PRIMES MODEL ©E3Mlab – ICCS/NTUA

Version 2 Energy System Model: Design and features

Context

The PRIMES energy system model has been developed in the context of a series of research programmes of the European Commission. The model has been successfully peer reviewed in the framework of the European Commission in 1997. From the very beginning, in 1993-1994, the PRIMES energy model was designed to focus on market-related mechanisms influencing the evolution of energy demand and supply and the context for technology penetration in the market. The PRIMES model also was designed to serve as an energy policy analysis tool including the relationships between energy policy and technology assessment.

Detailed technological models, often categorised in bottom-up approaches, have been among the first ever-constructed energy system models (including among others models developed in the context of DG XII research programmes, as for example EFOM). Such models have formulated a single, global mathematical programming (optimisation) problem that covers the energy system. In policy analysis, these models have been criticised for the lack of explicit representation of markets, the absence of market-based policy instruments and the lack of realism in formulating demand and the “individual” behaviour of demanders or suppliers. The efficiency gap problem illustrates the methodological failure of such bottom-up models, being unable to represent seemingly non cost-effective choices of consumers or producers. Micro-economic analyses suggested that the gap could be explained by specific conditions that prevail in the markets (distortions, barriers, etc.) and by the individual behaviour of economic agents (for instance, small consumers may use high subjective discount rates). In the context of technology assessment applications, it has been also stated that the lack of market mechanisms in the models may bring serious biases in the projections and the accurate estimation of future potential of technologies.

These critics, together with the need to represent the growing process of market liberalisation, motivated analysts to adopt market-oriented modelling approaches that involve explicitly market regimes and model separately the behaviour of economic agents. Such models can then incorporate detailed representations of policy instruments and structural options that may endogenously formulate the efficiency gap problem. These models are often called “new generation models” and currently prevail in policy analysis studies. Examples, which also include the modelling of energy-environment interactions, are IFFS, GEMS, GEMINI, ENPEP, NEMS (all in USA). These new generation models are often characterised as partial equilibrium models because they cover only the energy system and not the rest of the economy. They are also called generalised equilibrium models because they can formulate the behavioural conditions for the economic agents in a variety of mathematical formulations for the sub-models, and represent different market clearing regimes, reflected in the choice of algorithm for global model convergence (equilibrium).

The PRIMES energy system model belongs to same family of models and should be characterised as a hybrid model combining engineering-orientation with economic market-driven representations given that one of the main requirements set in the process of construction for PRIMES was that of continuity from older technological (or engineering explicit) energy models. The development of PRIMES has required intensive research work. The modular design of the model, required first to develop the sub-models, which cover demand and supply behaviour of the economic agents acting in the energy markets. The modules had to be designed simultaneously, in order to achieve consistency at the level of market integration. The cycle between construction of sub-models and integration has been repeated many times, as the overall model design proved to be more complex than initially planned. Hence, although several versions of the sub-models have been implemented (1995-1997), the integrated model ran as such for the first time in May 1997. We have named that model "version 1" of PRIMES. Version 2 of PRIMES has been released in June 1998.

The model version 1 has been used in 1997 in the evaluation of the set of policies and measures envisaged by the European Commission in preparation of the negotiation position of the EU for the Kyoto conference on climate change. The experience with the PRIMES use, proved to be very helpful for the modellers. Several model limitations have been depicted. They concerned the data and sectoral classifications, the lack of cost-supply responsiveness of the primary and secondary transformation sub-models, and the difficulty to control the interaction between centralised and independent power and steam producers.

These limitations gave rise to new important developments of the model, which has been profoundly redesigned in all the sub-models and the integration. The new version of the model (version 2 of PRIMES) adopted also a major innovation for the mathematical formulation and the integration, namely the non-linear mixed complementarity (MCP) formulation. It was the first time that a market oriented, detailed energy model was formulated in MCP and solved through the GAMS/CPLEX/PATH algorithm. This choice considerably improved the completeness of the model design and the consistency of interactions between supply and demand. Also, it allowed a shift away from the linear programming limitations, permitting the incorporation of non-linear mechanisms that relate to markets, resources and technological developments.

PRIMES model was used to prepare the European Union Energy and Emissions Outlook for the Shared Analysis project of the European Commission, DG XVII. It was also extensively used for the Environment DG, the Research DG and EEA as well as at government level in the EU. As regards the preparation of the report on "European Energy and Transport - Trends to 2030" in the context of the "Long Range Energy Modelling" framework contract for the Energy and Transport DG, the PRIMES model has been developed and used for the EU Member States, the new member-states and all associated countries. The current version of PRIMES (Version 2) is fully operational and calibrated on 2000 dataset for all countries represented.

Countries in PRIMES (as in 2005)

Ireland, Great Britain, Belgium, Luxembourg, Netherlands, Germany, France, Spain, Portugal, Denmark, Sweden, Norway, Finland, Austria, Italy, Switzerland, Slovenia, Czech, Slovakia, Poland, Hungary, Latvia, Estonia, Lithuania, Croatia, Yugoslavia, Romania, Albania, FYROM, Bosnia, Bulgaria, Greece, Turkey, Malta, Cyprus

Overview of the model

Scope and Objectives

The PRIMES model is a modelling system that simulates a market equilibrium solution for energy supply and demand. The model determines the equilibrium by finding the prices of each energy form such that the quantity producers find best to supply matches the quantity consumers wish to use. The equilibrium is static (within each time period) but repeated in a time-forward path, under dynamic relationships.

The model is behavioural but it also represents in an explicit and detailed way the available energy demand and supply technologies and pollution abatement technologies. The system reflects considerations about market economics, industry structure, energy/environmental policies and regulation. These are conceived so as to influence market behaviour of energy system agents. The modular structure of PRIMES reflects a distribution of decision making among agents that decide individually about their supply, demand, combined supply and demand, and prices. Then the market integrating part of PRIMES simulates market clearing.

The PRIMES model is a general-purpose model. It is conceived for forecasting, scenario construction and policy impact analysis. It covers a medium to long-term horizon. It is modular and allows either for a unified model use or for partial use of modules to support specific energy studies.

The model can support policy analysis in the following fields:

- standard energy policy issues: security of supply, strategy, costs etc.,
- environmental issues,
- pricing policy, taxation, standards on technologies,
- new technologies and renewable sources,
- energy efficiency in the demand-side,
- alternative fuels,
- conversion decentralisation, electricity market liberalisation,
- policy issues regarding electricity generation, gas distribution and refineries.

A fundamental assumption in PRIMES is that producers and consumers both respond to changes in prices. The factors determining the demand for and the supply of each fuel are analysed and represented, so they form the demand and/or supply behaviour of the agents. Through an iterative process, the model determines the economic equilibrium for each fuel market. Price-driven equilibrium is considered in all energy and environment markets, including Europe-wide clearing of oil and gas markets. The modelling framework takes into account Europe-wide networks, such as the Europe-wide power grid and natural gas network.

Although behavioural and price driven, PRIMES simulates in detail the technology choice in energy demand and energy production. The model explicitly considers the existing stock of equipment, its normal decommissioning and the possibility for premature replacement. At any given point in time, the consumers or producer select the technology of the energy equipment on an economic basis. These decisions can be influenced by policy (taxes, subsidies, regulation) market conditions (tariffs etc.) and technology changes (including endogenous learning and progressive maturity on new technologies)

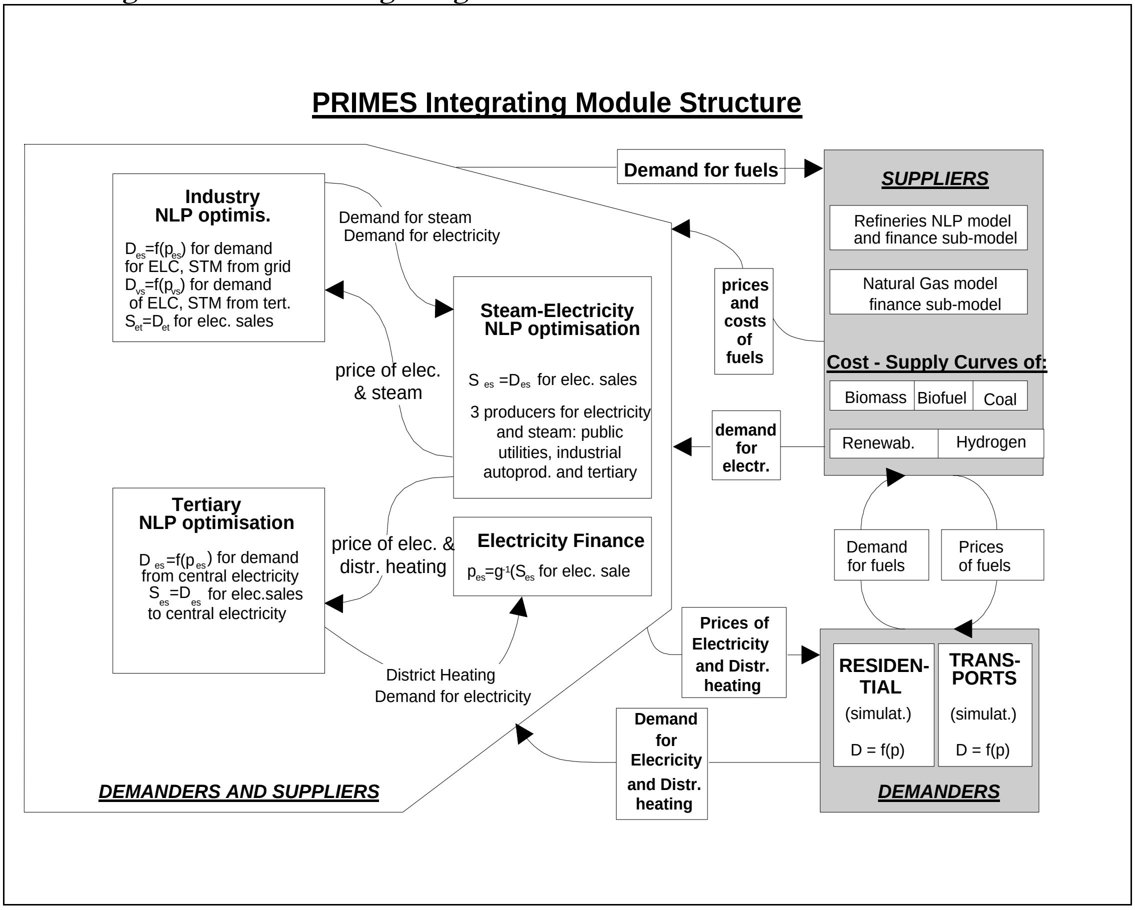
Due to the heterogeneity of the energy market no single methodology can adequately describe all demand, supply and conversion processes. On the other hand, the economic structure of the energy system itself facilitates its representation through largely separable individual units (such as households or industrial branches), each performing a number of individual functions.

Based on these principles, PRIMES is organised around a modular design representing in a different manner fuel supply, energy conversion and end-use of demand sectors. The individual modules vary in the depth of their structural representation. The modularity feature allows each sector to be represented in the way considered appropriate, highlighting the particular issues important for the sector. Furthermore, the modularity allows any single sector or group of sectors to be run independently for stand-alone analysis.

The model is organised by energy production sub-system (oil products, natural gas, coal, electricity and heat production, others) for supply and by end-use sectors for demand (residential, commercial, transport, nine industrial sectors). Some demanders may be also suppliers, as for example industrial co-generators of electricity and steam.

The different modules interact via the exchange of fuel quantities and prices, leading to the global equilibrium of the system.

Figure 1: PRIMES integrating module structure



Model formulation

At the global level, that is the market clearing level, the formulation of the model corresponds to a market equilibrium of the form:

Demand = Function (Price)

Supply = Demand

Price = Inverse Function (Supply)

The behaviour in the supply-side, corresponding to cost minimisation, is formulated as a set of non linear optimisation models and the demand-side has the form of a system of (non linear) equations, hence the equilibrium model can be written:

Solve for x,q,p,u that satisfy:

Supply side: Min $c \cdot x$

s.t. $A \cdot x \leq b, \quad x \in X$

Demand-side: $q = Q(p)$

Cost Evaluation: $u = f$ (c, x and other factors)

Equilibrium Condition: $p = u +$ taxes

where x and q denote supply and demand quantities, while u and p stand for producer and consumer prices.

The supply-side may include more than one non-linear mathematical programming problems corresponding to the behaviour of several supplying agents (for example, one for refineries, one for gas and one for electricity). In addition, the possibility that some suppliers of energy commodities may also be demanders for other energy commodities (for example, the electricity sector) is included in optimisation modules.

The design principles adopted for PRIMES follow the steps as below:

- We define which are the agents, the commodities and the markets; we proceed to an activity analysis, i.e. define supplying and demanding activities of agents for each commodity;
- we choose a mathematical formulation of each agent's behaviour and we specify the corresponding sub-model, while respecting activity analysis defined in the previous step; a sub-model may be a mathematical programming model (linear, non linear or mixed integer) or a system of (non linear) equations; all sub-models consider commodity prices are given; the supply sub-models have to correspond to cost minimisation and should satisfy demand; the demand sub-models must relate demand quantities to commodity prices; a supply sub-model may include formulations of market allocation among many suppliers, if necessary (for example between domestic production and imports);
- we define a price setting mechanism for each commodity; this may be based on average cost or marginal cost pricing and may include any other external factors influencing prices (for example world-wide leading prices); it is interesting to note that this part of the model can reflect realistic situations

concerning price-setting regimes (excluding artificial price-setting based on shadow prices); the price setting mechanisms draws on the results of the supply sub-modules; and

- we define the equilibrium conditions for all commodities by equalising producer prices (from step 3) and consumer prices (used in demand sub-models in step 2); taxes and subsidies may be included in these equilibrium conditions, such as excise taxes, VAT, carbon-tax and so on (other types of regulations must be incorporated in the corresponding sub-modules at the agent level).

The model is formulated as a global non-linear mixed complementarity problem (MCP) that includes all the equations/inequalities of the different modules and replaces the objective functions of each module with the Karush-Kuhn-Tucker first order optimality conditions.

Features of Sub-models

The supply modules simulate both the operation and the capacity expansion activities. The dynamic relationships involve stock-flow relations (for example capital accumulation), inertia in the penetration of new technologies, backward looking expectations (more formally, the model uses adaptive expectations) and consumer habits. Thus, the model integrates static and a dynamic solution under myopic anticipation, i.e. investment decisions are taken on the basis of prevailing prices at the time of investment.

Demand is evaluated at a national level. Electricity dispatching and capacity expansion are determined at a national level, depending however on a complex market allocation mechanism, operating through the electricity grid, Europe-wide. The natural gas distribution market clears at a multinational level, even wider than the European Union. The refinery sector operates at a national level, but capacities, market shares and prices depend heavily on Europe-wide competition. Indigenous energy production, for example coal and lignite supply curves, has, on the other hand, a country-specific character. Finally, energy savings, technology progress in power generation, abatement technologies, renewable energy forms and alternative fuels (biomass, methanol, hydrogen) are determined at the level of each country-specific energy system.

