SIXTH FRAMEWORK PROGRAMME

Project no: **502687**

NEEDS

New Energy Externalities Developments for Sustainability

INTEGRATED PROJECT

Priority 6.1: Sustainable Energy Systems and, more specifically,
Sub-priority 6.1.3.2.5: Socio-economic tools and concepts for energy strategy.

Technical Report n° D3.15 – RS 2a
"Interim Report on draft Pan European integrated model"

Submission date: November 2007

Start date of project: 1 September 2004 Duration: 48 months

Main Authors:
CES – KUL: D. Van Regemorter
CNR – IMAA: C. Cosmi, M. Salvia
ECN: K. Smekens
KANLO: A. Kanudia, R. Loulou
PSI: S. Kypreos
USTUTT – IER: M. Blesl, D. Bruchof, T. Kober

Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006)		
Dissemination Level		
PU	Public	
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	**x**
CO	Confidential, only for members of the consortium (including the Commission Services)	

Annex 1: The model database:

- **PanEU_Database_2007_10_03.zip**
- **SubRES_TMPL_2007_10_03.zip**

Introduction

Important advances have been made in the ability to analyse global, national and local issues and to support the formulation of policies using comprehensive partial equilibrium models such as TIMES. Nevertheless, the diffusion of the use of these models beyond the ETSAP members community (which includes also the EU Commission) requires additional efforts in the training of researchers and stakeholders on the use of these advanced tools for energy –environmental planning.

One of the objectives of RS2a activities within the NEEDS project is to foster the knowledge and use of the IEA – ETSAP tools, extending their application to the majority of the European countries (with particular reference to the New Member Countries). This will allow collecting and systematising the data on energy, environment and technology stocks at EU level with a country detail and extending the geographical coverage of the methodology also in line with the LCA and ExternE improvements.

With regard to the development of long term strategies, the research stream RS2a "Modelling Pan European Energy Scenarios" is aimed at the generation of comprehensive models of the energy systems of the EU countries, linked by energy and emissions trades into a multiregional Pan European model (PEM).

In this framework, the NEEDS TIMES Pan – EU model will make available a unique partial equilibrium modelling framework consistent with other important global energy modelling efforts (IEA-Paris, US-EIA) to support the formulation of energy, environmental and economic policies and decision making both at national and Pan-European level.

1. The modelling approach

1.1 Geographical coverage

The geographical coverage comprises 29 European countries for which the national energy system modelling is carried out by several teams of experts belonging to different institutions (Table 1). Some of the modellers staff are also members of ETSAP and expert developers and users of the TIMES methodology, described in the following.
This extended country coverage will allow to analyse also the possibility of adding cross country constraints and/or assumptions, for a more effective policy analyses both on country level and in a EU wide perspective. (ISIS, 2006)

Member State Models (MSM)	Country Code	Institution	ETSAP Member	Other Partners and outreach
Sweden	SE	CHALMERS (SE)	Y	

Norway	NO	“	Y	
Iceland	IS	“		
Spain	ES	CIEMAT (ES)		Y
Portugal	PT	CIEMAT/UNL (PT)		Y
Greece	GR	CRES (GR)	Y	
Malta	MT	“		
Cyprus	CY	“		
The Netherlands	NL	ECN (NL)	Y	
Ireland	IE	“		
Romania	RO	ENERO (RO)		Y
Italy	IT	IMAA-CNR (IT)	Y	
Slovenia	SI	INFM (IT)		
Belgium	BE	KUL (BE)	Y	
France	FR	KUL /CMA – ENSMP (FR)		Y
United Kingdom	UK	POLITO (IT)	Y	
Switzerland	CH	PSI (CH)	Y	
Denmark	DK	RISOE (DK)		Y
Estonia	EST	TTU (EST)		
Lithuania	LT	“		
Latvia	LV	“		
Germany	DE	USTUTT (DE)	Y	
Austria	AT	“		Y
Chzech R.	CZ	“		
Hungary	HU	“		
Slovachia	SK	“		
Poland	PL	“		Y
Finland	FI	VTT (FI)	Y	

Table 1: Country models developed within RS2a and responsible.

1.2 The TIMES model generator

The modelling platform for the development of these energy system models is The Integrated MARKAL-EFOM System (TIMES), developed by the Energy Technology Systems Analysis Programme (ETSAP, 2007) of the International Energy Agency (IEA), and widely used to implement national and global models worldwide (e.g. Gielen, 2003; OIAFEIA, 2003; Rafaj, 2005; Haurie, 2004).
TIMES is a generic model tailored by input data to represent the evolution over a period of up to 100 years of a specific energy-environment system at the world, national, regional, state, province, or community level. Technology characterizations (e.g., efficiency, availability, emission rates, costs), resource availability (e.g., amount available at a certain price), and environmental constraints (e.g., CAA requirements) are provided as inputs to the model, along with reference demands for energy services (e.g. commercial lighting, residential air conditioning, and many others). The model then determines the optimal mix of technologies and fuels at each period, the associated emissions, trading activity, and the equilibrium levels of demands.

From an operating point of view, the main components of the TIMES platform are:

- A set of data files that fully describe the energy system (technologies, commodities, resources and reference demands for energy services) in a format compatible with the associated model generator.
- The model generator (Loulou et al., 2005), consisting of the source code written in the GAMS - General Algebraic Modeling System (GAMS, 2007) computer programming language. It processes the data files, generates the matrix that specifies the mathematical programming problem, and post-processes the optimization results.
- A solver, consisting of a software package integrated with GAMS, which solves the mathematical programming problem.
- A "shell", i.e. a user interface named the Versatile Data Analyst (VEDA) (KanORS, 2007), that allows creating and managing the data input, running the model generator, and analysing results.

The main features of the TIMES based models, developed in the NEEDS project, are:

- Long term time horizon (2000-2050, by 5-year steps. The horizon may be different for country models and for the PEM, in order to take into account different standards of energy devices and technologies development,
- High technological detail in energy supply and end-use sectors,
- full representation of all energy vectors (energy forms) included in the detailed energy balances,
- Breakdown of demands for energy services,
- Evaluation of policies at technology level (e.g. integration of external cost into the cost of a technology) both at country level and for EU-wide perspective,
- Capability of analysing the impacts of different policies and price mechanisms (such as different tax or subsidy schemes for commodities and technologies, portfolio standards, etc.),
- Capability of evaluating the expected long-term impacts of LCA on results
- Scenario analysis.

1.3 The RES

The energy (and materials) system is represented as a network, depicting all possible flows of energy from resource extraction, through energy transformation and end-use devices, to demand for useful energy services (a schematic representation is given in Figure 1). Each element in the network is characterized by a set of technologies described by means of technical coefficients (e.g., capacity, efficiency), environmental emission coefficients (e.g., CO_2, SO_x, NO_x), and economic coefficients (e.g., capital cost, date of commercialization). Many such energy networks or Reference Energy Systems (RES) are feasible for each time period. TIMES finds the “best” RES for each time period by selecting the set of technologies and fuels that minimizes total system cost over the entire planning horizon.

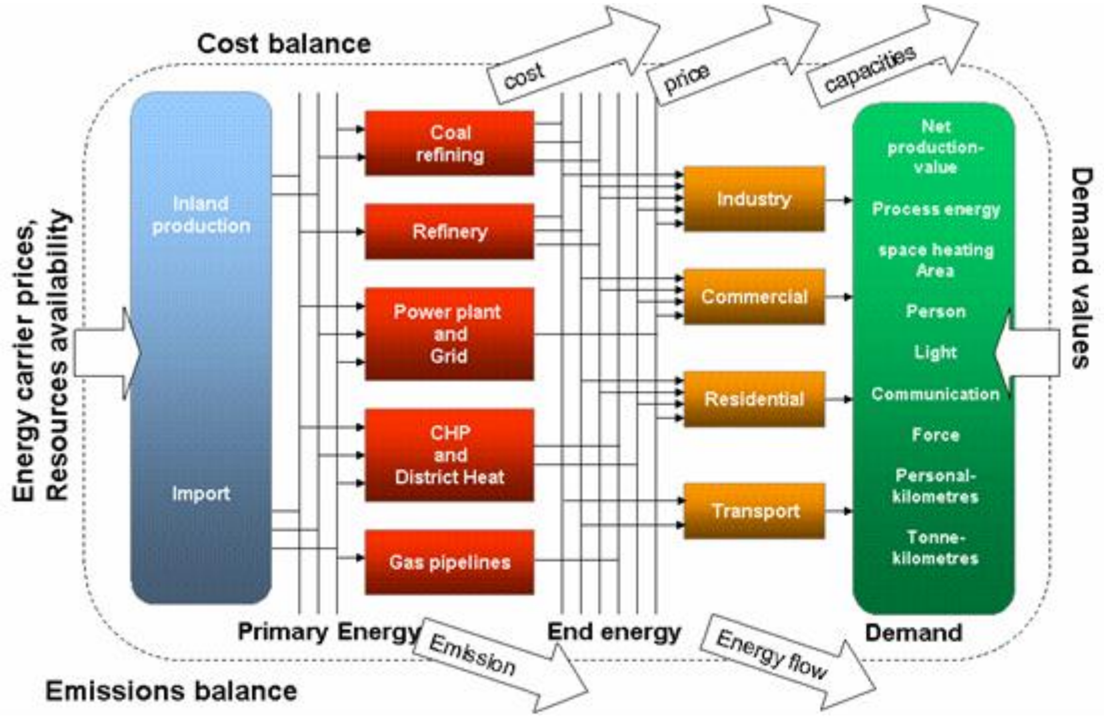


Figure 1: RES representation (Blesl, 2006)

In the NEEDS/TIMES models, the following sectors and demand categories were implemented (Loulou et al. 2005, Cosmi et al. 2006):

- *Transportation* includes road and rail for passengers and freight, navigation and aviation. In road transport, there are five demand categories for passenger travel (cars – short distance, cars -long distance, buses – urban, buses - intercity, two and three-wheelers/off road), and one for freight (trucks). In rail transport, there are three demand categories (passengers – light trains (metros), passengers - heavy trains and rail freight). The aviation and navigation sectors are modelled using a single generic technology each and a single generic demand each that reproduces the energy consumption.
- In *Residential* there are 11 end-uses (Space heating, Space Cooling, Water heating Cooking, Lighting, Refrigeration, Cloth washing, Cloth drying, Dish Washing, Other electric, Other energy), and the first three are differentiated by building categories (Single Family house – rural, Single Family house - urban, Multi Family Apartment). Similarly, the RES structure of the Commercial and Tertiary sector has nine end-uses (Space heating, Space Cooling, Water heating, Cooking, Refrigeration, Lighting, Public Lighting, Other electric, Other Energy Uses), with the first three being differentiated by building categories (Small / Large). Agriculture is modelled as a single generic technology with a mix of fuels as input and an aggregated useful energy demand as output.
- *Industry* is divided in two different sets: energy intensive industries and other industries. For the energy intensive industries, a process-oriented RES was adopted, whereas for other industries a standard structure consisting in a mix of five main energy uses (Steam, Process heat, Machine drive, Electrochemical, Others processes) was chosen. The energy intensive sectors were further separated into subsectors (steel production, cement production, aluminium,..). In order to start moving in the direction

of LCA/I and ExternE, the material demands for some sectors (as for example steel or limestone) were explicitly modelled.

- *Electricity and Heat production*: this sector regroups public power plants, auto production of electricity and CHP. In the RES, three types of electricity (High voltage, Medium voltage, and Low voltage) and two separated (not connected) grids for long distance (high temperature) and short distance (low temperature) heat are distinguished.
- *Supply:* Each primary resource (Crude Oil, Natural Gas, Hard coal, Lignite) is modelled by a supply curve with several cost steps. There are three categories of sources: located reserves (or producing pools), reserves growth (or enhanced recovery), and new discovery. In addition, five types of biomass are modelled: wood products, biogas, municipal waste, industrial waste-sludge, and bio fuels.

