SET-plan scenarios versus the STREAM model scenarios. This comparison is presented in the below spreadsheet

	B	C	D	E	F	G	H	I	J
1		EU 27		North		South		Central	
2	PJ	Reference 2030	Scenario 2030	North Reference	North	South Reference	South	Central Reference	Central
3									
10	Gross energy	75147	55289	4271	3365	17056	11200	29860	22124
11	Gross energy incl. off-shore consumption	75199	57807	4271	3410	17078	12523	29860	22886
12	Oil	22645	12131	1129	542	6355	3287	8851	4475
13	Coal	12185	4223	399	89	2167	761	4919	1713
14	Natural gas	20758	10342	644	515	4968	1643	7909	4264
15	Nuclear	9235	9069	633	527	947	923	4348	4371
16	RE	10376	22041	1466	1737	2642	5908	3834	8063
17	Wind	1448	2131	186	193	391	416	478	962
18	Biomass	6643	9159	804	933	1572	1650	2705	3389
19	Biogas	31	1311	31	52	0	369	0	515
20	Municipal Waste	352	3796	146	146	0	1035	0	1361
21	PV/CSP	116	680	6	10	59	443	30	192
22	Geothermal (Heat+Power)	202	396	0	7	195	189	0	15
23	Wave Power	0	240	0	19	0	55	0	96
24	Solar heating	60	2802	0	83	23	1347	0	912
25	Other RE	378	4119	6	119	277	2035	30	1215
26		8852	20517	1173	1444	2239	5505	3213	7442
27	RE share								
28	Converting [PJ]								
29	Electricity	15473	12957	1160	966	3907	2770	5979	4808
30	District Heating	4568	7371	642	713	934	1297	1495	2487
31									
32	**Electricity Production [PJ]**	15473	12957	1160	966	3907	2770	5979	4808
33	Oil	389	39	12	0	313	14	30	10
34	Nuclear	3047	2993	209	174	313	305	1435	1442
35	Coal	4322	1672	109	32	808	317	1831	644
36	Natural Gas	3387	1133	162	63	1250	222	1136	240
37	Wind Power	1448	2131	186	193	391	416	478	962
38	***Other RE***	1355	3465	189	211	430	1094	448	890
39	*Biomass*	1084	995	139	126	313	139	419	72
40	*Biogas*	12	491	12	19	0	139	0	192
41	*Municipal Waste*	85	949	32	37	0	263	0	337
42	*PV/CSP*	116	680	6	10	59	443	30	192
43	*Geothermal Power*	59	109	0	0	59	55	0	0
44	*Wave energy*	0	240	0	19	0	55	0	96
45	*Solar Heat*	0	0	0	0	0	0	0	0
46	*Hydrogene*	0	0	0	0	0	0	0	0
47									
63	**Oil/Gas Production [PJ]**								
64	Egetforbrug udvinding								
65	Flaring								
66									
67	**Final Energy Consumption [PJ] (excl. Transport)**	40728	30961	2591	2141	8938	5902	16227	12401
68	Electricity	14209	10811	1071	827	3600	2314	5470	3979
69	District Heat	3502	5753	507	564	711	1007	1134	1931
70	Oil	5085	1393	367	88	1348	261	2024	306
71	Coal	1519	522	52	19	159	65	572	289
72	Natural gas	13493	7254	193	172	2547	1167	5774	3373
73	RE (Biomass)	2919	5228	400	472	574	1088	1252	2524

As well as graphically;