The cost evaluation modules and the price-setting mechanisms are at the core of the model. The cost evaluation modules are attached to each energy supply module. The cost module considers total revenue requirements of the sector (based on total costs) and allocates payments over the consumers, according to a general Ramsey pricing rule (parameters are user selected). The pricing parameters reflect alternative market conditions and are linked to marginal and average values from the sector's optimisation. For example, these rules consider pricing aimed at peak shaving and load valley filling or average cost pricing. The allocation of payments is further determined, by considering possible cross-subsidisation policy or other distortions. In brief, the price-setting mechanism reflects the design considerations for the market clearing regimes. The value of parameters in these cost-pricing modules can be altered, in policy scenarios, to reflect structural change.

Prices of purchased fuels depend also on cost-supply curves that are exogenously specified, but operate within the equilibrium process. Such curves are used for all primary energy supply, including EU gas supply, coal, biomass and even renewable sources to reflect land availability constraints. They are also defined for imports.

Technology

As mentioned, PRIMES has been designed to support technology assessment at the energy system level. The dynamics, as simulated by the model, influence the penetration of new technologies.

Several parameters and formulations are built-in to represent non-economic factors that affect the velocity of new technology penetration. For example, the modules include learning by doing curves, parameters that represent subjective perception of technology costs as seen by consumers, standards, etc. These can be used to represent market failures or inertia that may deprive the system from adopting cost-effective technology solutions.

In addition, market related factors, as represented within the optimisation modules, could also explain the lack of decision for the most cost-effective solutions. These factors are related to the individual character of decision maker's optimality and this is represented in the model by design (different optimality conditions per module) and through the use of different parameters, for example by varying the discount rates with the consumer size.

Policy instruments can of course be examined though changes in model parameters and by this in the optimality conditions of economic actors, which influence technology choice and penetration. The model can in addition simulate accompanying policies that aim at structural improvements to maximise the effects of policy measures. For example, true cost pricing, removal of barriers, new funding mechanisms etc. can be reflected in the model with a view to changes of parameters that will influence technology choices and penetration.

Environment

The mechanisms relating pollution to energy activities are fully integrated into PRIMES, also involving pollution abatement choices. The optimisation modules can simultaneously consider energy and environment costs. Constraints are built in to represent environmental regulation. The technology choice mechanisms also consider abatement equipment. Policy measures dedicated to pollution can affect optimality of the economic actors’ choices as simulated by the model. Such measures can also include policy aiming at structural change. Finally, a module can compute dispersion and deposition of emitted pollutants.

The main policy instruments for the environment, as considered in PRIMES, are:

- Regulation by sector (in the form of a constraint of emissions by sector);
- Regulation by country (in the form of a global constraint taking into account emissions from all modules);
- Taxation for the environment. This can be either exogenously given (in which case the emissions are not explicitly limited) or endogenously (as the shadow price of the constraint binding the emissions); the latter case ensures a certain

environmental outcome, but the tax rate is determined only in the process of modelling;

- Pollution permits. A separate market for pollution permits can be implemented in the model. The different sectors can therefore trade (sell or buy) permits based on their initial endowment; the permit price is endogenously determined as the shadow price of the constraint binding the emissions;
- Subsidisation of abatement costs for electricity and steam.

Policy Instruments

Special care has been devoted to the representation of various policy instruments in the model. For some policy instruments, it is straightforward to build scenario variants and to evaluate the implications. For other instruments, the analysis is more sophisticated and has to combine evaluations outside the model with results from model runs.

Economic and fiscal instruments constitute an obvious case of straightforward use of the model. Excise taxes, VAT, carbon and energy taxes, etc., are explicitly represented for all energy forms and uses. Fully detailed tax scenarios can be assessed, including differentiation of rates by sector, combination with subsidies and exemptions, harmonisation across member states, etc. The consequences of higher taxation for costs of derived energy forms (e.g. steam, electricity) are endogenously derived.

Other economic instruments, like tradable emission rights (pollution permits) can also be formulated in PRIMES. Other measures such as new funding mechanisms for energy technologies, information campaigns and measures aiming at removal of barriers, can be evaluated at the energy system level (regarding their total effects) through the built in mechanisms of PRIMES, like perceived costs, risk premium, etc.

Command and control regulation, that is the pursuit of objectives through administrative processes, can be analysed through the use of constraints that are binding within the optimisation modules. The model can evaluate the effectiveness and compute proxies for the evaluation of the cost-effectiveness of the measures through the shadow costs of regulation. Emission norms, efficiency norms, regulations such as the "Non Fossil Fuel Obligation" can be represented and analysed.

Voluntary agreements are one of the cases for which the model-based analysis must be combined with ad hoc evaluation. Voluntary agreements can be represented as constraints within the optimisation modules. However, in reality, they are not necessarily imperative constraints, since deviations may be possible. After evaluations outside the model, the analyst can formulate constraints, do sensitivity analysis with the model and compare shadow prices to known higher cost threats for not respecting the voluntary agreements.

To study the general issue of internalisation of externalities one has to use an accounting framework for externalities1, consider internalisation through economic instruments or define a regulation scheme that will oblige the actors to take into account external costs. Total cost pricing was brought up in the debate as a means to regulate decision-making. Total cost (that is including external costs) can be imposed

---

[1] For example, EXTERNE results.

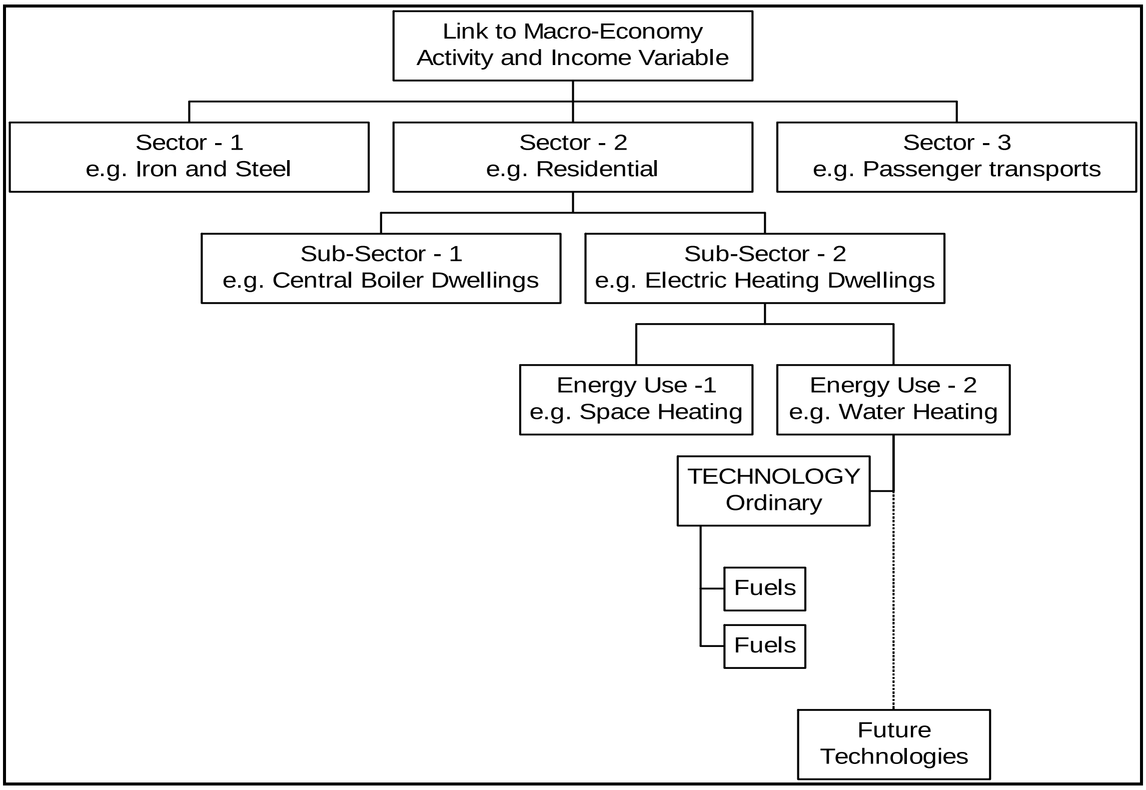
in all optimisation modules of PRIMES. This will influence technology choice and pricing throughout the system.

Description of the sub-models

The Demand Side Sub-Models

The demand-side sub-models of PRIMES V.2 have a uniform structure. Each sub-model represents a sector that is further decomposed into sub-sectors and then into energy uses. A technology operates at the level of an energy use and utilises energy forms (fuels). The following graphic illustrates the hierarchical decomposition of the demand-side models.

Figure 2: Hierarchical decomposition of the demand-side models in PRIMES



The data that are necessary to calibrate the model for a base year (2000) and a country can be divided in the following categories.

- Macro-economic data that correspond to demographics, national accounts, sectoral activity and income variables (EUROSTAT, UNFCC databases). These data usually apply to sectors.
- Structure of energy consumption along the above-described tree in the base year and structure of activity variables (production, dwellings, passenger-kilometres, etc.). Some indicators regarding specific energy consumption are also needed for calibration. The databases EUROSTAT, MURE, IKARUS, ODYSSEE, surveys and national sources have been used.

- Technical-economic data for technologies and sub-sectors (e.g. capital cost, unit efficiency, variable cost, lifetime, etc.).

The basic source of data for energy consumption by sector and fuel is EUROSTAT (detailed energy balance sheets). By using additional information (surveys of cogeneration operation and capacities and surveys on boilers), the balance sheets have been modify in order to represent explicitly the production of steam.

According to PRIMES definitions, steam includes industrial steam and distributed heat (at small or large scale). In the balance sheets, EUROSTAT reports on steam production in the transformation input/output only if the producers sell that steam. If the steam, irrespectively of the way it is produced (e.g. a boiler or a CHP plant), is used for self-consumption only, EUROSTAT accounts for only the fuels used to produce that steam and includes these fuels in final energy consumption. In the PRIMES database steam (including for self-consumption) is represented in the final energy consumption table of the balance sheet whereas the fuels used to produce that steam is shown in the table on transformation input. This is necessary for the model to calibrate to a base year that properly accounts for the existing cogeneration activities (even if they are used for self-generation of steam).

Demand side behaviour is driven by the minimisation of total energy and environment costs subject to total useful energy needs, energy use capacities, technology availability and emission constraints. In optimising, the energy agent may act on the mix of different production processes and/or end uses, the fuel mix, capacity replacement, technological choices, the degree of internal energy conversion, energy savings, abatement technologies and pollution permits.

The model evaluates consistently the potential of such new technologies, by considering simultaneously three types of mechanisms:

- economic optimality
- dynamics, i.e. constraints from existing capacity, and
- gradual market penetration and acceptance.

The non-linear optimisation is performed period by period in a time forward direction. In a given period a set of lagged values are used that are updated dynamically by the single-period optimisation results. Choices are constrained dynamically by the existing energy-use equipment. This may be renewed through investment while existing equipment is retired on the basis of retirement rates. The above decisions can be made on the grounds of available technologies in the different domains. Technology is considered to evolve in time, and is categorised in vintages (generations) presenting different characteristics.

Industry

In PRIMES, industry consists of nine sectors. For each sector different sub-sectors are defined. At the level of each sub-sector a number of different energy uses are represented. A technology at the level of an energy use may consume different types of fuels (one of which is steam generated from the power and steam sub-model of PRIMES, so only steam distribution and use costs are accounted for in the demand-side, together with a price for steam).

The sub-model design aims at building a structural model to represent in detail the engineering of final energy demand formation in industry, while expressing the cost minimisation behaviour of industrial companies.

In the second version of PRIMES, the aim of the industrial sub-model is to project demand for fuels, electricity and steam. These fuels are purchased from other sub-models of PRIMES. The self-production of electricity and steam is not included in the industrial sub-model, but is a part of the electricity and steam sub-model of PRIMES. This choice reflects the emerging market opportunities for independent generation of electricity and steam.

Modelling the structure of energy demand formation in industry is a complex task. This is due to the variety of technological cases in the industrial sectors and the heterogeneity of products, equipment, technologies, processes and energy uses. Given the focus of PRIMES for policy analysis, the modelling objective emphasises the potential for structural change in energy use in industry, a change that would involve new technologies, industrial processes, links to decentralised (self-supplied) energy conversion and the implied shifts in energy intensities.

The scope of the industrial demand sub-model of PRIMES is to represent simultaneously:

- the mix of different industrial processes (e.g. different energy intensity for scrap or recycling processes and for basic processing);
- the mix of technologies and fuels, including the use of self-produced by-products (fuels) and renewable energy forms;
- the links to self-supply of energy forms (e.g. cogeneration of electricity-steam, steam by boilers, use of by-products (fuels), heat recovery);
- the explicit and engineering-oriented representation of energy saving possibilities;
- the satisfaction of constraints through emission abatement, pollution permits and energy savings, and
- the rigidities of system change evolution because of existing capacities or dynamic technical progress.

The structure for the industrial sector is given below:

SECTOR	*SUB-SECTORS*	*ENERGY USES*
Iron and Steel	Electric arc	Air compressors
	Iron and Steel integrated	Blast furnace
		Electric arc
		Electric process
		Foundries
		Lighting
		Low enthalpy heat
		Motor drives
		Process furnaces
		Rolled steel
		Sinter making
		Steam and high enthalpy heat

SECTOR	*SUB-SECTORS*	*ENERGY USES*
Non ferrous metals production	Primary aluminium production	Air compressors
	Secondary aluminium production	Lighting
	Copper production	Motor drives
	Zinc production	Electric furnace
	Lead production	Electrolysis
	Other non ferrous metals production	Process furnaces
		Electric kilns
		Low enthalpy heat
		Steam and high enthalpy heat
SECTOR	*SUB-SECTORS*	*ENERGY USES*
Chemicals production	Fertilizers	Air compressors
	Petrochemical	Low enthalpy heat
	Inorganic chemicals	Lighting
	Low enthalpy chemicals	Motor drives
		Electric processes
		Steam and high enthalpy heat
		Thermal processes
		Energy use as raw material
SECTOR	*SUB-SECTORS*	*ENERGY USES*
Building materials production	Cement dry	Electric kilns
	Ceramics and bricks	Cement kilns
	Glass basic production	Air compressors
	Glass recycled production	Lighting
	Other building materials production	Motor drives
		Glass annealing electric
		Glass tanks electric
		Low enthalpy heat
		Glass annealing thermal
		Glass tanks thermal
		Material kilns
		Drying and separation
		Tunnel kilns
SECTOR	*SUB-SECTORS*	*ENERGY USES*
Paper and pulp production	Pulp production	Lighting
	Paper production	Motor drives
		Pulping electric
		Refining electric
		Steam and high enthalpy heat
		Low enthalpy heat
		Pulping steam
		Drying and separation
		Refining steam
SECTOR	*SUB-SECTORS*	*ENERGY USES*
Food, Drink and Tobacco production	Food, Drink and Tobacco goods	Air compressors
		Cooling and refrigeration

		Lighting
		Motor drives
		Drying and separation electric
		Steam and high enthalpy heat
		Low enthalpy heat
		Space heating
		Drying and separation thermal
		Specific heat
		Direct heat
SECTOR	*SUB-SECTORS*	*ENERGY USES*
Engineering	Engineering goods	Air compressors
		Lighting
		Motor drives
		Drying and separation electric
		Machinery
		Coating electric
		Foundries electric
		Steam and high enthalpy heat
		Low enthalpy heat
		Space heating
		Drying and separation thermal
		Coating thermal
		Foundries thermal
		Direct heat
SECTOR	*SUB-SECTORS*	*ENERGY USES*
Textiles production	Textiles goods	Air compressors
		Cooling and refrigeration
		Lighting
		Motor drives
		Drying and separation electric
		Machinery
		Steam and high enthalpy heat
		Low enthalpy heat
		Space heating
		Drying and separation thermal
		Direct heat
SECTOR	*SUB-SECTORS*	*ENERGY USES*
Other industrial sectors	Other industrial sectors goods	Air compressors
		Lighting
		Motor drives
		Drying and separation electric
		Machinery
		Steam and high enthalpy heat
		Low enthalpy heat
		Space heating
		Drying and separation thermal
		Specific heat
		Direct heat

Tertiary sector

The purpose of the tertiary sub-model of PRIMES is to project final energy demand of the services and agriculture sectors, as a function of economic activity of the sector, which is exogenous, and the prices of the energy forms as transmitted to these sectors from energy supply. Possible interactions with the production of electricity and steam are modelled though links of quantities and prices with the corresponding component of PRIMES.