Energy carriers were chosen starting from those reported in the Eurostat energy balances (Eurostat, 2005), and then aggregating some of them to adapt the list to the modelling objectives of the project. Regarding materials, it was decided to explicitly model only those whose production requires much more energy or which are important for the production processes modelled (e.g. scrap steel). Other materials are implicitly modelled as part of the variable costs and their related emissions are accounted for in the process emissions.

The *air emissions* modelled are Carbon Dioxide (CO2), Carbon Monoxide (CO), Methane (CH4), Sulphur dioxide (SO2), Nitrogen Oxides (NOx), Nitrous Oxide (NO), Particulate (PM 2.5 and PM 10), Volatile Organic Compounds (VOC), Sulphur hexafluoride (SF6) and Fluoro Carbons (CxFy).

A RES example for the Iron and Steel industry, with the indication of the materials considered is shown in Figure 2.

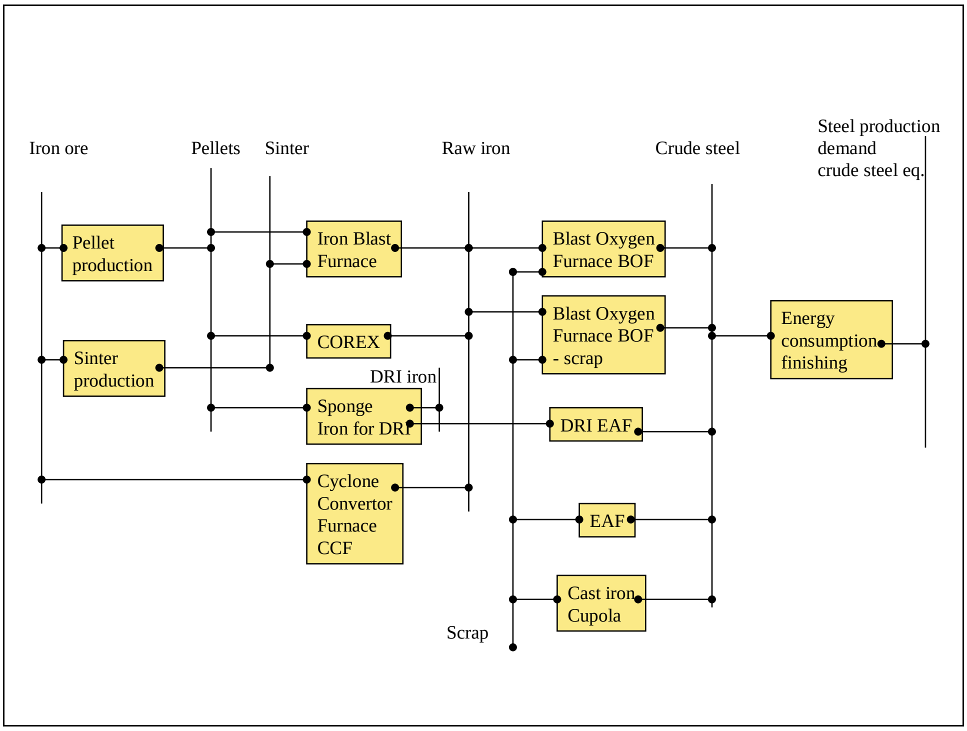


Figure 2: A RES example: the Iron and Steel industry (source ECN)

1.4 The multiregion approach

The Pan-European TIMES model is more than the sum of the national models as it allows to reflect links and to impose constraints at the European level, reflecting the coordination of policies across borders and, consequently, the harmonisation of the underlying country models features and assumptions. In this way, it can be useful for both EU policy evaluation and the analysis of national policies for evaluating the benefits of cooperation among countries, in the fulfilment of international agreements (such as the Kyoto Protocol).

As shown in Figure 3, the structure of the PEM, similar to the country models one, is made up by:

- *Five "templates"* that are elaborate Excel spreadsheets that lay down the basic structure of the country TIMES model and hold the data necessary to calibrate the energy flows of the base-year. Templates refer to five sectors (RCA: Residential/Commercial/Agriculture, IND: Industry, TRA: Transport, ELC: Electricity/Heat production, and SUP: Energy Supply) which have direct links to primary data sources and are periodically updated. The templates collect for each country, the following information: base-year energy flows, existing technology stocks, with their technical/environmental characteristics, discount rate, and transmission efficiency. With these data consistent base year demands for energy services are computed.
- *SubRes New Techs:* An excel spreadsheet where technical data characterising existing and future technologies and fuels are specified.

- *Scenario files*. They include sets of coherent assumptions about the future trajectories of demand drivers (population, GDP, sectors' outputs, households, etc.), leading to the building up of scenarios. In particular, demand drivers and the respective elasticities allow generating the demand projections of energy services over the time horizon for different scenarios, using the following general formula: Demand's growth rate = Driver's growth rate × Elasticity.
- *Additional data dictionary (DD) files* for specifying further technical features and constraints.

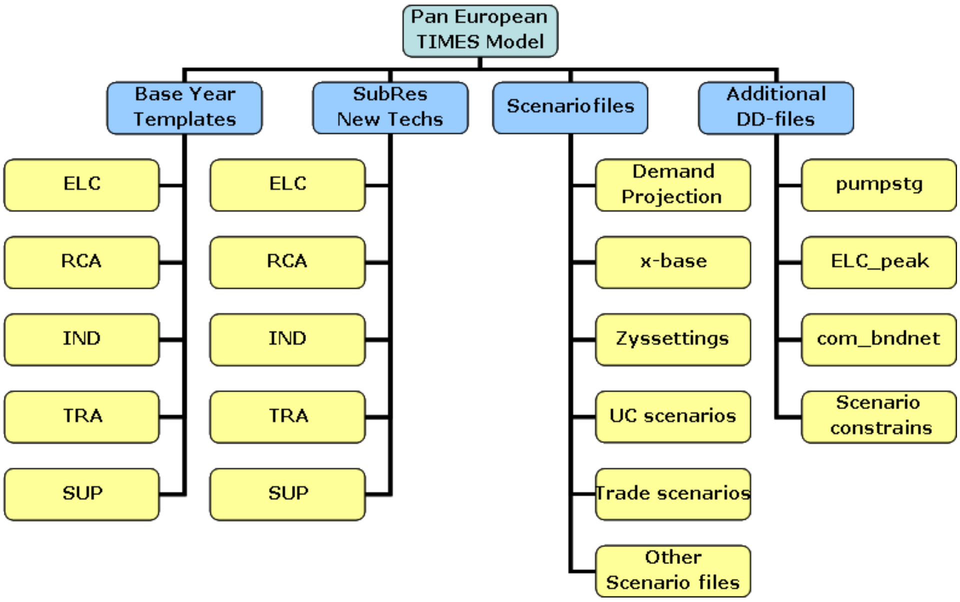


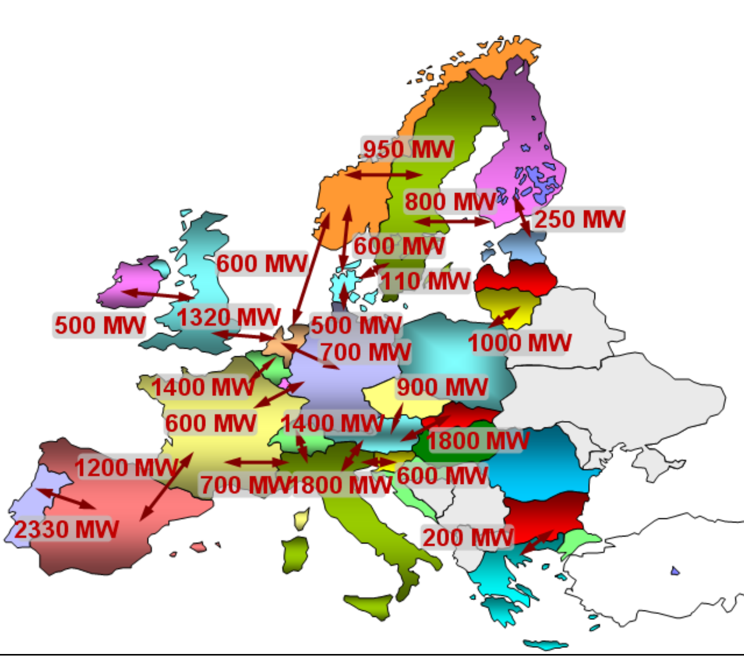
Figure 3: The Pan European model structure (Blesl et al., 2007a)

2. The trades in the Pan European model

The integration of the NEEDS country energy models into the multi-region PEM is realised by adding trading of energy commodities: electricity (ELC), refined petroleum products (RPP), natural gas (NGA), Liquefied Natural Gas (LNG), coal (COA), and solid biomass (SLB).

A summary of the trading structure adopted per each energy vector is presented in the following (Blesl et al 2007a, Loulou 2006a; Loulou 2006b).

Electricity (ELC)
The intra-European trade of High Voltage Electricity is treated as a set of bi-lateral endogenous trade variables by selected pairs of countries. Exchange technologies are defined with costs, efficiencies and interconnection capacities, as represented in Figure 4.



European Priority Projects

		P in MW	Year
DE	DK	500	2012
AT	CZ	900	2009
IT	SI	800	2011
PL	LT	1000	2013
ES	FR	1200	2009
BE	FR	400	2015
NL	UK	1320	2010

Figure 4: Interconnection capacities for electricity trade in the PEM (Blesl, 2007a).

Refined Petroleum Products (RPP)

The trade of Crude Oil and RPP is treated as a single external market (Figure 5). EU countries import and export from/to this market at exogenous prices (export price < import price). Prices may slightly differ between countries if desired, to reflect transportation costs.

The refining capacities are upper bounded to reflect the historical capacities (initially), and to allow some countries to remain exporters (along some trajectory). Countries with currently no refining capacity are not allowed to invest in refining capacity in the future.

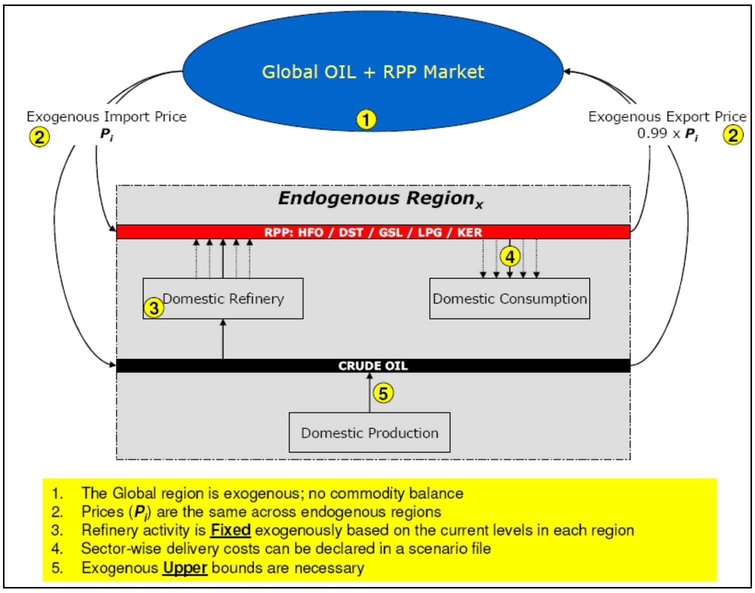


Figure 5: Schematic approach to represent trading of crude oil and RPPs in the NEEDS model (Kanudia A., 2006).