Tertiary is one of the fastest growing sectors in the last years. Energy demand in this sector also grows fast, as a consequence of the introduction of new energy uses, particularly regarding electricity, thermal comfort and cooling. For modelling, the main difficulty for the tertiary sectors comes from the introduction of new energy uses (such as air cooling), the increase in use of electrical equipment (computers etc.), and the heterogeneity of equipment, technologies and energy uses.

Given the orientation of PRIMES to support long run policy analysis, the modelling objective has to focus on the potential for structural change in energy use in tertiary, a change that would involve new technologies, links to decentralised energy conversion and the implied shifts in energy intensities. A top-down approach based solely on econometrics could not capture such a complex evolution and would not provide a basis for policy appraisal in view of the environmental objectives.

Deliberately, to represent such mechanisms one must support economic modelling with engineering evidence, an objective that always has been challenging for modellers. This is the model approach adopted by PRIMES, in view also of its use in RTD strategy analysis and the need to deal explicitly with technologies.

The scope of the tertiary demand sub-model of PRIMES is to represent simultaneously:

- the mix of different energy uses;
- the mix of technologies and fuels, including the use of renewable energy forms;
- the links to district heating, steam production from boilers and cogeneration;
- the explicit and engineering-oriented representation of energy saving possibilities;
- the satisfaction of constraints through emission abatement, pollution permits and energy savings, and
- the rigidities of system change evolution because of existing capacities or dynamic technical progress.

The aggregate tertiary comprises of 4 sectors: three service sectors and agriculture. At the level of the sub-sectors, the model structure defines groups of energy uses, which are further subdivided in energy uses defined according to the pattern of technology.

The structure of the tertiary sector is as follows:

SECTOR	*ENERGY USES*	*ENERGY TECHNOLOGIES*
Agriculture	Lighting	Lighting
	Space heating	Heating/Cooling
	Greenhouses	Pumping
	Electrical uses	Motor drives

	Pumping	Electrical equipment
	Motor energy	
SECTOR	*ENERGY USES*	*ENERGY TECHNOLOGIES*
Services		
Market Services	Lighting	Lighting
	Space heating	Electric heating/cooling
	Air conditioning	Gas heating/cooling
	Steam uses	Boiler heating/cooling
	Electrical uses	District heating
	Water heating	Electrical equipment
Trade	Lighting	Lighting
	Space heating	Electric heating/cooling
	Air conditioning	Gas heating/cooling
	Steam uses	Boiler heating/cooling
	Electrical uses	District heating
	Water heating	Electrical equipment
Public services	Lighting	Lighting
	Space heating	Electric heating/cooling
	Air conditioning	Gas heating/cooling
	Steam uses	Boiler heating/cooling
	Electrical uses	District heating
	Water heating	Electrical equipment

Residential sector

In the residential sector, energy is consumed as input in processes that provide services to the households, such as space heating, water heating, cooking, cooling, lighting and other needs. The decision about the level of energy consumption is related to the need for services covered by energy, which are further related to changes in prices and income as is true for other consumption commodities.

Energy consumption has, however, several special features, which need to be considered especially concerning the way they affect the dynamics of consumer response. In particular:

- The pattern of energy consumption is not usually controlled directly by the consumer, but is determined by the household technology (i.e. the type of fuel and equipment used for an energy service); the level of consumption is controlled, in the short run, by behavioural decisions in utilisation intensity;
- The household technology for energy consumption is largely embodied in the characteristics of dwellings and durable equipment. Consequently, responses to price shifts may involve long lags;
- Energy costs are normally billed to households periodically for several uses combined. Due to this fact, there may be no direct linkage between policy and cost, even for highly rational consumers; this also causes a delay of response when price shifts occur;

- Energy covers primary needs of households. The income elasticity is expected to be less than one, while substitutions by non-energy commodities are rather limited. In industrialised countries the share of energy in total consumption is close to saturation (taking account of price variations), a fact that explains the observed asymmetry in price elasticities with respect to positive or negative shifts. It should be noted, however, that PRIMES is not solely based on such overall elasticities but on a much more structural representation of demand and supply.

As a result of these special features of energy consumption in the residential sector, the model has to include both technological and behavioural components. Technological components are necessary to capture the physical constraints on energy conservation and use, while behavioural components are necessary to explain consumer expectations and their influence on equipment choice as well as to explain the influence of energy prices on energy consumption intensity. The model is designed to provide energy consumption forecasts for each end-use by fuel.

The fuel shares, for each end-use in which we have substitution between fuels, are assumed to represent fuel choice frequencies (which express the percentage of households that choose a specific fuel to serve an end-use). The probability that a given appliance (for space heating, water heating and cooking) is chosen to be installed in a dwelling is calculated as a function of a total perceived cost and of the maturity of equipment (so that inter-fuel substitution is constrained). The total perceived cost is a function of capital, maintenance and fuel (operating) cost of the equipment, as well as of the income of households. Especially, for cooking and water heating it is assumed that the total perceived cost also depends on the fuel choice made for space heating following the decision-tree approach mentioned above. This assumption leads to a “nested logit model” approach. The fuel shares obtained, are implemented for new dwellings and for the installation of new equipment due to normal replacement. As a result, updated fuel shares by end-use are computed, concerning both existing and new dwellings.

Specific electricity use is considered as non substitutable, for which an analysis in terms of electric appliances is formulated.

The residential sector distinguishes five categories of dwelling. These are defined according to the main technology used for space heating. They may use secondary heating as well. At the level of the sub-sectors, the model structure defines the categories of dwellings, which are further subdivided in energy uses. The electric appliances for non-heating and cooling are considered as a special sub-sector, which is independent of the type of dwelling. The structure is as follows:

SECTOR	*HOUSEHOLD TYPES*	ENERGY USES
Dwellings	Central boiler households that may also use gas connected to the central boiler (flats)	Space heating Cooking Water heating Air conditioning
	Households with mainly electric heating equipment (non partially heated)	
	Households with direct gas equipment for heating (direct gas for flats and gas for individual houses)	
	Households connected to district heating	

	Partially heated dwellings and agricultural households	
SECTORS	*ENERGY USES*	
Electric Equipment	Washing machines	
	Dish washers	
	Dryers	
	Lighting	
	Refrigerators	
	Television sets	

Transport sector

The transport module of PRIMES has been developed to study mainly the penetration of new transport technologies and their effects on emissions, besides the evaluation of the energy consumption and emissions in the transport sector. The emphasis is on the use of car technologies and on the long term (2030). The model structure is kept deliberately simple as it is made to interact as demand module with supply modules (refineries, new fuel production) of PRIMES.

The transport sector distinguishes passenger transport and goods transport as separate sectors. They are further subdivided in sub-sectors according to the transport mode (road, air, etc.). At the level of the sub-sectors, the model structure defines several technology types (car technology types, for example), which correspond to the level of energy use.

The overall demand for transport (passenger kilometres, ton kilometres) is determined by income/activity growth and by the overall price of transport. The overall price of transport is determined endogenously, as a function of the modal split and of the price per mode. The split of the overall transport activity over the different modes is driven by the price per mode and by behavioural and structural parameters. The price per mode depends on the choice of technology for new investment and on past investment for each transport mode. The technologies for new investment are chosen, based on the lowest expected usage costs.

The stock of vehicles inherited from the previous period is expanded in function of the transport needs per mode. The new stock composition determines the stock for the next period and influences the aggregate price per mode.

The structure of the transport sub-model is as follows:

SECTOR	*SUB-SECTORS*	*ENERGY TECHNOLOGIES*
Passenger transport	Busses	Internal combustion engines
	Motorcycles	Electric motors and hybrid
	Private cars	Fuel cell
	Passenger trains	Gas turbine and CNG
	Air transports	
	Navigation passengers	
SECTOR	*SUB-SECTORS*	*ENERGY TECHNOLOGIES*
Goods transport	Trucks	Internal combustion engines
	Trains	Electric motors and hybrid
	Navigation	Fuel cell
		Gas turbine and CNG

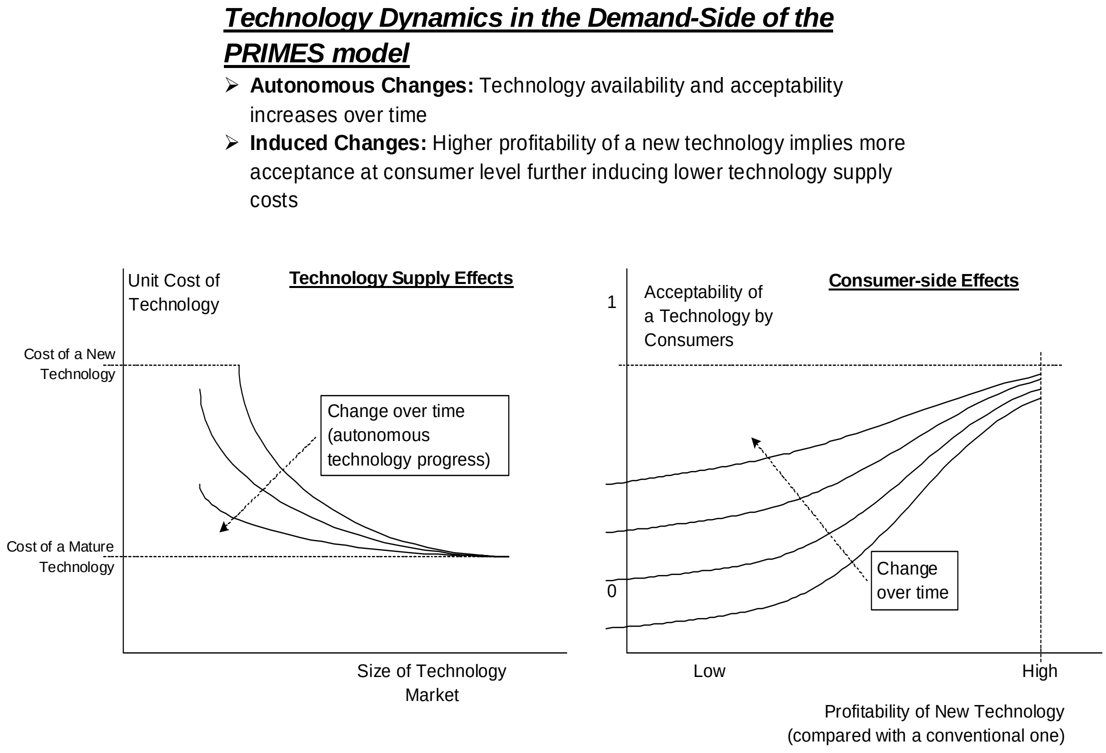
Technology dynamics in the demand side

The PRIMES dynamics consist of a sequence of static equilibria linked to each other through capital accumulation. The behaviour of economic agents is assumed to involve myopic anticipations. Obviously, PRIMES dynamics are quite different from that of models performing inter-temporal perfect foresight. Static market equilibrium as simulated by PRIMES may not be 'optimal' with reference to perfect foresight. This is particularly important for capacity expansion decisions and technology choice. For example, technology lock-ins may well be explained as a result of imperfect anticipation. PRIMES dynamics do so because the model wants to mimic the real behaviour of economic agents and the short-termism that often influences market equilibrium. Such behaviour obviously has consequences for both technology choice and dynamic evolution of technology.

The PRIMES model incorporates induced technology change in the demand-side of the model. Technology choice at the consumer level is based on total technology cost, which further depends on technology supply costs and acceptability of technology by the consumer. Both cost components can change endogenously. For example if a carbon constraint applies, the consumer might perceive more profitability from new technologies, the technology gets more acceptance and its penetration is further facilitated by decreasing technology supply costs; this leads to lower economic costs from complying with carbon constraints. These dynamic projections having autonomous components for technology progress, and represent different conditions over time for technology choice, acceptability and technology supply effects.

The following graphic illustrates these concepts regarding demand-side technologies in PRIMES.

Figure 3: Technology dynamics in PRIMES



Technology Dynamics in the Demand-Side of the PRIMES model

- **Autonomous Changes:** Technology availability and acceptability increases over time
- **Induced Changes:** Higher profitability of a new technology implies more acceptance at consumer level further inducing lower technology supply costs

Advanced technologies are, almost by definition, significantly more costly to adopt initially, in terms of capital spending. However, once the adoption of these technologies becomes marginally cost effective their market penetration develops a strong momentum leading to the decline in the additional capital charges involved in the use of the new technology. In other words, the anticipation of higher demand for advanced technologies leads energy equipment suppliers (manufacturers, maintenance and technical support operators) to make them more attractive and more acceptable by the market. This technology supply-side effect contributes to the acceleration of adoption of new technologies by consumers. Of course, both the availability of technologies and the technology adoption mechanism take into account the time limitations for system adjustment.

The above-defined mechanism allows for lower adaptation costs for the system and higher penetration of demand-side technologies, compared with cases that have a static view on technology change in demand-side energy technologies.

Under different scenario assumptions (e.g. high economic growth, introduction of global emission constraints etc.), the above mechanism triggers dynamics of technology change that differ from baseline conditions. The consumer may accelerate (or decelerate) the adoption of more efficient technologies along the schedule of normal replacement of his equipment, or even perform premature replacement of equipment. The way that alternative assumptions affect different energy consumers depends on the ability of the latter to adapt through investment in different -compared to baseline- technologies, structural shifts and changes in their choice of fuel mix.

The Power and Steam Generation Sub-model of PRIMES

There exists an important literature on electrical power economics and modelling. The different approaches have used a big variety of advanced mathematical techniques, including optimisation, probabilistic simulation and dynamic systems. Because of the complexity of electricity systems, the mathematical models have been specialised by focusing on some of the features of the system. With reference to their scope, the models can be classified in the following categories:

- models emphasising on the operation and dispatching of the electricity system; load flow and probabilistic techniques are commonly used;
- models emphasising on reliability issues especially regarding the transmission network; stability analysis techniques are often used;
- models emphasising on capacity expansion and plant selection; they usually follow dynamic programming and mixed-integer optimisation, as they represent discrete candidate plants; and
- models emphasising on the strategic economic issues and the interactions between the electricity system and the rest of energy systems and markets; a variety of economic modelling techniques are used.

PRIMES’ focus is mainly along the lines of this last category. However, given the importance of the sector, the model design gave importance to a minimum standard representation of the engineering aspects of the electricity system. In this sense it borrows elements from the engineering-oriented power economics modelling. In addition, it was aimed to design a model framework that would be easily expandable to construct sufficiently detailed model version that would be used specifically for the analysis of the electricity sector.

The aim of the electricity and steam sub-model of PRIMES is to simulate the behaviour of agents that use fuels and other energy forms to produce, transmit and distribute electricity, industrial steam and district heating. This behaviour concerns the choice of equipment and the fuel mix to satisfy demand, the setting of selling prices and the purchase of fuels from the energy markets. The model design is adapted to the very nature of the energy forms produced in this sub-model, related to the impossibility to use storage, the high degree of capital intensive equipment and the importance of technology choice for energy strategy.

The increasing importance of heat and power cogeneration possibilities and the prospects for increasing decentralisation of production led to the adoption of a unified modelling for power and steam production. The emergence of efficient smaller scale technologies and the opening of the markets to competition created new prospects for cogeneration and independent production. The modelling needs to tightly integrate producers of different nature, regarding for example economies of scale and market opportunities, into a single framework that will mimic the operation of the market.

The PRIMES model puts emphasis on the different nature of producers that operate in the market and the interaction between electricity and steam markets, as enabled by cogeneration. For example, it is necessary to distinguish producers according to their scale, but also according to the captive markets they might address. A utility can exploit high economies of scale, but can hardly benefit from the market of steam, as steam cannot be self-consumed. On the contrary, an industrial independent producer will operate at smaller plant size, loosing competitiveness as far as the economies of scale are concerned, but obtaining benefits from a high base load demand for steam that he can supply. A company operating at the level of local authorities may obtain benefits from niche markets (renewable energy forms, district heating), but it will face a highly fluctuating demand for heat and electricity.

The representation of different technologies that are now available or will be available in the future is a major focus of the model, as it is intended to also serve for strategic analyses on technology assessment. To support such analyses, the model uses a large list of alternative technologies and differentiates their technical-economic characteristics according to the plant size, the fuel types, the cogeneration techniques, the country and the type of producer. A model extension is also designed aiming at representing a non-linear cycle of the penetration of new technologies, for which learning through experience (and other industrial economic features) relates penetration with the technology performance.

The differences between the producer types play an important role in their ability to obtain interesting natural gas supply contracts. This issue seems to become very important in the future, as natural gas is emerging as the key fuel because of technology progress and environmental constraints. Again, a unified modelling approach is necessary to analyse the differentiated effects of natural gas for producers that differ as described above.

Both the market allocation from the producer perspective and the effects of natural gas supply conditions need a consideration of the time pattern of demand, production and fuel supply. In addition, the corresponding loads have to be considered in chronological terms, as serious limitations would arise in case of using load duration monotone curves, because of the need to analyse the synchronisation of the time patterns of electricity consumption, steam consumption and fuel supply (such as natural gas).

The consideration of intermittent energy sources, such as the renewable energy forms, also requires a representation of chronological curves, as the random availability of the source over time can be approximated. Nevertheless, the correct modelling of intermittent production also requires a representation of geographical characteristics of production and transmission and a modelling of congestion over the electricity networks. Obviously, such features are also necessary to adequately represent the market for steam and heat. Such features have not been yet introduced in PRIMES, as the model mainly aims to serve for integrated strategic analyses. The algebraic coding of the electricity and steam sub-model of PRIMES is enough generic and abstract, to provide a consistent framework for model expansion in the future, along the geographical or network congestion research lines.

The development of independent power and/or steam producers and their market forces heavily depend on the prevailing institutional regime in the market. In the past, market regulation, cross-subsidisation and the importance of returns to scale in power production have prevented small independent producers from entering the market. Exceptions have arisen in specific cases in which the scale of self-consumption or the existence of by-product fuels has permitted the survival of independent producers. The expectations for the future are different. New technologies allow for competitive production at a smaller scale, while the institutional regime in the market is increasingly opening to competition. Furthermore, the completion of the internal electricity market has now been decided in the EU.

To represent these market dynamics, the model design preferred the representation of representative companies operating under a market competitive regime. For example, the exchanges of electricity and steam between the companies are performed under marginal cost pricing in the model. This choice has a limitation, as it cannot represent transitory phenomena of oligopolistic nature that might prevail in the market. However, a full competitive regime has been preferred as PRIMES puts emphasis on strategic analysis. Constraints regarding for example the degree of opening of the market can be introduced in the model through parameters regulating market allocation to producers.

In addition, constraints that would increase the inertia of the market are introduced in the form of contracts. These apply to both the exchanges between the companies and the provisions of fuels.

Decision-making by electric utilities (or steam producers) may be considered in three different, yet interrelated, problems:

- the *strategic capacity expansion problem* which concerns the choice of new plants for construction, so as to meet future demand at a least long-run generation cost;
- the *operational plant selection and utilisation problem* which concerns the choice of existing plants to be committed in the system, so as to meet load at a least operation cost;
- the *cost evaluation and pricing policy* that has to be in conformity both with the long-term financial objectives of the company and with the aim to influence demand load.

In the electricity and steam sub-model of PRIMES, the representation of the above decision problems is in accordance with the optimal pattern of supply behaviour in a competitive equilibrium market. In particular, we formulate long run marginal cost principles for capacity expansion and short run marginal costing for dispatching and plant commitment. However, for price setting we formulate Ramsey pricing, for which the -user selected- pricing parameters are linked to marginal and average values from the sector's optimisation. Thus, alternative electricity market conditions can be reflected to consumers.

Engineering features

A fundamental characteristic of electric or steam producers is that they cannot store their product in order to meet fluctuations in demand. Thus, an important feature to be captured in modelling is the implications of changing time-related patterns of demand on plant capacity selection and utilisation.

At the level of the electricity and steam sub-model, demand for electricity and steam is considered as exogenously given, varying widely between different times of the day and between different seasons. The representation of demand is based on the definition of a chronological load curve, which depicts the load (e.g. in GW) as a function of time in a year. Within an iteration of the overall PRIMES model, the demand sub-models provide estimates of demand (as a function of time in a year). They use the same representation of time as the electricity and steam sub-model. Changes in the demand-side, for example, induced by prices or other factors, influence the electricity and steam sub-model. The latter may, for example, change prices that may further affect demand.

The closed-loop interaction performing at the level of the overall PRIMES model represents the link between demand and supply of electricity and stream in an endogenous manner. This link is fully defined over time of a year, since all the sub-models are synchronised at the same representation of time. This synchronisation concerns not only electricity and steam, but also fuels that are inputs to power and steam production, such as intermittent renewable energy sources for which the time pattern is important.

The second important feature is associated to transmission and distribution of electricity and steam, which operate over networks (cables and pipelines). The PRIMES model adopts a network representation but dissociates this from any geographical characterisation. In fact, nodes and arcs in PRIMES are virtual, without involving any physical characteristic other than losses and capacities. The adoption of a network representation endows the model with abstraction sufficient to expand the model so as to represent geographical or production characteristics in a more realistic way.

The interconnections between electricity companies are important, as electricity cannot be stored. Traditionally, interconnections between countries served to reduce the costs of system reliability for each country. They have also served to the establishment of contracts, concerning exchanges between countries that have reflected differences in the economics or capacities. The contracts have been always defined over time (time pattern), besides their contacted quantity. To this respect, the synchronisation feature of the model is useful to also represent contracts, which in fact are formulated as obligations for load exchanges. As the electricity market is being increasingly liberalised in Europe, the interconnections also serve to support market operations, covering commercial transactions between countries, but also among companies within a country. In other terms, the development of the network physically defines upper bounds to the possibilities for market-related transactions of electricity. At a more technical level, congestion over the network also limits market development. Market competition regimes, such as the single buyer or third party access, following the jargon adopted in the EU, can be also represented through different topologies of the connections in a network. For example, a consumer may be allowed to connect to a utility in another country, to reflect a situation in a third party access regime.

In brief, the representation of the network in PRIMES is an abstraction that serves to support the representation of engineering information about transmissions, but also serves to formulate the possibilities for commercial transactions. The algebraic coding of the model, regarding the network, is general enough to allow for an expansion of the model either towards engineering representation of the network and/or a generalised formulation of commercial agreements.

The temporal framework

The model horizon is composed of a set of periods of equal length (5-year periods). Activity variables related to generation, trade and sales are generally treated as time series, except some of the parameters that are assumed invariant with time. During a year, the conditions under which the electricity or steam system works may vary from day to day. The model therefore considers a set of typical days in a year. Each typical day is characterised by a different set of operating conditions for the system. Also, the operating conditions may exhibit significant variations during a single day. This is taken into account by decomposing the day in a set of time segments, each time segment leading to different operating conditions.

Regarding the dynamics of the decision-making, the model is flexible. Two anticipation regimes, activated through an optional switch, are formulated in the model:

- The myopic time-forward anticipation, in which the decision-maker has information only about the past and the present time-period while the model is solved dynamically along time-steps in a time-forward manner.
- The perfect foresight over finite horizon, in which the decision-maker has full and correct information about the future, over a finite horizon, and the model solves simultaneously (inter-temporally) for the set of time periods from present up to the horizon examined.

The building of equipment in the electricity and steam system requires several years. This has important implications for planning and plant type choice. The model considers the financial costs associated to the construction period but ignores the fact that the plant types differ in construction time, which may influence plant selection in particularly uncertain circumstances. Furthermore, under the myopic anticipation regime, the model considers that the plants can be constructed and immediately used within the 5-years runtime period of the model. In this sense, the model operates as if the current 5-years period is perfectly known by the decision-maker.

Producers, companies and market relationships

Self-production of electricity or steam technically differs from the production of utilities because a self-producer traditionally did not consider trading of production surplus. Along the rapid development of trade in the electricity market, the self-production changes in character, as trading -through interconnections- alters the economics of producers. The term “independent producers”, which is now widely used to characterise self-production among other cases, does not make reference to the purpose of production, but to the scale of the company, in comparison to large utility companies.

The economic choices of independent production usually are justified in a situation when one or more of the following conditions hold:

- the producer is also a consumer of his output, the consumption costs less in terms of transmission and distribution, and there is sufficient development of a market for trading excess supply;
- the producer has access to a free or cheap energy source (waste, by-products, and specific locations for renewable energy forms);
- the liberalisation of the market and privatisation of utilities leads to smaller scale companies that are necessary to cope with the eventual diseconomies of scale of large utilities.

The design of the model is oriented to cover these situations. Differences in return to scale, related to the average size of plants that a producer is allowed to handle, are compared against eventual gains in transmission and distribution, while market allocation constraints may limit or favour the development of independent production. Similarly, among the variety of fuels considered, the model explicitly represents cheap or free resources to which only some of the producers have access. In this sense, the companies (producers), represented in the model differ in purpose: a utility makes business by selling electricity or steam, an industrial company is mainly addressing its own demand but can profit from market development, etc.

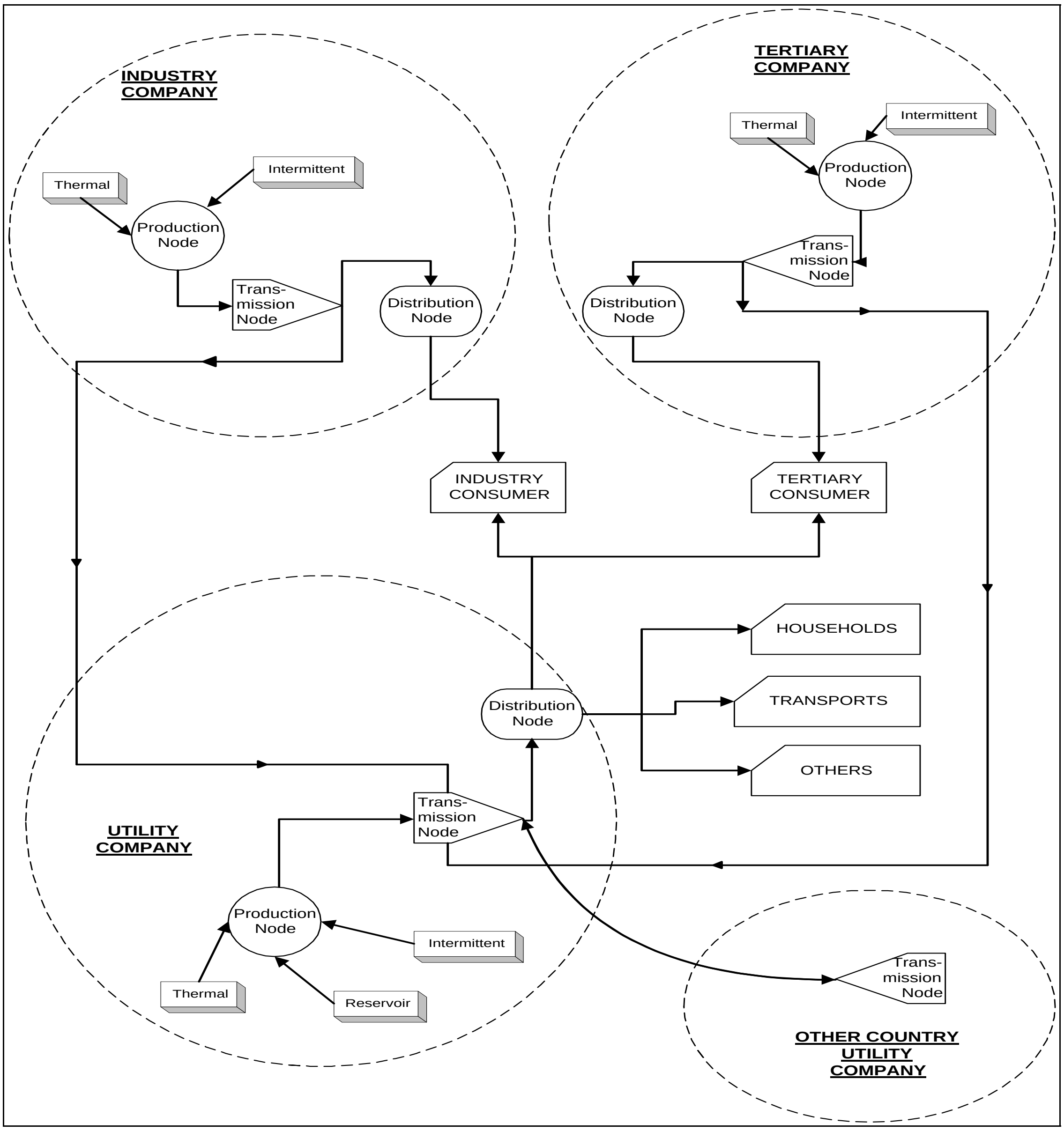
However, the model is not designed to represent adequately the development of multiple utilities in the same country or the case of independent producers, which transform from self-producers to small utilities. In compliance with the long-run orientation of the model, the design considers that these cases will be transitory, and that in the long term competition can be adequately approximated by means of the “representative firm” assumption. The different representative firms (producers) reflect then differences in purpose, in size or market opportunities.