Coal (COA)
One external source/destination for each type of coal represented in the RES (hard, brown, lignite) was created, with export and import prices chosen exogenously. The import price must be larger than the export price to avoid pathological behaviour (i.e. unrealistic arbitraging). European countries that are coal producers have a supply curve for each type of coal, which sell to the external market as well as supply the domestic market. Note that it is possible to specify different import prices by different countries, if deemed necessary, in order to roughly represent transportation costs due to different geographical locations.
For coal, the same structure as for OIL/RPP is used. The only difference is that the difference between the exogenous import and export prices would be significant, and computed as follows:

- Import: a “high” price + “high” transportation cost
- Export: a “low” price + NO transportation cost

This will ensure that regions with abundant local reserves see a low price in the domestic market, and those with low local reserves see a higher domestic price.

Natural Gas (NGA)
As for crude oil and RPP’s, for natural gas a “fully exogenous trade” structure was adopted. This approach has the merit of simplicity, but ignores the representation of the existing and future network of gas pipelines, which is outside the scope of the NEEDS project. In this approach, the production of NGA by European states (Netherlands, UK, Norway, …) is represented by supply curves, but the gas produced is exported to an exogenous external market at a price carefully chosen by the modeller (and also used for local demand). Each country is free to import gas from that same market.
The export price(s) is slightly below the import price(s) in order to avoid pathological behaviour. The prices were carefully chosen so as to result in realistic production levels by the European producing countries. Note that it could be possible to specify different import prices by different countries, if deemed necessary, in order to roughly represent different geographical locations[1].

Liquefied Natural Gas (LNG)
LNG can be considered as a global commodity with a world price (like crude oil). It is represented as a single external source/destination with an exogenously determined price (which may however have to be scenario dependent, like all other energy forms). Its representation requires the specification of points of entry in Europe (i.e. countries with sea access and potential for methane sea terminals), and the inclusion of gasification facilities in the TechRep (for these entry points only). Once gasified, LNG becomes NGA and is mixed with other NGA available in the country. It is currently not envisioned that European gas producing countries will liquefy their own gas, since EU’s gas resources are already declining, nevertheless this can also be done if deemed important.

Solid Biomass (SLB)

[1] Gas transport and distribution is the focus of another European ongoing project that will be using the PEM, namely the REACCESS FP7 proposal

It is treated as coal with the small difference that European countries will not export biomass to other European countries or to the rest of the World.
One external source for each type of solid biomass represented in the RES (e.g. wood pellets, chips) was created, with import prices chosen exogenously. European countries that are biomass producers have a supply curve for each type of biomass, which is used exclusively for consumption within that country. The prices were carefully chosen so as to result in realistic production levels by the European biomass producing countries. Note that it is possible to specify different import prices by different countries, if deemed necessary, in order to roughly represent different geographical locations.
Moreover, the biomass prices may have to be modified for GHG and other alternate scenarios, in order to represent the changes in World demand for biomass in some scenarios.

The main assumptions on trading flows are summarised in Table 2.

Commodity	**Source(s)**	**Destination(s)**	**Import price(s)**	**Export price(s)**	**Other**
Crude Oil	External Market + Producing European Countries	External Market	Exogenous	Exogenous	--
Natural Gas	External Market + Producing European Countries	External Market	Exogenous	Exogenous	--
Coal(s)	External Market + Producing European Countries	External Market	Exogenous	Exogenous	--
Liquefied Gas	External Market + point-of-entry European countries	Point-of-entry countries only	Exogenous (points-of-entry only)	N/A	Need to represent methane harbours and gasification plants as technologies (in point-of-entry countries only)
Solid Biomass(es)	External Market + Producing European Countries	External Market	Exogenous	Exogenous	--

Table 2: Summary of the trades structure (Loulou, 2006a)

3. The exogenous socio-economic assumptions

(Van Regemorter & Kanudia, 2006)

The construction of the reference useful energy demand projections is based on the general equilibrium model GEM-E3 (EU22 countries). This model produces a consistent set of drivers needed for the different country models. Though not specifically a projection tool, GEM-E3 insures a global consistency in the macroeconomic development of countries and sectors that is used to derive the demands for energy services. The model has been applied in many instances for policy analysis for the European Commission and by national governments for issues related to energy taxation, local pollution policy and long term climate policy. Exogenous inputs for GEM-E3 are:

- Population growth
- World energy prices
- Technical progress, energy intensity and labour productivity evolution
- Policy assumptions, e.g., Kyoto related policies, general taxation, specific measures already implemented or planned
- GDP growth target: although GDP is a result of GEM, rather than an exogenous assumption, an average EU GDP growth of 2 to 2.5% was targeted , in line with recent EC targets and past growth rates

The drivers generated by GEM-E3 to be used in the TIMES model are the following:

- GDP and GDP per capita growth rates
- Private consumption, as a proxy for disposable income
- Sectoral production growth with a distinction between energy intensive sectors (e.g., ferrous and non-ferrous metals, chemical sector, etc.), other industries, and services.

A GAMS program was written to compute the demand projections based on the GEM-E3 results, specific assumptions regarding elasticities and sectoral energy intensities and base year calibration data (see section 3.2). More details on the GAMS program are provided in Appendices A.1.
The demands derived from this exercise are the input to TIMES for the construction of the reference scenario. This scenario is not exactly a projection but will be the reference to which to compare policy scenarios.

3.1 The macroeconomic background from GEM-E3

The macroeconomic background for the EU27 was derived with GEM-E3. For the exogenous input such as energy prices and population growth we rely on EU projections.
The international energy prices are those used in PRIMES for the DGTREN projections[2]. After the sharp increase in 2005, the oil prices are returning to more average prices before gradually increasing after 2010, gas prices are evolving in parallel. For after 2030, the trend in price increase was prolonged.

	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Import price crude oil	6.51	5.38	5.41	5.79	6.56	6.94	7.01	7.08	7.15	7.23
Import price natural gas	3.65	4.09	4.13	4.46	5.17	5.39	5.45	5.50	5.56	5.61
Import price coal	1.60	1.51	1.61	1.70	1.76	1.80	1.81	1.82	1.83	1.84

[2] http://ec.europa.eu/dgs/energy_transport/figures/trends_2030_update_2005/index_en.htm

Table 3: World Energy Prices (EUR2000/GJ)

In consideration of the recent evolution of oil and gas prices, these assumptions will be revised and a sensitivity analysis of the model's response to oil prices variations is envisaged.

The EU-27 population is projected to remain rather stable, growing slightly till 2030 starting to decline afterwards.

Regarding the factor input evolution, labour productivity is assumed to improve at a rate around 1% per year with a slightly higher rate in the new member states in the first half of the projection horizon. The global energy efficiency of the economies is assumed to increase through technical progress, a decrease of the energy intensity of the energy intensive sector and a tendency towards more service oriented economies. In general it is assumed that in the long term the economic climate remains positive and that the EU can continue to benefit from the globalisation of the economy. The new member states are assuming to grow at an accelerated rhythm, after the slowdown of their economies at the end of the nineties and beginning of 2000 because of their restructuring. This induces a certain convergence within the EU. However in the long run, with the decline of the population in Europe, there is a slowdown of the economic growth.

	2010	2015	2020	2025	2030	2035	2040	2045	2050
Population	0.3%	0.2%	0.1%	0.0%	0.0%	-0.1%	-0.1%	-0.2%	-0.3%
GDP	2.2%	2.1%	2.1%	1.8%	1.7%	1.6%	1.5%	1.4%	1.2%
Private Consumption	1.9%	1.8%	1.8%	1.7%	1.6%	1.6%	1.6%	1.5%	1.4%
Industrial activity (energy intensive)	2.3%	2.2%	2.0%	1.6%	1.4%	1.2%	1.0%	0.7%	0.4%
Other industrial activity	2.2%	2.1%	2.0%	1.6%	1.5%	1.3%	1.2%	1.0%	0.8%
Transport activity	2.2%	2.1%	1.9%	1.5%	1.4%	1.2%	1.0%	0.8%	0.6%
Service sector activity	2.0%	2.0%	2.0%	1.9%	1.8%	1.8%	1.7%	1.7%	1.6%

Table 4: EU Demographic and Economic Development (annual growth rate)

These general growth assumptions are then used for deriving the energy service demands in the reference scenario. For the countries not modelled in GEM-E3, either national country data (for population growth) or an average of the evolution in the surrounding countries were used to derive the demands.

3.2 General approach to derive Useful Energy Demands

The projections derived with GEM-E3 give the drivers' evolutions used to generate the evolutions of the demands for energy services. All the data are in a single file (DEMPROJ.xls). The useful energy demand projections DEM_{rtj} by region (r), sector (j), and demand category (i) are projected using the following formula:

$$DEM_{rtj} = DEM_{r(t-1)j} \cdot (1 + DRGR_{rtj} * ELASI_{rj}) \\ *(1 + PRGR_{rtj} * ELASP_{rj}) \ *(1 - AEEI_{rtj})$$

Where:

- The drivers by demand category $DRGR_{r,t,j}$ and their elasticities $ELASI_{rj}$ and $ELASP_{rj}$ are defined in the DEMPROJ.xls.

- The initial value of energy services $DEM_{r,0,j}$ is taken from the base year template calibration.
- The price evolution $PRGR_{r,t,j}$ is also derived from GEM-E3 and is used for some demand category to take into account the price effect in the reference scenario. The last term defines the price independent demand change due to autonomous efficiency improvement. This is mainly used to reflect intrasectoral structural evolution not directly linked to energy price evolution in the industrial sector.

This approach is used for the commercial, transportation and industry sectors. For the residential sector the approach is more specific and is described hereafter. The same approach could also be possible for the commercial sector. However, because of the lack of data in most countries and the difficulty of projecting the number of buildings, it was not considered. Therefore there is only one general category for the commercial sector, without distinction between new and existing.

The assumptions regarding the activity elasticity of the useful energy demand are given in the next table. The price elasticity has been assumed to -0.3 for all demand categories.

			Driver	Activity Elasticity			
				< 2010	≥ 2010	≥ 2020	≥ 2030
Residential	Heating		Private Consumption per head	0.5	0.3	0.2	0.2
	Hot water		Private Consumption per head	0.8	0.5	0.2	0.2
	Cooling		Private Consumption per head	0.8	0.8	0.3	0.3
	Appliances		Private Consumption per head	0.8	0.5	0.25	0.25
	Other		Private Consumption per head	0.3	0.3	0.25	0.25
Commercial	Heating		Service sector Activity	0.6	0.35	0.2	0.2
	Hot water		Service sector Activity	0.6	0.4	0.3	0.3
	Cooling		Service sector Activity	0.5	0.5	0.4	0.4
	Appliances		Service sector Activity	1	0.6	0.6	0.6
	Other		Service sector Activity	0.8	0.4	0.4	0.4
Industry	Energy Intensive		Energy Intensive Activity	0.8	0.8	0.8	0.8
	Other		Other Industry Activity	1	1	1	1
Transport	Passenger	car	Private Consumption	1	1	0.95	0.95
		public	Population	1	1	1	1
	Freight	road	Transport sector activity	0.8	0.8	0.8	0.8
		rail	Transport sector activity	0.9	0.9	0.9	0.9
	Air		Transport sector activity	1.2	1.2	1	1
	Navigation		Transport sector activity	0.9	0.9	0.9	0.9
Agriculture			Agriculture activity	0.6	0.5	0.3	0.3

Table 5: Activity Elasticities

The assumptions behind these figures are briefly described hereafter.

- **Residential demand**: for the basic needs, the drivers are either the evolution in the number of households or the population growth. For the other demand categories, the evolution in income is the dominant factor. In the long run, a certain saturation and changes in consumption patterns will lessen the link between driver and demand. This is further discussed in the next section.

- **Commercial demand**: follows the sectoral activity but with a decreasing elasticity over time.
- **Industrial and agriculture demand**: the demand follows the sectoral production evolution
- **Passenger transport**: there is a shift from public transport towards the private car with increasing income; the greater urbanisation will contribute to a lesser increase in the passenger-km demand.
- **Freight transport**: accompanies more closely the growth of GDP with a slight shift away from road transport.

These assumptions are clearly disputable given the uncertainty around the possible future development patterns, therefore they may be adapted by the national teams.

3.3 The useful energy demand in the residential sector

Projection of the heat/cooling/hot water demands

The heat/cooling/water demands relate to the characteristics of the dwellings. Therefore the projection for the residential sector has to be done in three steps:

1. Projection of the number of dwellings and its allocation by category
2. Projection of the heat/cooling/hot water demand per dwelling by category
3. Projection of the total demand

Number of dwellings

The projection of the number of households is based on the population growth used in GEM-E3, and on the evolution of the number of persons per household

Existing dwellings: the stock of existing dwellings in the base year is taken from the template calibration; the number of remaining dwellings at each period is computed via a demolishing rate assumption and its allocation between dwelling categories.

New dwellings: the number of new dwellings is computed given the number of households and the stock of existing dwellings remaining in each period. The allocation of the total stock to building types is done with exogenous shares based on assumptions such as urbanisation trends and age pattern evolution.

The heat/cooling/hot water demands per dwelling

The starting point is the demand per dwelling calibrated in the RSD template. A first step is the correction of the demand for heat and for cooling for temperature. This might be important for some countries as 2000 was a warm year. An index based on degree-days can be used, computed as the normal degree-days (reflecting the heat needed in a normal year) divided by the year 2000 degree-days (the heat demand is multiplied by this index in the GAMS program).

Unit heat demand per dwelling for existing dwellings: its evolution depends on the stock structure in terms of construction year: demolishing mainly affects the oldest dwellings with the highest unit heat demand thus making the average stock more efficient. If there are survey data on the stock structure and the demolishing rate, it might be possible to compute an efficiency improvement factor, otherwise an exogenous factor is used. No distinction is made between types of dwelling;

The same approach is used for **hot water demand** but taking into account the evolution in the number of persons per household.
For **cooling**, two types of data are needed:

- cooling demand per dwelling
- share of dwellings with cooling

Therefore the data have to be supplemented with assumptions on the penetration rate. The penetration rate is computed in the GAMS program given two figures, first the maximum penetration rate and second the number of years after which this rate will be attained.
Unit heat demand per dwelling for new dwellings: for new construction demand depends on the regulation in place regarding efficiency requirements (e.g. K-norms) and the average area of new houses. For the first period after the base year, it can be computed either based on the heat demand per dwelling constructed in the base year and by applying an evolution factor to the average heat demand in the base year, corrected for temperature, or by external data if available. This heat demand should take into account any new regulation already approved. Possible future regulation should be included in the shell improvement technologies which can then be imposed if such a regulation is imposed.
For both new and existing buildings, the demand per dwelling is then projected given the drivers' evolution from GEM-E3 and the assumed elasticity.

The total heat/cooling/hot water demands
The projection of heat/cooling/hot water demands in existing/new dwellings is then derived by multiplying the demand per dwelling by the number of dwellings in each category.

4. The scenarios

In the NEEDS project, a baseline and a few policy scenarios are being implemented for the Pan-European model to assess the following key energy and environment issues in Europe: EU Energy Import dependency, Kyoto Protocol extension, Local/Regional Environmental Policies. (Kypreos & Van Regemorter 2006, Kypreos et al. 2006, Cosmi et al, 2007)

Three policy scenarios of interest for EU stakeholders are being analysed at the Pan EU level, based on the following key issues:

- *A Post-Kyoto climate policy scenario* with a target for the EU compatible with the recent EU Communication (2007)2 "Limiting Global Change to 2 C° - The way ahead for 2020 beyond" and with 450 ppmv will be run. The percentage of CO2 emissions reduction for Europe will be derived from the global target using the results of a study carried out by IPTS and KUL for DGENV with POLES and GEM-E3 which will be soon available.
- *Enhancement of endogenous energy resources*: it is aimed to reduce import dependence on oil and gas by introducing constraints on imports as fraction of

primary energy use. This will increase the use of renewables, energy efficiency and conservation, biomass for bio-fuels and eventually hydrogen production advanced nuclear for those countries they want to keep this option. Based on the results of the scenario policy conclusion will be drawn. For EU the importance of "Strategic partnerships" for oil and gas imports will be identified and policy options for "Strategic reserves" proposed.

- *Air Quality Policies.* It will deal with the introduction of policy targets for air quality (to be derived by RS1b) with specific emission targets by country. In alternative it will internalize local externalities costs by country and then find out what level of emission reduction that implies and where the reduction will take place. It has been proposed to apply gradually increasing pollution taxes to get transparent results. These decisions will be further investigated in the light of the results obtained for the Reference Scenario and the inputs from other RS.

Moreover, two scenario variants will be investigated:

- A crisis scenario under moderate economic growth and pessimistic technological change assumptions to check for robust but conservative technological options.
- A case of improved environmental quality by indogenizing externalities related to local air pollution and global externalities to assess synergies.

In many cases, Scenario Variants could require alternative descriptions of future technologies by incorporation of learning by doing (LbD) and learning by searching (LbS) cost reductions, efficiency improvements and high diffusion rates for advanced technologies.
This improvement could be induced by high RD&D spending, learning investments, feed-in tariffs, international spill-over and cooperation.

To give an idea of how scenario assumptions are translated in technical terms for the model, Table 6 reports an extract of some scenario assumptions introduced in the PEM files of different countries.

		Year	BAU scenario	BAU scenario	BAU scenario	BAU scenario	BAU scenario	BAU scenario	BAU scenario	BAU scenario	BAU scenario	BAU scenario	BAU scenario	BAU scenario	BAU scenario	BAU scenario	BAU scenario	BAU scenario	BAU scenario	BAU scenario	BA scena
Country			**AT**	**CH**	**CY**	**CZ**	**DE**	**DK**	**EE**	**ES**	**FI**	**GR**	**HU**	**IE**	**IT**	**LT**	**LV**	**MT**	**NL**	**PL**	**PT**
GHG reduction pathway		2010	No min and max	No min and max	No min and max	No min and max	No min and max	No min and max	0.1	No min and max	No min and max	No min and max	No min and max	NO	No min and max	No min	No min	No min and max	NO	No min and max	No r and r
		2020	values	values	values	values	values	values	0.1	values	values	values	values	POLICY	values	and max	and max	values	POLICY	values	valu
		2030							0.1							values	values				
		2040							0.05												
		2050							0.05												
Minimum share of renewables in PEC		2010	No min and max	No min and max	No min and max	No min and max	No min and max	No min and max	0.1	No min and max	No min and max	No min and max	No min and max	no policy	No min and max	0.0	49,3%	No min and max	5%	No min and max	>0.:
		2020	values	values	values	values	values	values	0.1	values	values	values	values		values	0.1	0.5	values	10%	values	
(efficiency method)		2030							10%							10%	52%				
		2040							15%							8%	54%				
		2050							16%							7%	55%				
Min. and max. values for electricity prod. based on renewables (in PJ)		2005								x= 73.36											
	Wind (on+offshore)	2010	x ≤ 16.22	x ≤ 2.9	x ≤ 2	x ≤ 2.51	101,7 ≤ x ≤ 181,3	29.1 ≤ x ≤ 68.0	0.1 ≤ x ≤1	163.8 ≤ x	x ≤ 2.88	x ≤ 1.63	x ≤ 4.00		8,1 ≤ x	0.1 ≤ x ≤ 1	0.1 ≤ x ≤1	x ≤ 1		x ≤ 47.71	
	Wind (on+offshore)	2020	x ≤ 19.53	x ≤ 4.7	x ≤ 2	x ≤ 7.38	141,5 ≤ x ≤ 296,4	29.1 ≤ x ≤ 68.0	1 ≤ x ≤ 2				x ≤ 4.82		11,2 ≤ x	1 ≤ x ≤ 3	1 ≤ x ≤ 2	x ≤ 1		x ≤ 51.71	
	Wind (on+offshore)	2030	x ≤ 24.17	x ≤ 6.6	x ≤ 2	x ≤ 12.26	181,3 ≤ x ≤ 351,3	29.1 ≤ x ≤ 68.0	2 ≤ x ≤ 3				x ≤ 5.96		15,4≤ x	3 ≤ x ≤ 5	2 ≤ x ≤ 3	x ≤ 1		x ≤ 55.71	
	Wind (on+offshore)	2040	x ≤ 29.57	x ≤ 8.4	x ≤ 2	x ≤ 17.13	221,2 ≤ x ≤ 371,4	29.1 ≤ x ≤ 68.0	3 ≤ x ≤ 4				x ≤ 7.29		19,7 ≤ x	4 ≤ x ≤ 7	3 ≤ x ≤ 4	x ≤ 1		x ≤ 60.51	
	Wind (on+offshore)	2050	x ≤ 36.17	x ≤ 10.3	x ≤ 2	x ≤ 22	261 ≤ x ≤ 389	29.1 ≤ x ≤ 68.0	4 ≤ x ≤ 6		x ≤ 50.4	x ≤ 36.7	x ≤ 8.92		19,7 ≤ x	6 ≤ x ≤ 10	4 ≤ x ≤ 6	x ≤ 1		x ≤ 67.90	x ≤ 1
	Wind (onshore)	2005												8.11 ≤ x ≤ 8.35					9.97 ≤ x ≤ 10.57		
	Wind (onshore)	2010												16.36 ≤ x ≤ 17.50					14.95 ≤ x ≤ 15.96		
	Wind (onshore)	2020												21.25 ≤ x ≤ 22.63					16.93 ≤ x ≤ 18.08		
	Wind (onshore)	2030												25.72 ≤ x ≤ 26.48					18.98 ≤ x ≤ 19.23		
	Wind (onshore)	2040												29.00 ≤ x ≤ 29.55					21.23 ≤ x ≤ 21.50		
	Wind (onshore)	2050												32.10 ≤ x ≤ 32.45					24.11 ≤ x ≤ 24.26		
	Wind (offshore)	2005												0.31 ≤ x ≤ 0.31					0 ≤ x ≤ 1.45		
	Wind (offshore)	2010												7.72 ≤ x ≤ 7.72					1.5 ≤ x ≤ 14.71		
	Wind (offshore)	2020												30.71 ≤ x ≤ 34.62					3.20 ≤ x ≤ 21.73		
	Wind (offshore)	2030												38.77 ≤ x ≤ 44.50					13.09 ≤ x ≤ 169.35		
	Wind (offshore)	2040												46.35 ≤ x ≤ 48.13					159.95 ≤ x ≤ 237.33		
	Wind (offshore)	2050												51.08 ≤ x ≤ 51.46					247.78≤ x ≤ 263.7		
		2005								x=82.15											
	Hydro (Run+Dam)	2010	x ≤ 203.85	x ≤ 139.8	x ≤ 0.2	x ≤ 11.02	81,7 ≤ x ≤ 83,9	x ≤ 0.1	x ≤ 1	137.5 ≤ x	x ≤ 48.96	x ≤ 13.31	x ≤ 7.2		187 ≤ x	1 ≤ x ≤ 3	7 ≤ x ≤ 10	0		x ≤ 30	
	Hydro (Run+Dam)	2020	x ≤ 219.30	x ≤ 142.9	x ≤ 0.2	x ≤ 11.57	88,1 ≤ x ≤ 90,7	x ≤ 0.1	x ≤ 1				x ≤ 16.2		227 ≤ x	1 ≤ x ≤ 3	7 ≤ x ≤ 10	0		x ≤ 32.45	
	Hydro (Run+Dam)	2030	x ≤ 219.30	x ≤ 146.0	x ≤ 0.2	x ≤ 11.94	88,1 ≤ x ≤ 92,9	x ≤ 0.1	x ≤ 1				x ≤ 25.2		234 ≤ x	1 ≤ x ≤ 3	7 ≤ x ≤ 10	0		x ≤ 33.96	
	Hydro (Run+Dam)	2040	x ≤ 219.30	x ≤ 149.2	x ≤ 0.2	x ≤ 12.32	88,1 ≤ x ≤ 92,9	x ≤ 0.1	x ≤ 1				x ≤ 25.2		234 ≤ x	4 ≤ x ≤ 5	7 ≤ x ≤ 10	0		x ≤ 35.52	
	Hydro (Run+Dam)	2050	x ≤ 219.30	x ≤ 152.3	x ≤ 0.2	x ≤ 12.72	88,1 ≤ x ≤ 92,9	x ≤ 0.1	x ≤ 1		x ≤ 57.6	x ≤ 17.8	x ≤ 25.2		234 ≤ x	5 ≤ x ≤ 7	7 ≤ x ≤ 10	0		x ≤ 37.16	x ≤
	Hydro (Run small)													0.33					0.05		
	Hydro (Run small)																		0.17		
	Hydro (Run small)																		0.22		
	Hydro (Run small)																		0.23		