Thus three types of companies are considered in PRIMES V.2:

- a utility aiming at producing electricity and/or steam, transmit and distribute electricity and transmit steam to other companies (not distribute steam); the utility can exchange electricity with other companies through links of the transmission nodes;
- an industrial company aiming at producing electricity and/or steam, mainly to supply his own demand (for several industrial sectors); it can supply the excess power to the utility company, but it cannot distribute or exchange steam for purposes other than supplying its own needs (this assumption is made to reflect the special quality of industrial steam); and
- a tertiary (small independent producer) company aiming at producing electricity and/or steam; regarding electricity, the aim is to act as independent generator and sell electricity through the utility’s grid or to directly supply tertiary electricity needs; for steam, the tertiary company acts as a utility for

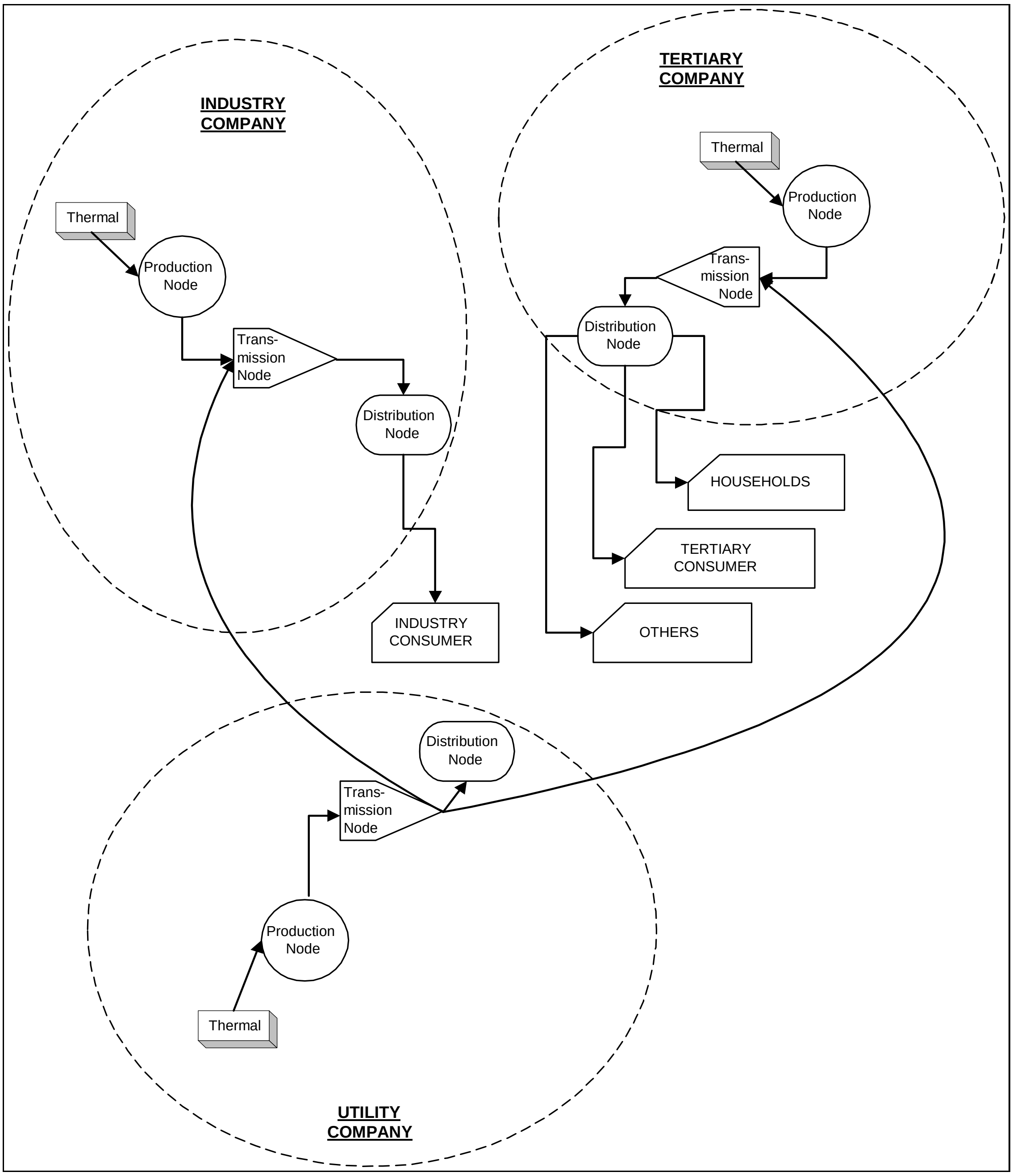
district heating, sometimes purchasing steam from the utility company and distributing district heating to the consumers (except industrial consumers); no steam connections among countries are represented.

Figure 4: The electricity network in PRIMES Version 2



All companies own production plants. It is not possible to share a plant among companies. There is no ownership of transmission and distribution grids represented in the model, but the receiving company pays transport services at variable costs, which are also paid implicitly through the marginal cost (dual variable) of the corresponding capacity constraint. In the model, there exists one company per type in each country. This assumption is equivalent to an assumption about the existence of a representative firm per company category. The consumers are not connected to utilities or other companies outside their country of origin. They can be indirectly supplied from other countries through the transmission nodes linking the countries, via the corresponding utilities.

Figure 5: The steam network in PRIMES Version 2



The companies can agree electricity or steam exchange contracts among each other and with the consumers. The contracts involve a quantity, a time pattern over typical days of a year, duration, a flexibility degree and a route (sequence of nodes) that is used to fulfil the contract along the topology of the network. Contracts can also exist as regards input fuels used by electricity and steam generation companies. Such contracts involve a quantity, degree of flexibility and a price. Time of use limits on fuels is generally represented through constraints that restrict the dispersion of fuel use over time segments. In general the model considers 13 fuels that can be purchased in the market. Fuels are characterised by their purchase prices, taxes and availability limits.

Furthermore the companies can be constrained by policy, through the following types of restrictions:

- upper emission limit;
- obligation to use a certain percentage of non fossil fuels, or renewable energy forms, in the company's energy balance;
- fuel obligations, expressed as lower bounds to fuel consumption per company;
- upper bounds on investment in new plants;
- capacity reserve margins.

The same constraints can apply at the country level, to reflect national policies.

Finally the model includes the possibility of having different discount rates per company and country.

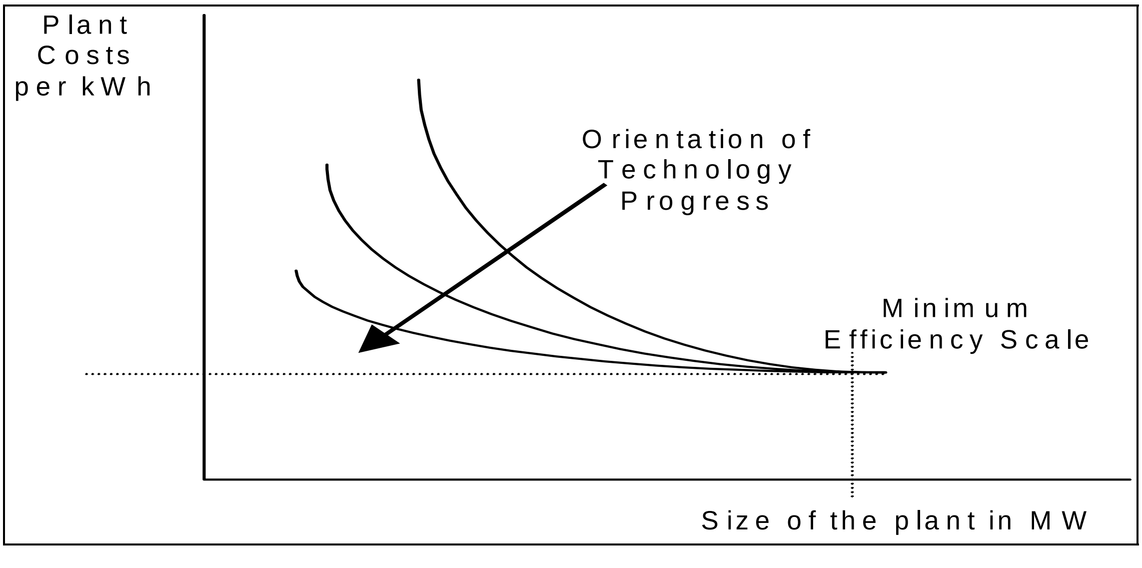
Technical-economic characterisation of plants

Power technologies are characterised by the type of fuel they can use, their efficiency in generating heat and/or power, their cogeneration technique (if applicable), their availability, their investment costs and their operating costs.

The model put emphasis on the representation of plant efficiency and performance as a function of plant size. It is assumed that utilities can invest in large size plants and benefit from economies of scale, while industrial power and steam producers can invest only in relatively small size plants. The relationship of plant performance as a function of plant size is considered as varying with the type of technology and time. Through this assumption, the model attempts to capture a technology progress that would bridge the gap between the plant sizes, in terms of performances and costs. Such an example has been recently observed with the developments in gas turbine technologies and the combined cycle plants.

The following scheme illustrates how a certain type of technology progress reduces differences of plant performance across plant sizes.

Figure 6: Relationship between pant performance and size



The model distinguishes the old plants existing in the base year and the potential plants, i.e., those that might be built through investment. No further investment in old plants is considered. However the model treats endogenously retrofitting options for these plants, as the extension of their lifetime may be judged as economical when existing plants reach the end of their lifetimes. Retrofitting involves capital costs and fixed costs that rapidly increase over time.

The technical-economic characteristics of the new power and steam plants are fixed over time. Once a new plant is built it remains as candidate for commitment in operation over its lifetime. New reservoir plants are not considered in the model, however all intermittent plants are fully endogenous. In any case, known power plant investments in the future can be introduced exogenously in the model.

More specifically the model considers the following plant categories:

- existing thermal plants of which the capacities are known in the base year;
- new thermal plants that are candidate for investment;
- existing hydroelectric reservoir plants of which the capacities are known in the base year;
- existing intermittent renewable energy plants of which the capacities are known in the base year;
- intermittent renewable energy plants that are candidate for investment.

The variety of different plant types is incrementally specified in the model, by combining the elements from the following sets: generic plant technology, type of fuel combustion including multiple fuel capability (if applicable), cogeneration technique (if applicable), company type and country. The technical-economic characteristics of the plants differ across the above items. Regarding new plants, technology progress is represented as technological generations that are considered as different plant types.

The model considers the following information to characterise a plant technology:

- capital cost (Euro’00/kW) and financial charges during construction;
- variable cost (per kWh produced) and annual fixed costs (per kW). The fixed costs increase over time, as the plant becomes older;
- thermal efficiency rate and multiple fuel capability, if applicable. Rate of electricity auto-consumption per plant;
- plant availability rate and rate of utilisation for intermittent plants.
- time-related characteristics of a plant, like technical lifetime and economic lifetime (used for capital amortisation);
- technical parameters for the feasible combinations of electricity and steam output, if applicable;
- an old plant (in the category of existing plants) can be retrofitted at the moment of decommissioning (which is exogenous). The retrofitting extends the lifetime of the plant and involves capital and fixed cost payments;
- intermittent plants are linked to renewable resources for which the time pattern of supply is given;

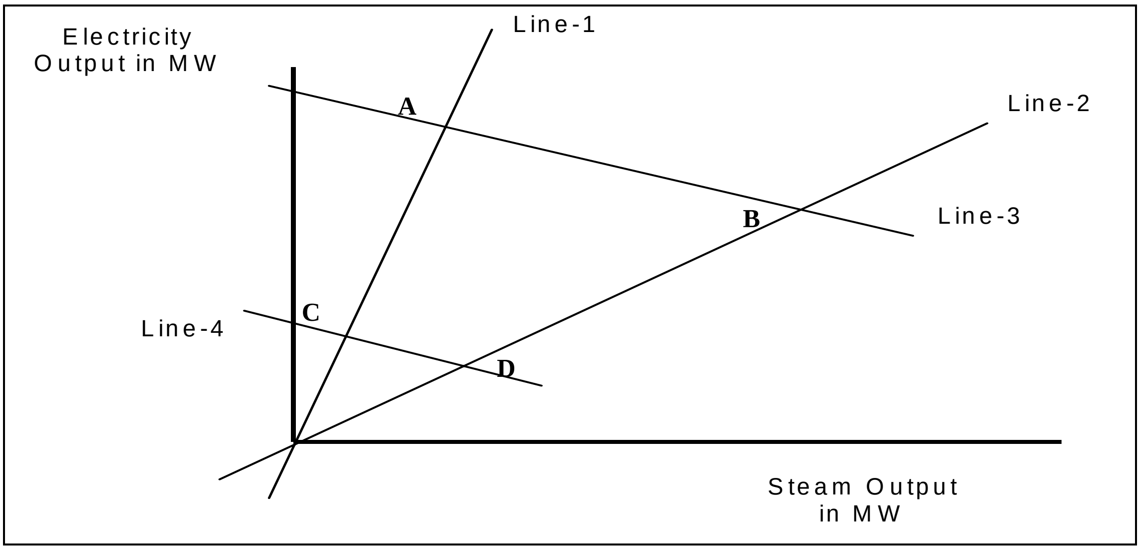
- reservoir plants can operate at the limits of energy available from inflow water (exogenous) in the lakes, during each year;
- to reflect future technologies, it is assumed that new plant technologies will become available at different points in time (exogenous parameter).

The cogeneration technologies constitute a valid substitute of the traditional heat producing technologies, as for example boilers. Their importance and their rapid emergence in the market justify their inclusion in the set of power technologies.

Cogeneration can be obtained through changes in the circuit of steam in thermal power plants. If it is intended to obtain big quantity of steam, then the change of the circuit is important, consisting in conducting steam to demand, instead of recycling through the cooling system of the plant. This kind of technology, usually termed "back pressure" technique, has significant negative implications for the electric efficiency rates of the plant and can achieve high steam to electricity ratios. If the quantity of steam, required to conduct to demand, is rather small, then steam can be just extracted at some point of the steam circuit. In this so-called "steam extraction" case, the steam to electricity ratio is small, but the implications on the electric efficiency ratios are also small.

All the above-mentioned techniques of cogeneration are represented in PRIMES. To unify and simplify the modelling of cogeneration, the model considers that the feasible combination of electricity and heat output from a thermal plant are constrained within a surface delimited by four lines, as in the following scheme.

Figure 5: Feasible domain of cogeneration per unit of nominal electric power



The feasible domain of cogeneration is the area ABCD. Line 1 denotes the maximum electric power and minimum steam combinations. Line 2 denotes the minimum electric power and maximum steam combinations. Line 3 is an iso-fuel line (equal electric efficiency of the plant), per unit of maximum use of nominal electric power. Finally, line 4 is also an iso-fuel line, defined for the minimum electric output necessary to obtain a steam output. Of course, depending on the cogeneration techniques, the slope and the exact position of these lines can change, but the basic shape of the feasible domain for electric and steam output combinations remain the same. The above lines are introduced in the model as linear constraints, specifically calibrated for each cogeneration technique and type of plant. Line 4 (the minimum power) is incompatible with the continuous character of the activity variables, as assumed in the model and therefore of no relevance within the modelling context.

The PRIMES Model Application

Model Nomenclature

Regions: 35 European countries

Fuel types: 26 energy forms in total; Coal, Lignite, Coke, Peat and Other solid fuels, Crude-oil, Residual Fuel Oil, Diesel Oil, Liquefied Petroleum Gas, Kerosene, Gasoline, Naphtha, Other oil products, Bio-fuels, Natural and derived gas, Thermal Solar (active), Geothermal low and high enthalpy, Steam (industrial and distributed heat), Electricity, Biomass and Waste, Hydrogen, Solar electricity, Wind, Hydro.

Demand Sectors:

Residential: The residential sector distinguishes five categories of dwelling. These are defined according to the main technology used for space heating. They may use secondary heating as well. At the level of the sub-sectors, the model structure defines the categories of dwellings, which are further subdivided in energy uses. The electric appliances for non-heating purposes are considered as a special sub-sector, which is independent of the type of dwelling. Four energy use types are defined per dwelling type.

Tertiary: *The commercial and agriculture sector distinguishes* 4 sub-sectors. At the level of the sub-sectors, the model defines energy services, which are further subdivided in energy uses defined according to the pattern of technology. In total more than 30 end-use technology types are defined.

Industry: *The industrial model formulates* 9 industrial sectors *separately*, namely iron and steel, non ferrous, chemicals, non-metallic minerals, paper and pulp, food drink tobacco, engineering, textiles, other industries. For each sector different sub-sectors are defined (in total about 30 sub-sectors, including recycling of materials). At the level of each sub-sector a number of different energy uses are represented (in total about 200 types of energy use technologies are defined).

Transports: The transport sector distinguishes passenger transport and goods transport as separate sectors. They are further subdivided in sub-sectors according to the transport mean (road, air, etc.). At the level of the sub-sectors, the model structure defines several technology types (car technology types, for example), which correspond to the level of energy use. Within modes like road transport there is therefore a further subdivision, i.e. the model distinguishes for road passenger transport between public road transport, motorcycles and private cars. The model considers 6 to 10 alternative technologies for transport means such as cars, busses, trucks; the number of alternatives is more limited for rail, air and navigation

Supply Sectors:

Electricity production: 148 different plant types per country for the existing thermal plant types; 678 different plant types per country for the new thermal plants; 3 different plant types per country for the existing reservoir plants; 30 different plant types per country for the existing intermittent plants. Chronological load curves, interconnections, network representation; three typical companies per country; Cogeneration of power and steam, district heating

Refineries: 4 refineries with typical refinery structure defined at the level of country regions; 6 typical refining units (cracking, reforming etc.) in each region

Natural gas: Regional supply detail (Europe, Russia, Middle Africa, North Sea etc.)

Time Horizon

PRIMES is a long-term model that is being set to consider the period 1990-2030, running by period of 5 years.

PRIMES output files include:

- Full detailed EUROSTAT Energy Balance sheets per country and per year
- Energy demand tables with the above mentioned classification
- Energy costs and prices
- Power generation park, load factors, investment and marginal costs (central systems, combined heat-power, exchanges).
- CO_2 emissions by sector and fuel as well as other energy related emissions; this allows for more in depth environmental studies depending on the degree of information incorporated on abatement technologies and policies.

Case Studies and Planning Applications

- Energy and environment technology assessment
- Energy system implications of policy instruments for the environment (taxation, abatement standards, pollution permits)
- All issues of energy policy, investment plans and energy pricing policy
- Energy system implications and forecasting for the penetration of new energy technologies in energy savings, energy demand, power generation etc.
- Energy supply to Europe: energy import dependency analysis.

Required Infrastructure

- Hardware: Workstation with Windows NT/XP
- Software: GAMS Ver. 2.25 with PATH solver, CONOPT3 and Cplex (or OSL), MS EXCEL ver. 7.0 or later

APPENDIX

Sample of PRIMES Data

Source: PRIMES NTUA

Macroeconomic indicators

	1990	1995	2000	2005	2010	2015	2020	2025	2030
Gross domestic product at market prices (000 MEuro'00)	199.8	216.2	248.3	276.3	308.1	337.7	367.4	398.7	432.1
Income - Private consumption (000 MEuro'00)	105.5	114.5	128.9	142.1	157.4	173.4	190.1	207.3	225.6
Value added (MEuro'00)									
	1990	1995	2000	2005	2010	2015	2020	2025	2030
Manufacturing									
- Energy Intensive Manufacturing	15428	16186	18830	21196	23972	26128	28100	30078	32053
- Metals	4985	3523	3624	3591	3620	3607	3561	3510	3457
- Chemicals	5139	7149	9171	11154	13308	14863	16303	17770	19306
- Paper	2942	3141	3444	3820	4177	4556	4948	5320	5640
- Building Materials	2362	2374	2592	2631	2867	3102	3288	3479	3652
- Non Energy Intensive Manuf.	37198	34917	39990	44120	48978	53939	58568	63416	68298
- Food	3447	5536	6155	6764	7512	8200	8757	9314	9689
- Textiles	3285	2533	2843	2927	3003	3046	3061	3070	3073
- Engineering	13951	12722	15148	16999	19250	21633	23878	26283	28879
- Others	6445	3720	4339	4834	5435	6035	6638	7281	7946
- Construction	10070	10405	11505	12596	13778	15025	16234	17467	18711
Services									
- market services	43795	52489	63544	76054	89979	102021	115471	130259	146774
- non market	45054	48631	52235	55208	58860	62422	65634	68391	71144
- trade and transports	39971	41799	43864	47776	52079	57277	62140	67287	72462
Agriculture	2561	3254	3573	3615	3752	3830	3896	3953	4004
Energy Sector	3666	6082	7949	9397	10706	11745	12696	13696	14703
TOTAL	187672	203358	229985	257366	288326	317362	346505	377079	409439
Demographic and Climatic assumptions									
	1990	1995	2000	2005	2010	2015	2020	2025	2030
Population (000)									
Degree days	2277	2460	2254	2254	2254	2254	2254	2254	2254
Historical average	2634	2634	2634	2634	2634	2634	2634	2634	2634

Source: PRIMES NTUA

Industrial sectors indicators and structural data

DISCOUNT RATE (%)									
	1990	1995	2000	2005	2010	2015	2020	2025	2030
All industrial sectors	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0
IRON AND STEEL INDICATORS									
	1990	1995	2000	2005	2010	2015	2020	2025	2030
SECTORAL PRODUCTION (in ktn)		11558	11600	11108	10640	10117	9587	9008	8425
integrated steelworks		9860	8886						
electric prossesing		1698	2714			**MODEL RESULTS**			
ENERGY INTENSITY by process (toe/unit of production)	1990	1995	2000	2005	2010	2015	2020	2025	2030
integrated steelworks		0.395	0.497						
electric prossesing		0.156	0.176			MODEL RESULTS			
NON FERROUS METALS INDICATORS									
	1990	1995	2000	2005	2010	2015	2020	2025	2030
SECTORAL PRODUCTION (in ktn)		965	1113	1226	1430	1580	1701	1815	1927
primary aluminium		0	0						
secondary aluminium		0	0						
copper		376	424						
zinc		211	264						
lead		122	119						
other non ferrous products (indicator)		256	306			MODEL RESULTS			
ENERGY INTENSITY by process (toe/unit of production)	1990	1995	2000	2005	2010	2015	2020	2025	2030
primary aluminium		-	-						
secondary aluminium		-	-						
copper		0.415	0.462						
zinc		0.299	0.298						
lead		0.121	0.129						
other non ferrous products		0.510	0.566			MODEL RESULTS			
CHEMICALS INDICATORS									
	1990	1995	2000	2005	2010	2015	2020	2025	2030
SECTORAL PRODUCTION (Indicator)		7149	9171	11144	13301	14847	16285	17735	19241
fertilisers/inorganic chemicals		702	1013						
petrochemicals		2495	2957						
other chemical products		1784	2219						
pharmaceuticals/cosmetics		2168	2982			MODEL RESULTS			
ENERGY INTENSITY by process (toe/unit of production)	1990	1995	2000	2005	2010	2015	2020	2025	2030
fertilisers/inorganic chemicals		0.889	1.064						
petrochemicals		0.711	0.483						
other chemical products		0.182	0.217						
pharmaceuticals/cosmetics		0.045	0.050			MODEL RESULTS			
BUILDING MATERIALS INDICATORS									
	1990	1995	2000	2005	2010	2015	2020	2025	2030
SECTORAL PRODUCTION (Indicator)		10320	10252	9684	9806	9836	9691	9533	9320
cement in ktn		8223	8175						
ceramics		117	146						
glass basic in ktn		1213	1116						
glass recycled in ktn		303	372						
other non-metallic minerals		463	443			MODEL RESULTS			
ENERGY INTENSITY by process (toe/unit of production)	1990	1995	2000	2005	2010	2015	2020	2025	2030
cement in ktn		0.086	0.075						
ceramics		0.398	0.368						
glass basic in ktn		0.292	0.274						
glass recycled in ktn		0.189	0.181						
other non-metallic minerals		0.272	0.215			MODEL RESULTS			
PAPER AND PULP INDICATORS									
	1990	1995	2000	2005	2010	2015	2020	2025	2030
SECTORAL PRODUCTION (Indicator)		3141	3444	3820	4177	4556	4948	5320	5640
pulp		362	448						
paper		1397	1749			MODEL RESULTS			
ENERGY INTENSITY by process (toe/unit of production)	1990	1995	2000	2005	2010	2015	2020	2025	2030
pulp		0.388	0.324						
paper		0.150	0.133			MODEL RESULTS			
OTHER INDUSTRIAL SECTORS INDICATORS									
	1990	1995	2000	2005	2010	2015	2020	2025	2030
SECTORAL PRODUCTION (Indicator)		24511.49	28484.77	31451.54	35155.11	38842.45	42280.79	45855.84	49433.31
Food, Drink and Tobacco		5536	6155						
Engineering		12722	15148						
Textiles		2533	2843						
Other Industries		3720	4339			MODEL RESULTS			
ENERGY INTENSITY by process (toe/unit of production)	1990	1995	2000	2005	2010	2015	2020	2025	2030
Food, Drink and Tobacco		0.110	0.112						
Engineering		0.039	0.031						
Textiles		0.091	0.086						
Other Industries		0.411	0.484			MODEL RESULTS			

Source: PRIMES NTUA

Tertiary sector indicators and structural data

TOTAL TERTIARY

INDICATORS	1990	1995	2000	2005	2010	2015	2020	2025	2030
Value added (000MEuro'00)	131.38	146.17	163.22	182.65	204.67	225.55	247.14	269.89	294.38
Energy intensity (toe/000MEuro'00)	0.026	0.031	0.025			MODEL RESULTS			

DISCOUNT RATES (%)	1990	1995	2000	2005	2010	2015	2020	2025	2030
market services	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0
non market services	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0
trade	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0
agriculture	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0

STRUCTURE OF FINAL ENERGY DEMAND (%)	1990	1995	2000	2005	2010	2015	2020	2025	2030
by sector									
market services	47.4	42.0	45.9						
non market services	23.2	20.0	21.9						
trade	14.9	14.2	16.5						
agriculture	14.4	23.8	15.8			MODEL RESULTS			
by energy use	1990	1995	2000	2005	2010	2015	2020	2025	2030
heating and cooling	75.5	67.2	74.2						
electric appliances	10.0	9.0	10.6						
Agriculture specific uses	14.4	23.8	15.2			MODEL RESULTS			

MARKET SERVICES

INDICATORS	1990	1995	2000	2005	2010	2015	2020	2025	2030
Value added (000MEuro'00)	43.79	52.49	63.54	76.05	89.98	102.02	115.47	130.26	146.77
Floor space per capita (sqm/capita)	7.9	8.2	8.4	9.0	9.7	10.3	11.0	11.7	12.6
Energy intensity (toe/000 Euro'00)	0.036	0.037	0.030			MODEL RESULTS			

STRUCTURE OF FINAL ENERGY DEMAND (%)	1990	1995	2000	2005	2010	2015	2020	2025	2030
space heating	73.0	72.0	70.0						
air cooling	0.3	0.5	1.3						
other heating uses	16.2	17.1	17.5						
electrical uses	6.5	7.0	8.0						
lighting	4.1	3.4	3.2			MODEL RESULTS			

SPECIFIC ENERGY CONSUMPTION (USEFUL ENERGY / FINAL ENERGY)	1990	1995	2000	2005	2010	2015	2020	2025	2030
space heating	0.71	0.71	0.71						
air cooling	2.50	2.50	2.50						
other heating uses	0.68	0.68	0.71						
electrical uses	0.30	0.30	0.30						
lighting	0.10	0.10	0.10			MODEL RESULTS			

NON MARKET SERVICES

INDICATORS	1990	1995	2000	2005	2010	2015	2020	2025	2030
Value added (000MEuro'00)	45.05	48.63	52.23	55.21	58.86	62.42	65.63	68.39	71.14
Floor space per capita (sqm/capita)	3.0	3.0	3.1	2.9	2.8	2.8	2.8	2.7	2.7
Energy intensity (toe/sqm)	0.017	0.019	0.017			MODEL RESULTS			

STRUCTURE OF FINAL ENERGY DEMAND (%)	1990	1995	2000	2005	2010	2015	2020	2025	2030
space heating	77.0	75.0	73.0						
air cooling	0.2	0.2	0.2						
other heating uses	11.8	12.5	10.5						
electrical uses	6.0	6.5	7.0						
steam uses	0.0	1.5	5.3						
lighting	5.0	4.3	4.1			MODEL RESULTS			

SPECIFIC ENERGY CONSUMPTION (USEFUL ENERGY / FINAL ENERGY)	1990	1995	2000	2005	2010	2015	2020	2025	2030
space heating	0.71	0.71	0.71						
air cooling	2.50	2.50	2.50						
other heating uses	0.68	0.68	0.71						
electrical uses	0.30	0.30	0.30						
steam uses	0.00	1.00	1.00						
lighting	0.10	0.10	0.10			MODEL RESULTS			

TRADE

INDICATORS	1990	1995	2000	2005	2010	2015	2020	2025	2030
Value added (000MEuro'00)	39.97	41.80	43.86	47.78	52.08	57.28	62.14	67.29	72.46
Floor space per capita (sqm/capita)	2.1	2.3	2.5	2.5	2.4	2.5	2.6	2.6	2.7
Energy intensity (toe/sqm)	0.013	0.016	0.016			MODEL RESULTS			