Table 6: Technical assumptions in the PEM (Source IER)

5. The draft model results

The implemented modelling platform allows analysing a large amount of data that are usually aggregated into reference output tables and graphs.

In what follows some of the preliminary results of the NEEDS Pan EU model obtained from the optimisation of the BAU scenario as well as the Post-Kyoto climate policy scenario are presented.

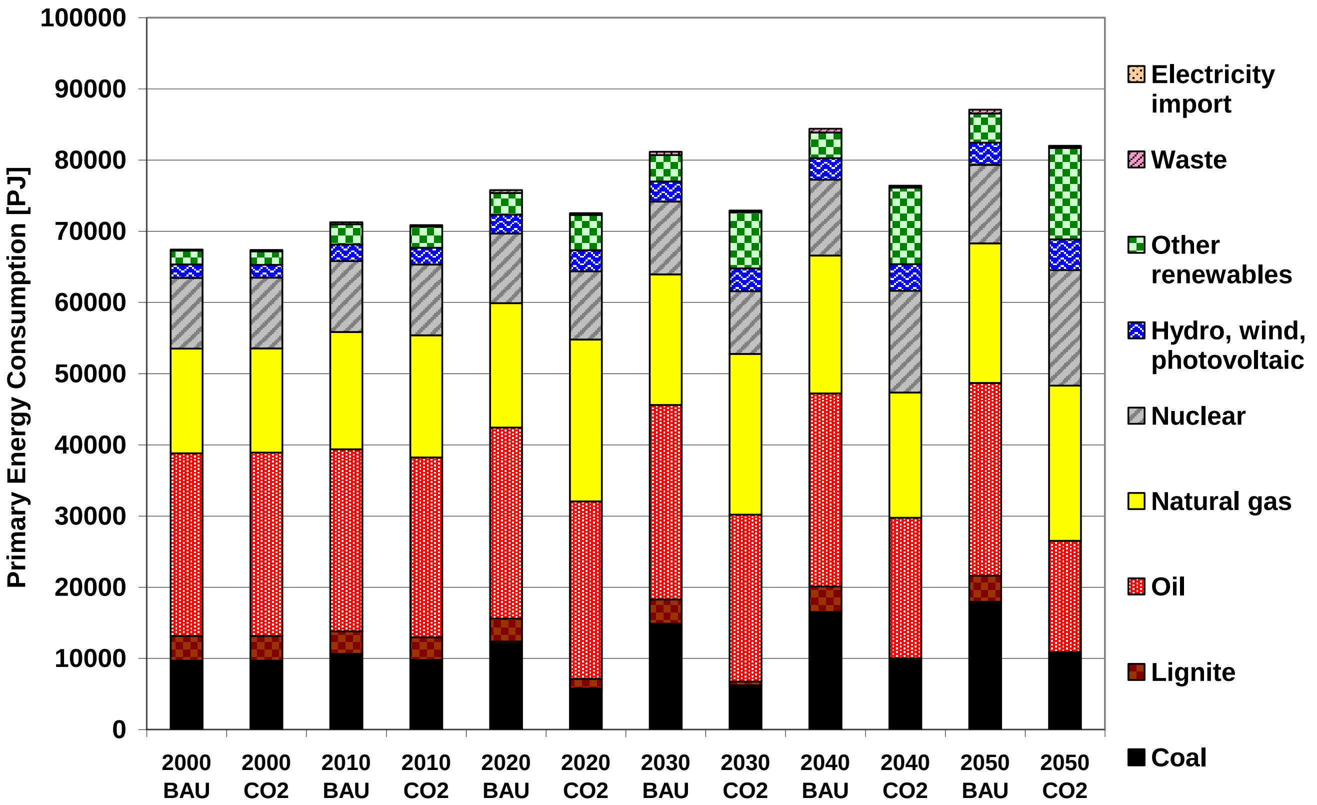


Figure 6: Total primary energy consumption in the EU27 Pan European model (Blesl et al., 2007b)

On the entire time horizon, the **primary energy consumption** in the BAU and in CO_2 450 ppm scenarios increases respectively about 29% and 22%, as shown in Figure 6.

In the BAU scenario natural gas and oil are the predominant energy sources (accounting for about 50% of primary fuel consumption) and their use increases respectively 33% and 5% on the full time horizon. Coal use (its share being about 14% in year 2000) represents still a main source in 2050 with a share of 21%, increasing 86% on overall. At the same time, nuclear, which share at primary energy consumption is about 15% in the year 2000, increases by 11% to 11 EJ in 2050, whereas its share remains almost constant (13%).

In the CO_2 scenario, oil consumption decreases sharply (-39%) whereas natural gas consumption increases +49%. Coal use is also increasing but its share in 2050 is slightly lower than in year 2000 (12%).

In agreement with the modelling assumptions, renewable use increases in both scenarios, with a remarkable share in the CO_2 scenario (hydro, wind and photovoltaic are more than doubled and other renewable use rises from 1913 PJ in the base year to 12838 PJ in 2050, representing the 14% of primary energy consumption in 2050).

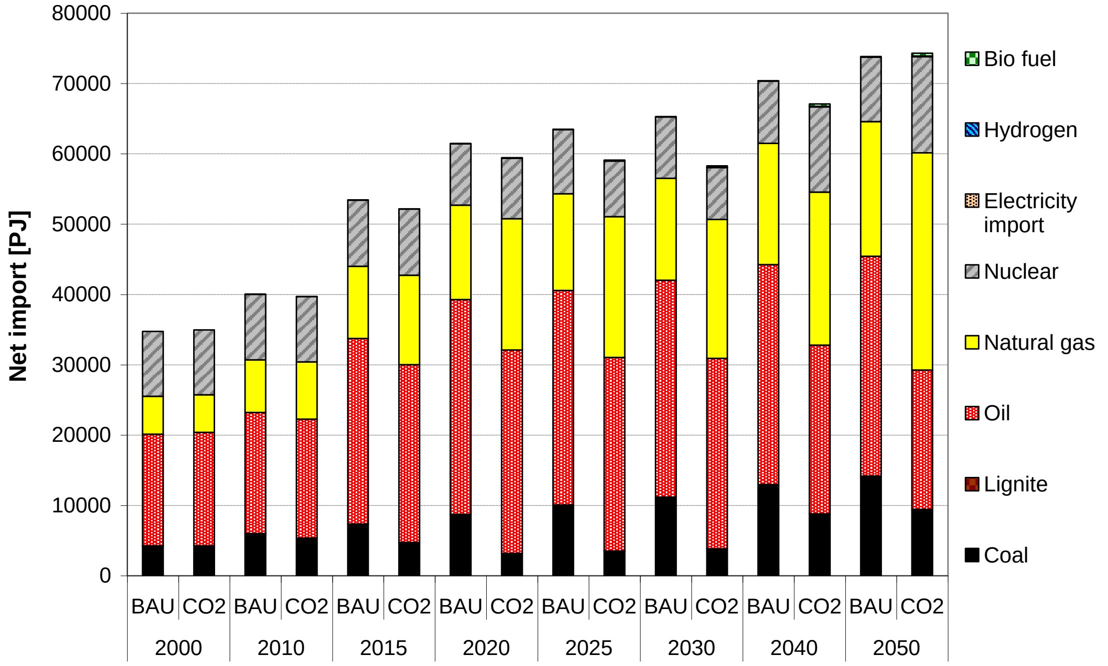


Figure 7: Net imports by fuels in the EU27 Pan European model (Blesl et al., 2007b)

As concerns the **net energy imports** (Figure 7), it could be noticed a remarkable overall increase in both scenarios. Substancial increases can be observed for natural gas (from 5400 PJ in 2000 to 30877 PJ in 2050 in the CO_2 440ppmv scenario), coal (from 4230 PJ to a maximum value of 14162 PJ in the BAU scenario) and oil (from 15861 PJ to 31246 PJ in the BAU scenario). Nuclear use is almost constant in the BAU scenario, but increases in the CO_2 450 ppm scenario.

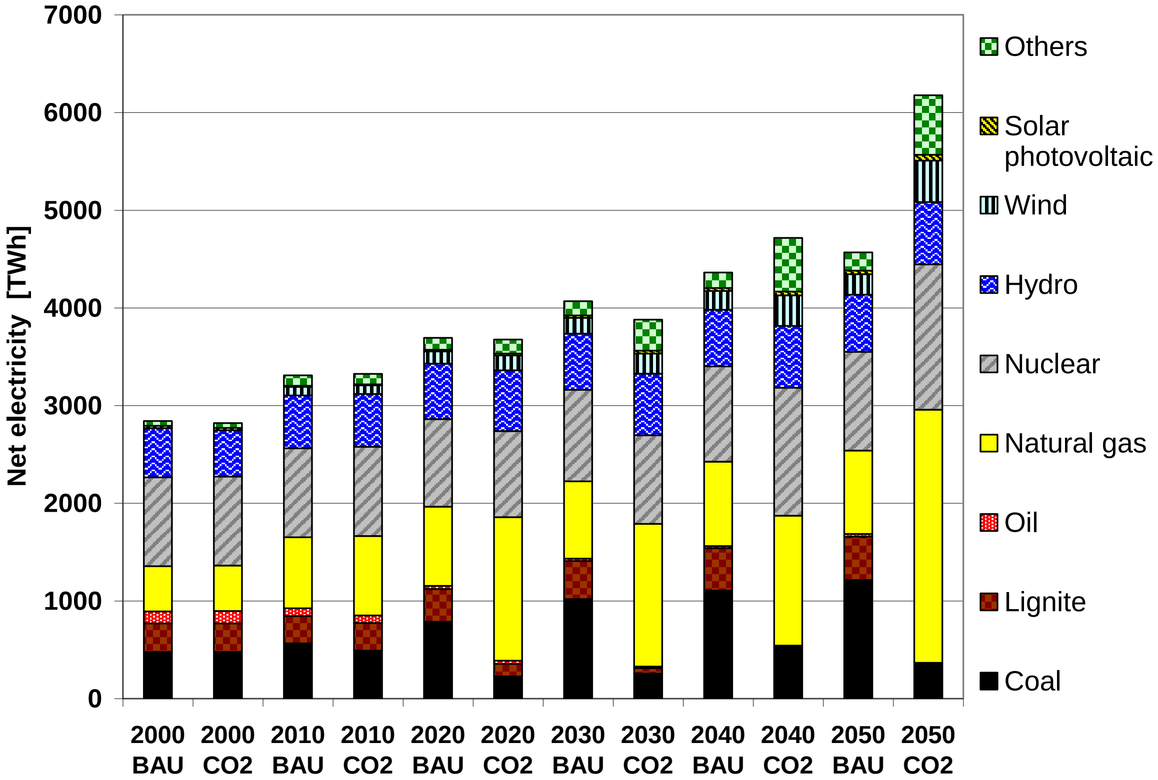


Figure 8: Net electricity generation in TWh in the EU27 Pan European model (Blesl et al., 2007b)