STRUCTURE OF FINAL ENERGY DEMAND (%)	1990	1995	2000	2005	2010	2015	2020	2025	2030
space heating	57.5	56.0	55.0						
air cooling	7.0	9.0	10.3						
other heating uses	19.0	17.6	16.4						
electrical uses	9.0	11.0	12.5						
steam uses	0.0	0.0	0.0						
lighting	7.5	6.4	5.8			MODEL RESULTS			

SPECIFIC ENERGY CONSUMPTION (USEFUL ENERGY / FINAL ENERGY)	1990	1995	2000	2005	2010	2015	2020	2025	2030
space heating	0.71	0.71	0.71						

Source: PRIMES NTUA

Residential sector indicators and structural data

INDICATORS									
	1990	1995	2000	2005	2010	2015	2020	2025	2030
Household Income (Euro'00/household)	27090	28130	30456	32224	34374	36626	38837	41386	44179
Household size (persons/household)	2.56	2.49	2.42	2.35	2.28	2.22	2.16	2.12	2.08
Population (000 persons)	9968	10137	10246	10366	10440	10507	10572	10619	10628
Number of households (000)	3894	4071	4234	4411	4579	4733	4894	5009	5108
Discount rate (%)	17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5
DECOMPOSITION OF NUMBER OF HOUSEHOLDS BY HOUSEHOLD TYPE (%)									
	1990	1995	2000	2005	2010	2015	2020	2025	2030
Central Boiler Houses	55.8	56.4	55.5						
Electric Heating Houses	9.5	10.4	11.0						
Individual Gas Heating Houses	13.9	16.4	18.5						
District Heating Houses	0.4	0.2	0.2						
Non-full Heating Houses	20.4	16.6	14.8				MODEL RESULTS		
NUMBER OF APPLIANCES (millions)									
	1990	1995	2000	2005	2010	2015	2020	2025	2030
washing machines	3.20	3.62	4.04						
dish washers	1.14	1.40	1.81						
dryers	1.87	2.15	2.43						
refrigerators	5.96	6.82	7.52						
television sets	4.22	4.94	6.01				MODEL RESULTS		
STRUCTURE OF FINAL ENERGY DEMAND IN HOUSEHOLDS (%)									
	1990	1995	2000	2005	2010	2015	2020	2025	2030
for heating/cooling purposes	94.7	94.7	94.7						
electric appliances	5.3	5.3	5.3				MODEL RESULTS		
STRUCTURE OF FINAL ENERGY DEMAND FOR HEATING/COOLING (%)									
	1990	1995	2000	2005	2010	2015	2020	2025	2030
by household type									
central heating	55.7	56.4	55.3						
with electric heating equip.	8.9	9.8	10.4						
gas connected heating equip.	14.5	17.3	19.6						
connected to district heating	0.4	0.2	0.2						
non-full heating	20.5	16.4	14.4				MODEL RESULTS		
by energy use									
space heating	82.1	80.6	79.7						
cooking	12.6	13.3	13.7						
water heating	5.2	5.8	6.1						
air conditioning	0.1	0.3	0.5				MODEL RESULTS		
SPECIFIC ENERGY CONSUMPTION FOR HEATING/COOLING (USEFUL ENERGY / FINAL ENERGY)									
	1990	1995	2000	2005	2010	2015	2020	2025	2030
Central Boiler Houses	0.72	0.72	0.73						
Electric Heating Houses	0.90	0.90	0.91						
Individual Gas Heating Houses	0.72	0.72	0.72						
District Heating Houses	0.66	0.66	0.66						
Non-full Heating Houses	0.66	0.67	0.69				MODEL RESULTS		
SPECIFIC ENERGY CONSUMPTION OF ELECTRIC APPLIANCES (kWh per aplliance)									
	1990	1995	2000	2005	2010	2015	2020	2025	2030
washing machines	262	266	246						
dish washers	131	133	123						
dryers	156	158	146						
refrigerators	172	175	161						
television sets	89	91	84						
Lighting (kwh/household/year)	635	673	658				MODEL RESULTS		

Source: PRIMES NTUA

Transports sector indicators and structural data

INDICATORS	1990	1995	2000	2005	2010	2015	2020	2025	2030
Household Income (Euro'00/capita)	10582	11297	12585	13712	15076	16498	17980	19522	21232
Gross Domestic Product (000MEuro'00)	199.8	216.2	248.3	276.3	308.1	337.7	367.4	398.7	432.1
Population (000 persons)	9968	10137	10246	10366	10440	10507	10572	10619	10628
Passenger transports									
Travel per person (km/capita)	11232	12147	13190	13479	13979	15070	16432	17826	19372
Passenger-km per car	23092	22811	22646	22646	22646	22646	22646	22646	22646
Number of Cars ('000)	3864.2	4273.0	4678.0						
Cars per 100 households	99.2	105.0	110.5						
Energy intensity (toe/MEURO'00)	48.8	48.6	46.7						
Vehicles efficiency indicator (toe/Mpkm)	45.9	45.2	44.5						
Freight transports									
Activity per unit of GDP (tkm/000 Euro'00)	195.3	221	187						
Energy intensity (toe/MEURO90)	12.8	13.5	14.7						
Vehicles efficiency indicator (toe/Mpkm)	65.6	61.1	78.3				MODEL RESULTS		

DECOMPOSITION OF ACTIVITY IN PASSENGER TRANSPORTS BY TRANSPORT MODE (%)	1990	1995	2000	2005	2010	2015	2020	2025	2030
road transport	90.5	90.4	88.6						
- buses	9.7	10.2	9.2						
- motorcycles	1.1	1.1	1.1						
- private cars	79.7	79.2	78.4						
train transport	6.5	6.1	6.4						
aviation	2.6	3.1	4.8						
navigation	0.4	0.3	0.2				MODEL RESULTS		

VEHICLES EFFICIENCY INDICATOR BY MODE IN PASSENGER TRANSPORTS (toe/Mpkm)	1990	1995	2000	2005	2010	2015	2020	2025	2030
road transport	40.1	40.1	36.3						
- buses	7.1	5.1	5.0						
- motorcycles	12.9	13.5	12.4						
- private cars	44.5	44.9	40.3						
train transport	17.4	20.2	16.2						
aviation	322.2	245.2	235.2						
navigation	0.2	0.3	0.2				MODEL RESULTS		

DISCOUNT RATE BY MODE IN PASSENGER TRANSPORTS (%)	1990	1995	2000	2005	2010	2015	2020	2025	2030
road transport									
- buses	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
- motorcycles	17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5
- private cars	17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5
train transport	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
aviation	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0
navigation	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0

DECOMPOSITION OF ACTIVITY IN FREIGHT TRANSPORTS BY TRANSPORT MODE (%)	1990	1995	2000	2005	2010	2015	2020	2025	2030
road transport (trucks)	64.1	72.3	69.8						
train transport	21.5	15.3	16.5						
navigation	14.5	12.4	13.7				MODEL RESULTS		

VEHICLES EFFICIENCY INDICATOR BY MODE IN FREIGHT TRANSPORTS (toe/Mtkm)	1990	1995	2000	2005	2010	2015	2020	2025	2030
road transport (trucks)	95.2	75.9	106.8						
train transport	6.1	6.8	5.6						
navigation	22.9	41.6	21.2				MODEL RESULTS		

DISCOUNT RATE BY MODE IN FREIGHT TRANSPORTS (%)	1990	1995	2000	2005	2010	2015	2020	2025	2030
road transport (trucks)	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0
train transport	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
navigation	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0

Source: PRIMES NTUA Capacity Data for Existing in 1995 Thermal plants		Nominal installed capacity	Decommissioning Schedule[1]							
PLANT SIZE	TYPE	MW	MW decomissioned in year							
		1990	1995	2000	2005	2010	2015	2020	2025	2030
Conventional Thermal -Monovalent or Polyvalent with Coal										
Small	with CHP	253	3	26	50	85	4	27	59	0
Medium	with CHP	0	0	0	0	0	0	0	0	0
Big	with CHP	1494	0	443	714	47	290	0	0	0
Small	Only electricity	557	252	113	64	36	28	32	4	28
Medium	Only electricity	0	0	0	0	0	0	0	0	0
Big	Only electricity	4248	314	1024	697	1486	728	0	0	0
Conventional Thermal - Open Cycle Monovalent Coal										
Big	with CHP	0	0	0	0	0	0	0	0	0
Big	Only electricity	0	0	0	0	0	0	0	0	0
Conventional Thermal - Open Cycle Monovalent L		0								
Big	with CHP	0	0	0	0	0	0	0	0	0
Big	Only electricity	0	0	0	0	0	0	0	0	0
Conventional Thermal - Open Cycle Monovalent F		0								
Big	with CHP	0	0	0	0	0	0	0	0	0
Big	Only electricity	0	0	0	0	0	0	0	0	0
Conventional Thermal - Open Cycle Monovalent G		0								
Big	with CHP	0	0	0	0	0	0	0	0	0
Big	Only electricity	0	0	0	0	0	0	0	0	0
Conventional Thermal - Open Cycle Monovalent B		0								
Big	with CHP	0	0	0	0	0	0	0	0	0
Big	Only electricity	78	0	0	0	10	0	0	68	0
Combined Cycle Gas Turbine - Current generation										
Small	with CHP	0	0	0	0	0	0	0	0	0
Medium	with CHP	0	0	0	0	0	0	0	0	0
Big	with CHP	0	0	0	0	0	0	0	0	0
Small	Only electricity	7	0	0	0	0	0	0	7	0
Medium	Only electricity	0	0	0	0	0	0	0	0	0
Big	Only electricity	300	0	40	54	0	206	0	0	0
Turbine Plants with Gas/Diesel Machines										
	Diesel	0								
Small	with CHP	33	0	0	11	4	3	2	8	5
Small	Only electricity	3	0	0	0	0	0	0	0	3
Medium	Only electricity	0	0	0	0	0	0	0	0	0
Big	Only electricity	593	29	0	162	278	96	28	0	0
	Natural Gas	0								
Small	with CHP	0	0	0	0	0	0	0	0	0
Small	Only electricity	0	0	0	0	0	0	0	0	0
Medium	Only electricity	0	0	0	0	0	0	0	0	0
Big	Only electricity	0	0	0	0	0	0	0	0	0
Boilers for Steam		0								
Small		0	0	0	0	0	0	0	0	0
Big		0	0	0	0	0	0	0	0	0
Conventional Nuclear										
Small number of Units		5794	0	0	0	0	0	1764	1900	2130
Massive Investment		0	0	0	0	0	0	0	0	0
New Nuclear Technologies (New Design revolutio		0								
Small number of Units		0	0	0	0	0	0	0	0	0
Massive Investment		0	0	0	0	0	0	0	0	0

[1] Decommissioning schedule is taken from EURPROG'98 report of UNIPEDE until 2010, based on technical lifetime of plants beyond

Source: PRIMES NTUA Capacity Data for New Thermal plants		Decided Investment[1]				Potential investment beyond 2005
PLANT SIZE	TYPE	MW available for operation in year				MW
		1995	2000	2010	2030	2005 and beyond
Advanced Thermal - Polyvalent with Coal						
Small		0	0	0	0	uncostrained
Medium	with CHP	0	0	0	0	uncostrained
Big	with CHP	0	0	0	0	uncostrained
Small	Only electricity	3	0	0	0	uncostrained
Medium	Only electricity	0	0	0	0	uncostrained
Big	Only electricity	0	0	0	0	uncostrained
Advanced Thermal - Polyvalent without Coal						
Small	with CHP	95	552	0	0	uncostrained
Medium	with CHP	0	0	0	0	uncostrained
Big	with CHP	4	0	0	0	uncostrained
Small	Only electricity	0	1	0	0	uncostrained
Medium	Only electricity	0	0	0	0	uncostrained
Big	Only electricity	0	0	0	0	uncostrained
Advanced Thermal - Open Cycle Monovalent Coal						
Big	with CHP	0	0	0	0	uncostrained
Big	Only electricity	24	0	0	0	uncostrained
Advanced Thermal - Open Cycle Monovalent Lignite						
Big	with CHP	0	0	0	0	uncostrained
Big	Only electricity	0	0	0	0	uncostrained
Advanced Thermal - Open Cycle Monovalent Lignite						
Big	with CHP	0	0	0	0	uncostrained
Big	Only electricity	3	0	0	0	uncostrained
Advanced Thermal - Open Cycle Monovalent Gas						
Big	with CHP	38	0	0	0	uncostrained
Big	Only electricity	0	6	0	0	uncostrained
Advanced Thermal - Open Cycle Monovalent Biomass and Waste						
Big	with CHP	0	0	0	0	uncostrained
Big	Only electricity	1	0	0	0	uncostrained
Advanced Thermal - Open Cycle Supercritical and Ultra-supercritical Coal						
Big	with CHP	0	0	0	0	uncostrained
Big	Only electricity	0	0	0	0	uncostrained
Fluidized Bed Combustion - Coal and Lignite						
Small	with CHP	0	0	0	0	uncostrained
Medium	with CHP	0	0	0	0	uncostrained
Big	with CHP	0	0	0	0	uncostrained
Small	Only electricity	0	0	0	0	uncostrained
Medium	Only electricity	0	0	0	0	uncostrained
Big	Only electricity	0	0	0	0	uncostrained
Integrated Gasification Combined Cycle - Coal, Lignite, biomass						
Big	with CHP	0	0	0	0	uncostrained beyond 2010
Big	Only electricity	0	0	0	0	uncostrained beyond 2010
Combined Cycle Gas Turbine - Current generation						
Small	with CHP	0	90	0	0	uncostrained
Medium	with CHP	0	0	0	0	uncostrained
Big	with CHP	0	0	0	0	uncostrained
Small	Only electricity	0	0	0	0	uncostrained
Medium	Only electricity	0	0	0	0	uncostrained
Big	Only electricity	987	1185	0	0	uncostrained
Combined Cycle Gas Turbine - New generation						
Small	with CHP	0	0	0	0	uncostrained beyond 2010
Medium	with CHP	0	0	0	0	uncostrained beyond 2010
Big	with CHP	0	0	0	0	uncostrained beyond 2010
Small	Only electricity	0	0	0	0	uncostrained beyond 2010
Medium	Only electricity	0	0	0	0	uncostrained beyond 2010
Big	Only electricity	0	0	0	0	uncostrained beyond 2010
Turbine Plants possible with Steam Injection Facilities or Advanced Gas/Diesel Machines						
	Diesel					
Small	with CHP	33	127	0	0	uncostrained
Medium	with CHP	0	0	0	0	uncostrained
Big	with CHP	5	1	0	0	uncostrained
Small	Only electricity	7	4	0	0	uncostrained
Medium	Only electricity	0	0	0	0	uncostrained
Big	Only electricity	0	0	0	0	uncostrained
	Natural Gas					
Small	with CHP	0	0	0	0	uncostrained
Small	Only electricity	0	0	0	0	uncostrained
Medium	Only electricity	0	0	0	0	uncostrained
Big	Only electricity	0	0	0	0	uncostrained
Fuel Cells of 1st Generation for Power generation (high temperature)						
Small	with CHP	0	0	0	0	uncostrained beyond 2010
Medium	with CHP	0	0	0	0	uncostrained beyond 2010
Big	with CHP	0	0	0	0	uncostrained beyond 2010
Small	Only electricity	0	0	0	0	uncostrained beyond 2010
Medium	Only electricity	0	0	0	0	uncostrained beyond 2010
Big	Only electricity	0	0	0	0	uncostrained beyond 2010
Fuel Cells of 2d Generation for Power generation (high temperature)						