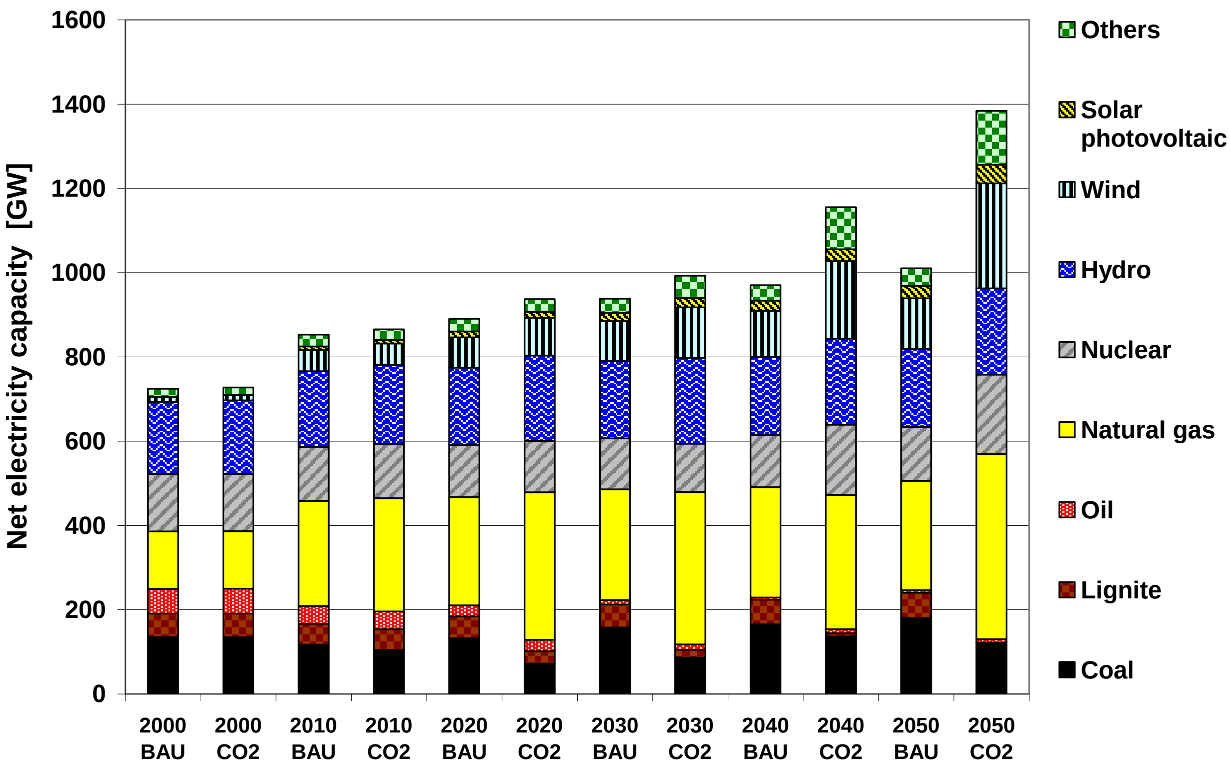


Figure 9: Net electricity generation capacity in [GW] in the EU27 Pan European model (Blesl et al., 2007b)

On the overall time horizon the total electricity production increases about 61% in the BAU scenario and 119% respectively in the CO_2 450 ppm scenario, with a maximum net installed capacity of 1383.7 GW in 2050 in the CO_2 450 ppm scenario. (see Figure 8 and Figure 9).

Major resources for electricity production in year 2000 are nuclear, hydro, natural gas, and coal, whose contribution in 2050 for the BAU scenario are respectively 22%, 13%, 19%, and 27%. In the CO_2 450 ppm scenario, coal use diminishes by 6% whereas natural gas use is highly increased (its share being about 42%) fostered by the increasing contribution of natural gas fuelled CHPs.

The contribution of renewable energy sources to the net generated electricity is obviously higher in the CO_2 450 ppm scenario compared to the BAU scenario: hydro, wind and photovoltaic contributing for about 1122 TWh in 2050 and other renewable resources (wood, geothermal, waste, and biogas) for about 609 TWh, representing all together about 28 % of the total net produced electricity in 2050.

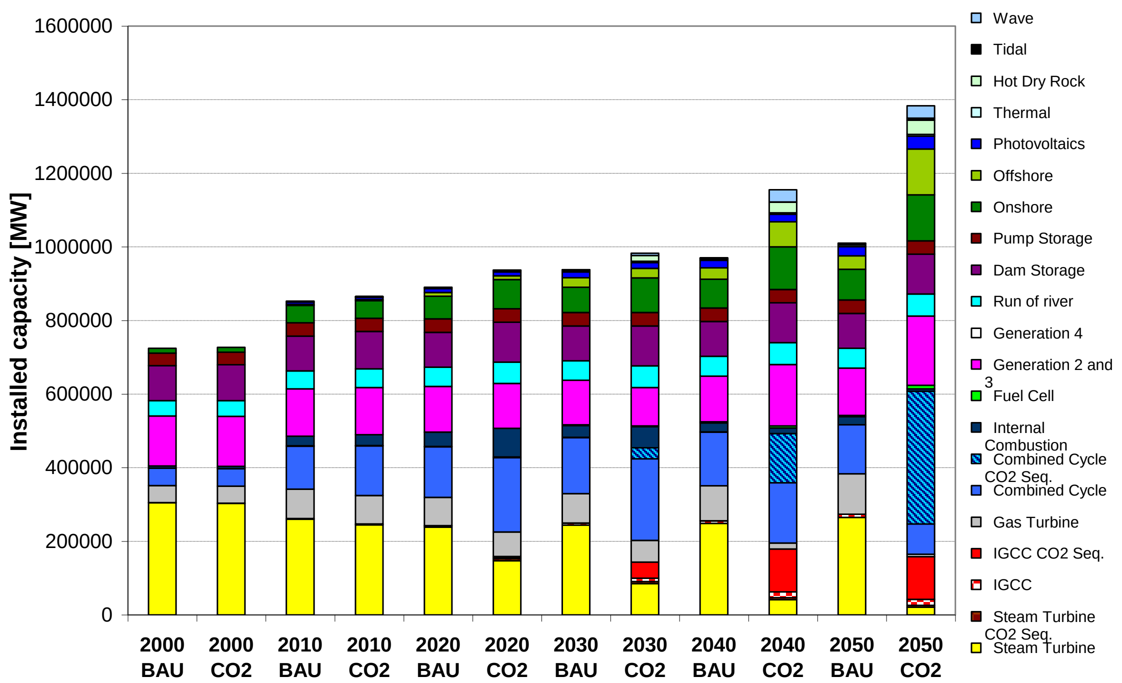


Figure 10: Net electricity generation capacity by technologies in [GW] in the EU27 Pan European model (Blesl et al., 2007b)

Figure 10 emphasises the contribution of the different technologies to electricity generation. It can be seen that the traditional technologies are progressively substituted by new and more efficient technologies (e.g. IGCC, gas turbines, combined cycle power plants and gas turbines). The CO_2 450 ppm scenario shows for the periods after 2030 a predominant use of fossile fuels in combination with carbon capture and storage technologies. Among renewable technologies, apart from hydro, wind onshore is mostly used. Moreover, in the reduction of CO_2 emissions, CO_2 sequestration has a high importance.

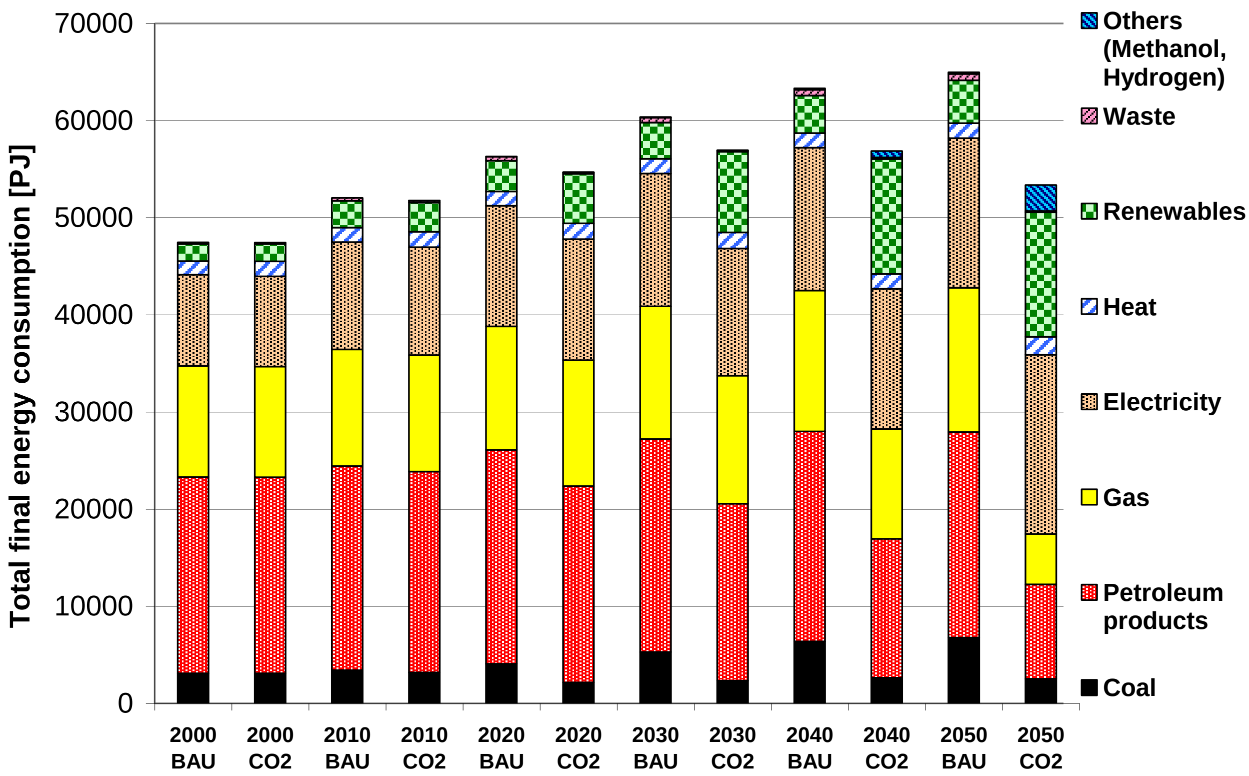


Figure 11: Total final energy consumption in the EU27 Pan European model (Blesl et al., 2007b)

In the BAU scenario, the overall increase of final energy consumption is about 37% (Figure 11). Among the fossil fuels a remarkable increase of coal and gas use (+120% and +30% respectively) can be observed. Other energy sources and renewable energies grow by factor 2.8 in total but still remain on a lower level (8% at total final energy consumption in 2050). Electricity is expected to increase by 64 % over the time horizon. The use of oil products is slightly increasing (+5%).

In the CO_2 450 ppm scenario, the overall increase of final energy consumption is about 25% (Figure 11). The fossil fuels´ use is obviously decreasing (gas -54%, oil products -52% and coal -18%). Renewable heat and electricity show a very high increase (renewable use is about six times higher and electricity is almost doubled). Other energy vectors (methanol and hydrogen), whose contribution represent about 0.3% of final energy consumption in the BAU scenario, increase up to 5% in the CO_2 450 ppm scenario.

A deepen analysis of fuel use by sector (Figures 12, 13 and 14) highlights the different choices of the model in presence of a constraint on CO_2 emissions.

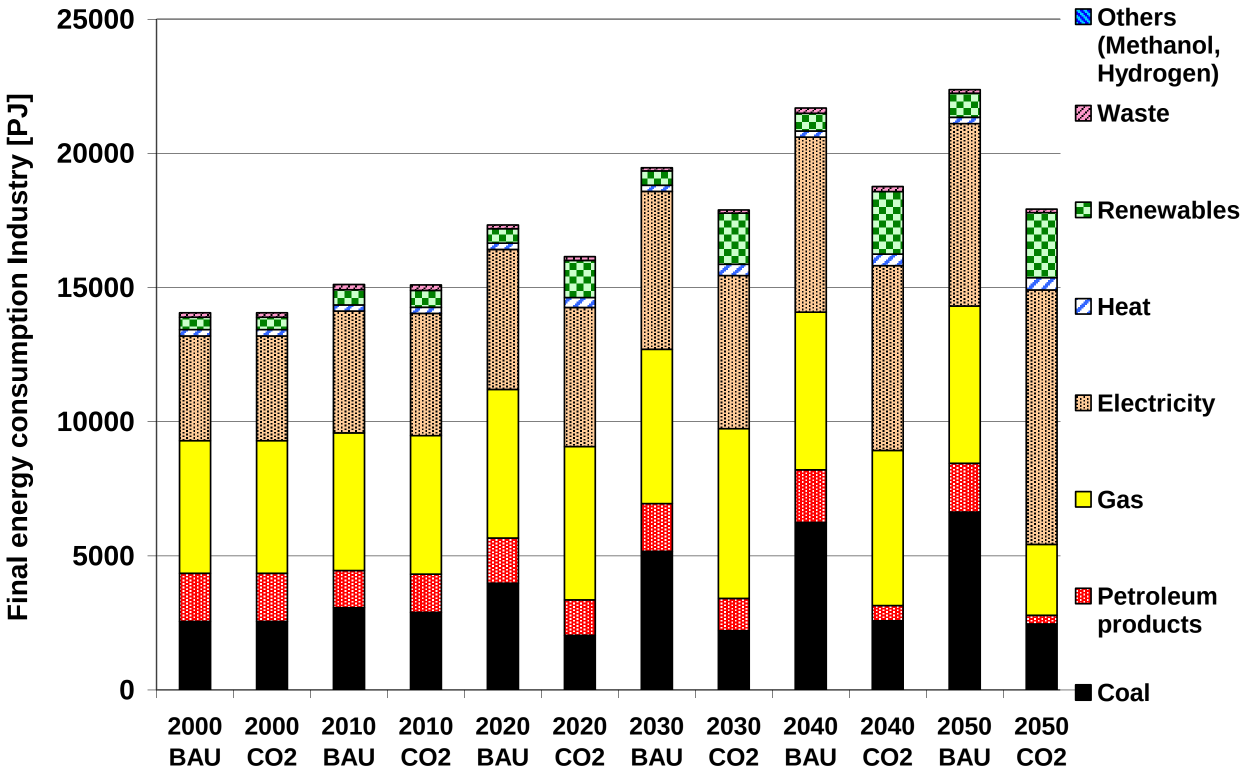


Figure 12: Total final energy consumption Industry in the EU27 Pan European model (Blesl et al., 2007b)

In fact, it could be seen that in the industry sector the most frequently used fuels in the BAU scenario are electricity, gas and coal, whereas in the CO_2 450 ppm scenario coal use decreases sharply with electricity and renewable use increasing remarkably.

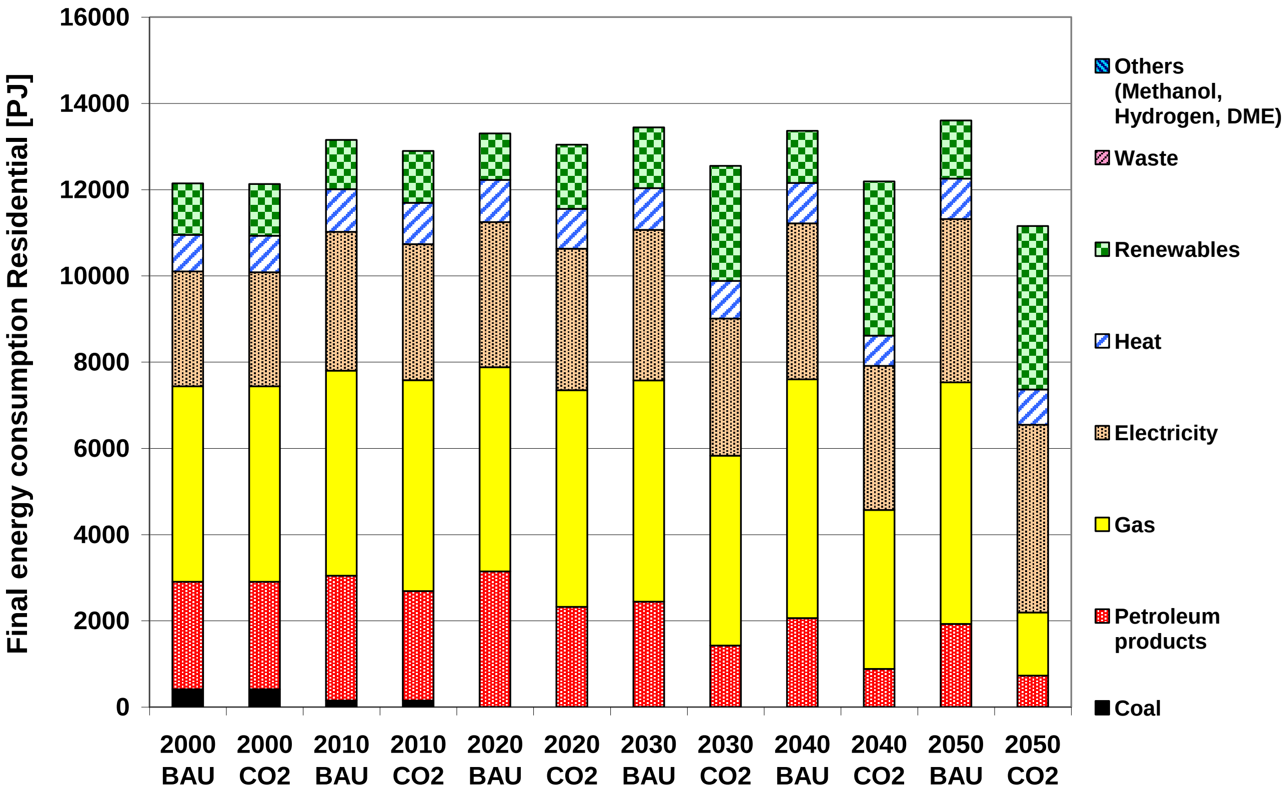


Figure 13: Total final energy consumption Residential in the EU27 Pan European model (Blesl et al., 2007b)

In Residential sector, the most consumed fuels in the BAU scenario are gas, electricity and oil products of which electricity use is increasing, gas is almost constant and oil product use decreases. Coal, which is today mainly used in Eastern European countries, phases out and is not used after 2010. Heat consumption remains on a relatively constant level of about 950 PJ.

In the CO_2 450 ppm scenario, gas and oil consumption decrease significantly in favour of increased renewable use and electricity consumption.

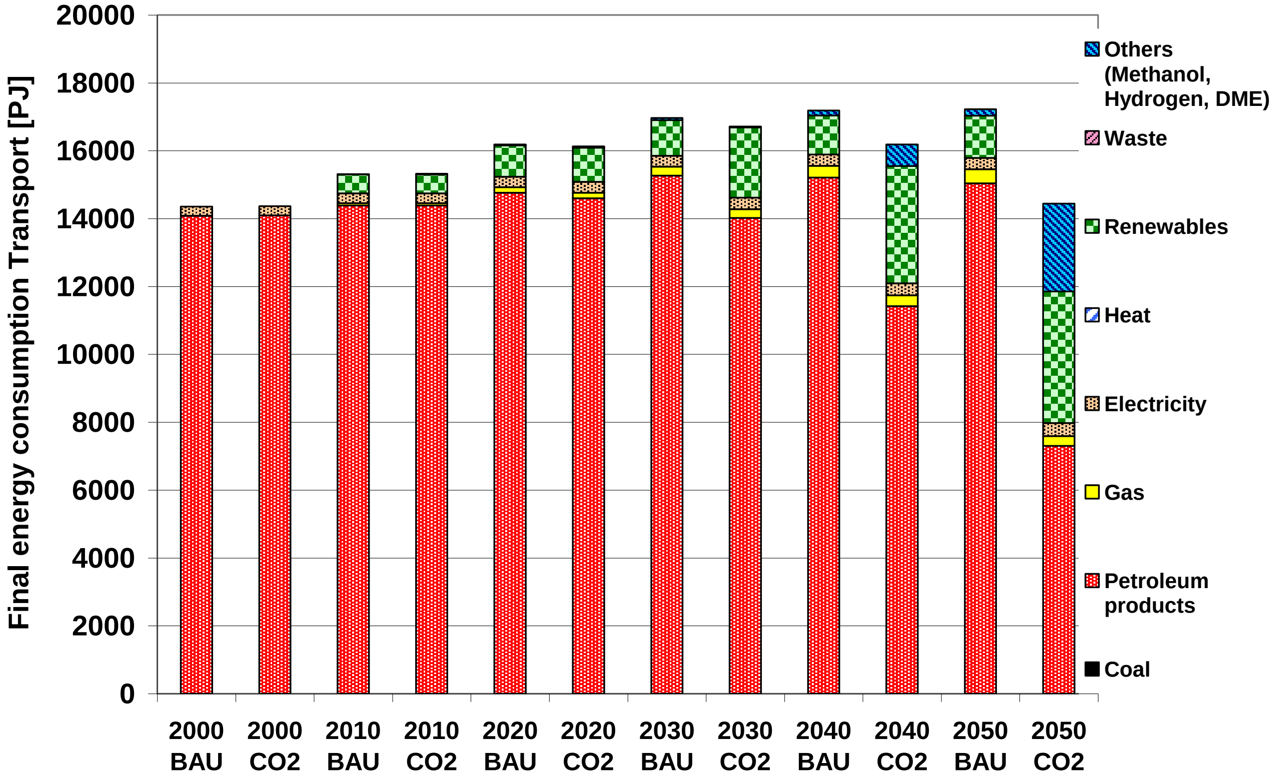


Figure 14: Total final energy consumption Transport in the EU27 Pan European model (Blesl et al., 2007b)

In the transport, sector oil products remain the predominant fuels in the BAU scenario, while they are progressively progressively substituted by renewables (biodiesel and ethanol) and other fuels (methanol, hydrogen and DME) in the CO_2 450 ppm scenario.

I

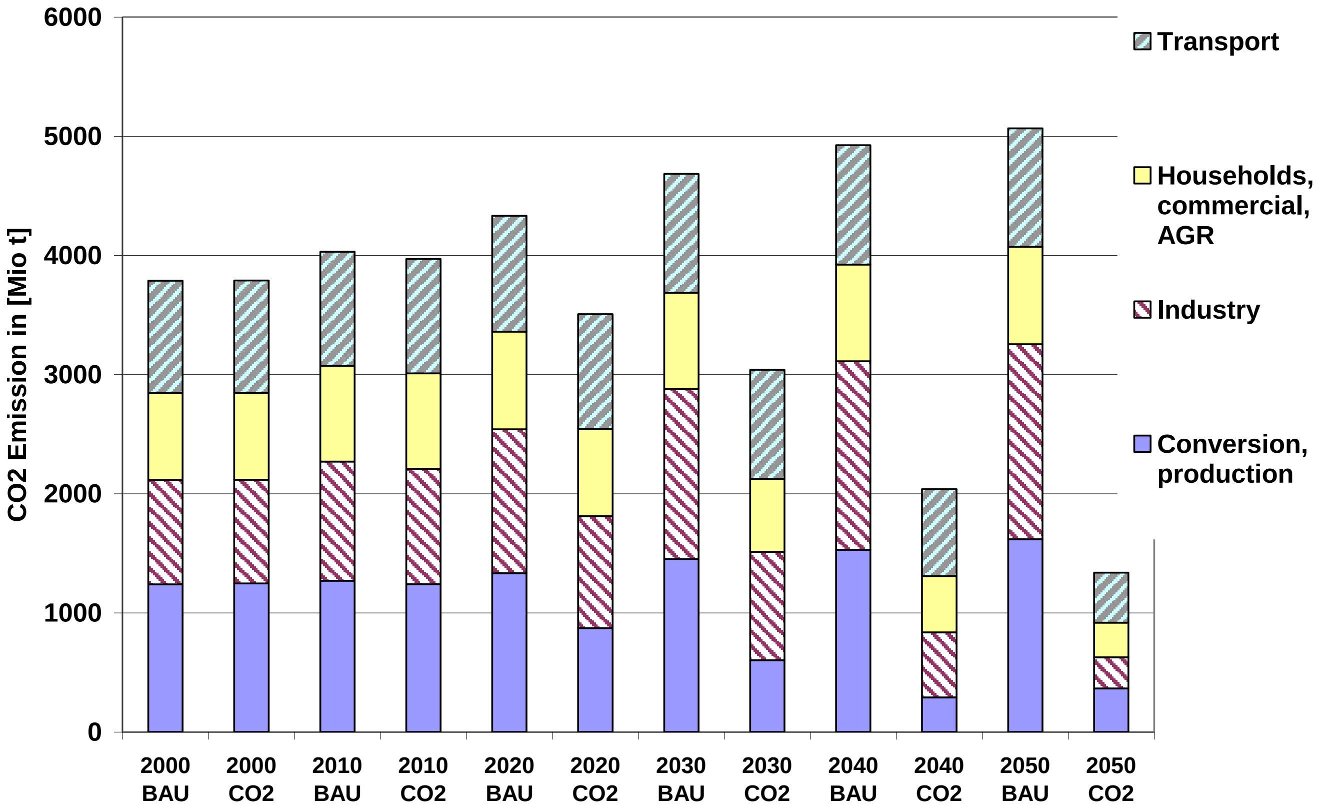


Figure 15: CO2 emissions by sector in the EU27 Pan European model (Blesl et al., 2007b)

As concerns the development of CO_2 emissions from 2000 to 2050 (Figure 15), in the BAU scenario the carbon dioxide emissions increase by 34% on the overall time horizon. The highest increase could be observed in Industry (+87%) and conversion and production (+31%). Residential, commercial and agriculture increase by 12% in total and the CO_2 emissions in transport by 5%. In 2050 industry and conversion represent the main contributors to the CO2 emissions accounting each one for 32% of the estimated CO2 emissions whereas the contribution of transport is about 20%.

In the CO_2 450 ppm scenario, CO_2 emissions from industry decrease by 71%, Residential, Commercial and Agriculture by 70%, Transport by 60%. The sectors which give the highest contribution in 2050 are transport (31%) and conversion and production (27%). The share of industry residential, commercial and agriculture represents 20% and 22% of the 2050 CO_2 total emissions respectively.

8. Conclusions and Further developments

The TIMES Pan European model, under development in the framework of the 6th FP Integrated Project NEEDS, is more than the sum of the 29 national models as it can demonstrate the benefits of coordinated policies across the borders of Europe, contrasting them with the fragmentation of national policies.
It is characterised by a long-term time horizon, high technological detail (in energy supply and end-use sectors), open and updateable format without need to change the software. Moreover its built-in flexibility facilitates the integration of LCA and ExternE evaluation methodologies.

The main model output of scenario analysis, for a given policy option and the set of exogenous assumptions adopted, is the energy system's response over the chosen time horizon. Illustrative parameters of this response are the equilibrium quantities and prices of energy vectors (primary energy and secondary fuels), the shadow prices for each policy constraint, capacities of energy technologies, emissions (GHG and local air pollutants) and other burdens. In addition, total system cost provides a global assessment of the ease or difficulty of attaining certain targets (e.g. CO2 emission constraints) selected for analysis. These results will constitute new input data for both LCA and ExternE, to be used for iterative, convergent evaluations.

The final PEM report (due in Month 46, July 2008) will provide more detailed information of the final configuration of the Pan-European model and will present the final results for the full set of analysed scenarios.

References

- Blesl M. *The Pan-European NEEDE TIMES model. II* Annual Review of the NEEDS Project, Rome, 9 November 2006.
- Blesl M., Kober T., Bruchof D. *The Pan European NEEDS-TIMES model - State of Art.* VII RS 2a Workshop – Plenary session, Leuven, April 17, 2007 (2007a).
- Blesl M., Kober T., Bruchof D. *The Pan European NEEDS-TIMES model Activities and Final Results* VIII RS 2a Workshop, Amsterdam October 24, 2007 (2007b)
- Cosmi C, Blesl M, Kanudia A, Kypreos S, Loulou R, Smekens K, et al. *Integration of country energy system models in a Pan European framework for supporting EU policies.* In: Aravossis K, Brebbia CA, Kakaras E, Kungolos AG, editors. Environmental Economics and Investment Assessment, Southampton (UK) and Boston (USA): WIT Press; p. 97-106, 2006.
- Cosmi C., Blesl M., Cuomo V., Kypreos S., Van Regemorter D. *The NEEDS scenarios: Final configuration*. II NEEDS Policy Workshop, Ljubljana, March 9, 2007. (http://www.needs-project.org)
- Energy Technology Systems Analysis Programme (ETSAP); 2007 <http://www.etsap.org>.
- GAMS "The General Algebraic Modeling System". 2007. www.GAMS.com.
- Gielen, D., *The Future Role of CO2 Capture and Storage - Results of the IEA-ETP Model*, IEA/EET Working Paper, EET/2003/04, November 2003.
- Haurie, A., Kanudia, A., Loulou, R., Van Regemorter, D., Vaillancourt, K., *The EFDA World Model. Final Report prepared for EFDA*, ORDECSYS, HALOA/KANORS and KUL, 2004.
- ISIS *First Integrated Report* Deliverable D5.1 of the Research Stream Integration EU Integrated Project NEEDS "New Energy Externalities Developments for Sustainability" October, 2006
- KanORS Consulting Inc., VEDA (VErsatile Data Analyst), 2007, http://www.kanors.com/software.htm.
- Kanudia A. *Representing Crude Oil and RPP Trading in the Pan-European Model*. Internal NEEDS/RS2a technical document. 15 May 2006.
- Kypreos, S., and Van Regemorter, D. *Scenarios to be generated with the TIMES model for NEEDS.* NEEDS Internal working paper RS2a WP2.3, 27 February 2006.
- Kypreos, S., Van Regemorter, D., and Guel, T. *Key Drivers for Energy Trends in EU; Specification of the Baseline and Policy Scenarios*. NEEDS Internal working paper RS2a WP2.3, 12 January 2006
- Loulou R. Energy Trading in the Pan European Model. NEEDS RS2a Goteborg Meeting, May-June 2006b.
- Loulou R. *The trade of Gas, Coal, and Biomass in the Pan-European Model: A Proposal for discussion*. Internal NEEDS/RS2a technical document. March 21, 2006a.

- Loulou, R., Kanudia, A., Vaillancourt, K., Smekens, K., Tosato, G.C., Van Regemorter, D., Blesl, M., Cosmi, C., Salvia, M. & Schulz, T., *Draft common structure of the national country models.* Deliverable D1.4 of the EU Integrated Project NEEDS "New Energy Externalities Developments for Sustainability", 31 August 2005.
- OIAFEIA-Office of Integrated Analysis and Forecasting, Energy Information Administration, U.S. Department of Energy, Washington, DC, The System for Analysis of Global Energy markets (SAGE) model of the US-EIA, DOE/EIA-M072 (2003)/1, August 2003. http://www.eia.doe.gov/bookshelf/docs.html.
- Rafaj, P., Kypreos, S., Barreto, L., 2005: Flexible Carbon Mitigation Policies: Analysis with a Global Multi-regional MARKAL Model. In Haurie, A., Viguier, L., (Editors) Coupling Climate and Economic Dynamics, Kluwer Academic Publishers. Dordrecht, the Netherlands. ISBN 1-4020-3424-5.
- Van Regemorter D, Kanudia A. Projections of the demand of energy services for NEEDS. Internal NEEDS/RS2a technical document, 2006.

Appendices

A.1 The GAMS program to compute demand projections

The GAMS program (demproj.gms) calls a gdx file GEME3-TIMES.gdx with the data from GEM-E3 and an xls file Scen_DEMPROJ.xls with all the other data needed. It is activated in VEDA-FE (graphic view) by clicking on demand. The scen_DEMPROJ.xls must be imported once before running the program to get the fill table correct and then reimported after running. The GAMS program generates also a xls file with the growth rate of the drivers (DRIVERSGRTIMES.xls) and a file with some other results from the calibration (DEMANDTIMES.xls).
Income and price elasticities: there are default values given; if users want to change these they have to change it only for their country breaking the link with the default value. It is not recommended to change the price elasticities
Baseyear demands: are automatically linked with a fill table to the template data
Residential data: they are read from RCA template and have been added in the RSD_BAL sheet; every team has to introduce their own data.

Attribute	Comm Name	Unit	Description
VA_HouseStock	RHRE	Thous.	Dwelling stock in base year
VA_HouseStock	RHUE	Thous.	
VA_HouseStock	RHME	Thous.	
VA_HouseShCool	RCRE	%	Share of dwelling with cooling in base year
VA_HouseShCool	RCUE	%	
VA_HouseShCool	RCME	%	
VA_HouseCoolTarget		%	Target for the share of dwellings with cooling
VA_HsClTrgtYears		Unit	Number of years after which the target share is reached
VA_TempCorr		index	Index for correction for temperature (degreedays)
VA_PersPHHold		Unit	Number of persons per household
VA_PphhEvol		rate	Yearly change in number of persons per household
VA_DemolHouses		thous	Number of dwellings demolished per year
VA_DemolShare	RHRE	%	Share of type in existing dwelling
VA_DemolShare	RHUE	%	
VA_DemolShare	RHME	%	
VA_ConstrShare	RHRN	%	Share of type in new dwellings
VA_ConstrShare	RHUN	%	
VA_ConstrlShare	RHMN	%	
VA_HeatNewVsOld	RHRN	proportion	Heat demand in new dwellings related to heat demand in existing dwellings
VA_HeatNewVsOld	RHUN	proportion	
VA_HeatNewVsOld	RHMN	proportion	
VA_ImprovOld		rate	Yearly improvement in efficiency of existing dwellings