Source: PRIMES NTUA

Capacity Data for Existing in 1995 Renewables plants

PLANT SIZE	TYPE	Nominal installed capacity	Decommissioning Schedule[1]							
		MW	MW decomissioned in year							
		1990	1995	2000	2005	2010	2015	2020	2025	2030
Reservoir plants										
Big	Lakes	25.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Big	Pumping	1306.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Run of river plants										
Small		2.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Medium		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Big		78.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Geothermal plants										
Big		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wind Power Onshore - Current generation										
Small		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Medium		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Big		4.5	0.0	0.0	0.0	0.0	4.5	0.0	0.0	0.0
Photovoltaic - Current generation										
Small		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Medium		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Big		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[1] Decommissioning schedule is taken from EURPROG'98 report of UNIPEDE until 2010, based on technical lifetime of plants beyond

Source: PRIMES NTUA

Capacity Data for New Renewables plants

PLANT SIZE	TYPE	Decided Investment			Potential investment beyond 2000[2]						
					MW						
		2000	2005	2010	2000	2005	2010	2015	2020	2025	2030
Reservoir plants											
Big	Lakes	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Big	Pumping	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Run of river plants											
Small		0.0	0.0	0.0	0.6	2.4	4.8	7.6	9.9	10.9	11.9
Medium		0.0	0.0	0.0	4.4	15.0	25.0	34.6	39.8	39.8	39.8
Big		0.0	0.0	0.0	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Geothermal plants											
Big		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wind Power Onshore - Current generation											
Small		0.0	0.0	0.0	0.0	23.8	38.4	53.8	62.4	68.8	72.4
Medium		0.0	0.0	0.0	0.0	35.7	57.5	80.7	93.5	103.3	108.5
Big		6.2	12.4	14.0	6.2	184.2	307.2	438.7	520.6	589.1	637.8
Advanced Wind Power Onshore - New generation											
Small		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Medium		0.0	0.0	0.0	9.0	11.8	52.8	106.2	171.0	218.2	0.0
Big		0.0	115.0	0.0	206.0	234.0	648.7	1188.5	1843.9	2321.5	0.0
Photovoltaic - Current generation											
Small		0.0	0.0	0.0	7.2	162.2	206.1	209.1	210.4	209.9	0.0
Medium		0.0	0.0	0.0	10.3	231.7	294.4	298.7	300.6	299.9	0.0
Big		2.0	2.1	2.2	10.4	189.6	242.1	248.0	252.1	254.2	0.0
Photovoltaic - New generation											
Small		0.0	0.0	0.0	0.0	3.3	22.9	107.7	228.0	396.8	0.0
Medium		0.0	0.0	0.0	0.1	4.7	32.7	153.9	325.7	566.8	0.0
Big		0.0	0.0	0.0	0.0	3.8	26.2	123.1	260.5	453.4	0.0
New Solar Thermal											
Big		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
New Tidal, Ocean etc.											
Big		0.0	0.0	0.0	0.0	0.0	2.5	5.0	7.5	10.0	0.0

[1] Decided investment are taken from EURPROG'98 report of UNIPEDE

[2] ECN

Source: PRIMES NTUA Additional data for Renewables energy forms	%			Winter (Nov -Apr)					Summer (May - Oct)				
PLANT SIZE TYPE	Load Factor	Utilisation rate		Supply load pattern[1]					Supply load pattern[1]				
	Yearly	Winter	Summer	21:00-08:00	08:00-11:30	11:30-13:00	13:00-18:30	18:30-21:00	21:00-08:00	08:00-11:30	11:30-13:00	13:00-18:30	18:30-21:00
Reservoir plants													
Lakes		1.00	0.73	0.00	0.50	1.00	0.75	1.00	0.00	0.50	1.00	0.75	1.00
Pumping		1.00	1.00	0.00	0.00	0.90	0.10	0.00	0.00	0.00	0.80	0.10	0.00
Run of river plants	0.56	0.65	0.52	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Geothermal plants	0.72	0.80	0.80	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Wind Power Onshore	0.27	0.40	0.35	1.00	0.55	0.40	0.55	1.00	1.00	0.55	0.40	0.55	1.00
Photovoltaic	0.09	0.30	0.70	0.00	0.35	1.00	0.35	0.00	0.00	0.35	1.00	0.35	0.00
New Solar Thermal	0.09	0.30	0.70	0.00	0.35	1.00	0.35	0.00	0.00	0.35	1.00	0.35	0.00
New Tidal, Ocean etc.	0.36	0.45	0.35	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

[1] Compares the supply load in a specified time segment (daytime hours during a season) with the peak load observed during the same season.

Load factor is computed by the following formula:

LF=SUM(SE, U(SE)*D(SE)*SUM(TS, SLP(TS)*H(TS)))/8760

where:

SE: season
TS: time segment
U(SE): utilisation rate of capacity
D(SE): days in season (182 for winter, 183 for summer)
SLP(TS): load pattern at each daytime segment
H(TS): hours in each time segment (on a daily basis)

TS: Daytime segments	from... to...	**H(TS)**
1st	21:00-08:00	11 hours
2nd	08:00-11:30	3.5 hours
3rd	11:30-13:00	1.5 hours
4th	13:00-18:30	5.5 hours
5th	18:30-21:00	2.5 hours

SE: Seasons	from... to...	**D(SE)**
Winter	Nov -Apr	182 days
Summer	May - Oct	183 days

Source: PRIMES NTUA Demand load patterns[1]	%			Winter (Nov -Apr)					Summer (May - Oct)				
Electricity demand	Load Factor	Peak ratio		Demand load pattern					Demand load pattern				
	Yearly	Winter	Summer	21:00-08:00	08:00-11:30	11:30-13:00	13:00-18:30	18:30-21:00	21:00-08:00	08:00-11:30	11:30-13:00	13:00-18:30	18:30-21:00
Industry	0.76	1.00	0.98	0.73	0.83	1.00	0.83	0.74	0.70	0.80	1.00	0.80	0.71
Households	0.53	1.00	0.84	0.40	0.65	0.76	0.42	1.00	0.46	0.58	0.80	0.79	1.00
Tertiary	0.54	1.00	0.78	0.52	0.63	1.00	0.47	0.58	0.72	0.77	1.00	0.44	0.49
Transports	0.63	1.00	0.71	0.69	0.80	1.00	0.79	0.70	0.55	0.78	0.84	1.00	0.78
Other	0.99	1.00	1.00	0.99	0.99	1.00	0.99	1.00	0.99	0.99	1.00	0.99	1.00
TOTAL	0.69	13.00	11.77	8.08	10.36	13.00	8.73	11.40	7.85	9.11	11.77	9.36	9.79
Demand Load in GW (1995)	*peak*	***11.80***	***10.32***	*7.12*	*9.26*	*11.80*	*7.75*	*10.31*	*6.79*	*7.96*	*10.32*	*8.26*	*8.72*
Electricity imports/exports	Load Factor	Peak ratio		Imports-Exports load pattern					Imports-Exports load pattern				
	Yearly	Winter	Summer	21:00-08:00	08:00-11:30	11:30-13:00	13:00-18:30	18:30-21:00	21:00-08:00	08:00-11:30	11:30-13:00	13:00-18:30	18:30-21:00
Imports	0.57	1.00	0.70	1.00	1.00	0.10	1.00	1.00	1.00	1.00	0.30	1.00	1.00
Exports	0.81	1.00	0.85	0.70	0.60	1.00	0.60	0.60	0.70	0.40	0.60	0.40	0.40
Imports Load in GW (1995)	*peak*	1.00	0.70	1.00	1.00	0.10	1.00	1.00	1.00	1.00	0.30	1.00	1.00
Exports Load in GW (1995)	*peak*	1.00	0.85	0.70	0.60	1.00	0.60	0.60	0.70	0.40	0.60	0.40	0.40
Steam demand	Load Factor	Peak ratio		Demand load pattern					Demand load pattern				
	Yearly	Winter	Summer	21:00-08:00	08:00-11:30	11:30-13:00	13:00-18:30	18:30-21:00	21:00-08:00	08:00-11:30	11:30-13:00	13:00-18:30	18:30-21:00
Industry	0.88	1.00	0.95	0.90	0.95	1.00	0.93	0.90	0.85	0.95	1.00	0.90	0.85
Households	0.62	1.00	0.70	0.50	0.85	0.70	0.90	1.00	0.70	0.80	0.60	0.85	1.00
Tertiary	0.57	1.00	0.70	0.55	0.95	1.00	0.80	0.55	0.50	0.95	1.00	0.70	0.50
Other	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL	0.87	2.53	2.37	2.24	2.41	2.53	2.34	2.25	1.99	2.26	2.37	2.13	2.00
Demand Load in GW (1995)	*peak*	***2.48***	***2.34***	*2.21*	*2.36*	*2.48*	*2.30*	*2.23*	*1.98*	*2.23*	*2.34*	*2.11*	*1.99*

[1] Compares the load in a specified time segment (daytime hours during a season) with the peak load observed during the same season.

Load factor is computed by the following formula:

LF=SUM(SE, U(SE)*D(SE)*SUM(TS, SLP(TS)*H(TS)))/8760

where:

SE: season
TS: time segment
U(SE): demand peak ratio
D(SE): days in season (182 for winter, 183 for summer)
SLP(TS): load pattern at each daytime segment
H(TS): hours in each time segment (on a daily basis)

TS: Daytime segments	from... to...	**H(TS)**
1st	21:00-08:00	11 hours
2nd	08:00-11:30	3.5 hours
3rd	11:30-13:00	1.5 hours
4th	13:00-18:30	5.5 hours
5th	18:30-21:00	2.5 hours
SE: Seasons	from... to...	**D(SE)**
Winter	Nov -Apr	182 days
Summer	May - Oct	183 days

Source: PRIMES NTUA

Power and steam generation system general information

		2000	2005	2010	2015	2020	2025	2030
Import/Export capacity (in MW)								
Exports of electricity		1036.2	1005.1	1003.1	1001.1	999.1	997.1	995.1
Imports of electricity		2336.3	2334.6	2333.4	2333.5	2331.9	2330.3	2328.7
Import price of electricity (Euro'90 / MWh)								
Contracted quantities (for all time segments)		26.00	26.00	26.00	26.00	26.00	26.00	26.00
Not contracted quantities (for all time segments)		26.00	26.00	26.00	26.00	26.00	26.00	26.00
Capacity of the Electricity Transmission Network (MW)								
from Other Generators	to Utility							
from Industrial Autoproducers	to Utility							
Capacity of the Electricity Transmission Network (MW)[1]								
Exports	to the rest of the world							
Imports	from the rest of the world							
Capacity of the Steam Transmission Network (MW)								
from Utility	to Tertiary	1000	1500	2000	2500	3000	4000	5000
from Utility	to Industry	1000.0	1250.0	1500.0	1750.0	2000.0	2250.0	2500.0
Operation and Maintainance Costs of the Electricity Transmission Network (Euro'90 / MWh)								
from Other Generators	to Utility	6.24	6.24	6.24	6.55	6.88	7.22	7.58
from Industrial Autoproducers	to Utility	3.25	3.25	3.25	3.25	3.25	3.25	3.25
Operation and Maintainance Costs of the Electricity Distribution Network (Euro'90 / MWh)								
from Industrial Autoproducers	to Industry	0.98	0.98	0.98	0.98	0.98	0.98	0.98
from Utility	to Industry	6.50	6.50	6.50	6.50	6.50	6.50	6.50
from Other Generators	to Tertiary	19.50	19.50	19.50	19.50	19.50	19.50	19.50
from Utility	to Tertiary	26.00	26.00	26.00	26.00	26.00	26.00	26.00
from Utility	to Households	41.60	41.60	41.60	41.60	41.60	41.60	41.60
from Utility	to Transports	6.50	6.50	6.50	6.50	6.50	6.50	6.50
from Utility	to Others	6.50	6.50	6.50	6.50	6.50	6.50	6.50
Operation and Maintainance Costs of the Electricity Transmission Network (Euro'90 / MWh)								
Exports	to the rest of the world	3.47	3.47	3.47	3.47	3.47	3.47	3.47
Imports	from the rest of the world	3.47	3.47	3.47	3.47	3.47	3.47	3.47
Operation and Maintainance Costs of the Steam Transmission Network (Euro'90 / MWh)								
from Utility	to Tertiary	2.60	2.60	2.60	2.60	2.60	2.60	2.60
from Utility	to Industry	2.60	2.60	2.60	2.60	2.60	2.60	2.60
Operation and Maintainance Costs of the Steam Distribution Network (Euro'90 / MWh)								
from Industrial Autoproducers	to Industry	1.30	1.30	1.30	1.30	1.30	1.30	1.30
from Other Generators	to Tertiary	9.10	9.10	9.10	9.10	9.10	9.10	9.10
from Other Generators	to Households	9.10	9.10	9.10	9.10	9.10	9.10	9.10
from Other Generators	to Others	9.10	9.10	9.10	9.10	9.10	9.10	9.10
Efficiency of Electricity Transmission Network								
Industrial Autoproducers		1.00	0.99	0.99	0.99	0.99	0.99	0.99
Other Generators		1.00	0.99	0.99	0.99	0.99	0.99	0.99
Utility		1.00	0.99	0.99	0.99	0.99	0.99	0.99
Efficiency of Electricity Distribution Network								
Industrial Autoproducers		0.96	0.97	0.97	0.97	0.97	0.97	0.98
Other Generators		0.96	0.97	0.97	0.97	0.97	0.97	0.98
Utility		0.96	0.97	0.97	0.97	0.97	0.97	0.98
Efficiency of Steam Transmission Network								
Industrial Autoproducers		1.00	1.00	1.00	1.00	1.00	1.00	1.00
Other Generators		1.00	1.00	1.00	1.00	1.00	1.00	1.00
Utility		1.00	0.99	0.99	0.99	0.99	0.99	0.99
Efficiency of Steam Distribution Network								
Industrial Autoproducers		0.98	0.98	0.98	0.98	0.98	0.98	0.98
Other Generators		0.98	0.98	0.98	0.98	0.98	0.98	0.98
Utility		0.98	0.98	0.98	0.98	0.98	0.98	0.98
Discount rates								
Industrial Autoproducers		0.120	0.120	0.120	0.120	0.120	0.120	0.120
Other Generators		0.120	0.120	0.120	0.120	0.120	0.120	0.120
Utility		0.080	0.080	0.080	0.080	0.080	0.080	0.080
Potential production of steam from CHP plants (upper bound, % of total steam production)								
Country Level		9999.000	0.550	0.575	0.600	0.625	0.650	0.650
Industrial Autoproducers		9999.000	0.250	0.300	0.350	0.400	0.450	0.500
Other Generators		9999.000	0.050	0.100	0.125	0.150	0.175	0.200
Utility		9999.000	0.300	0.325	0.350	0.375	0.400	0.425

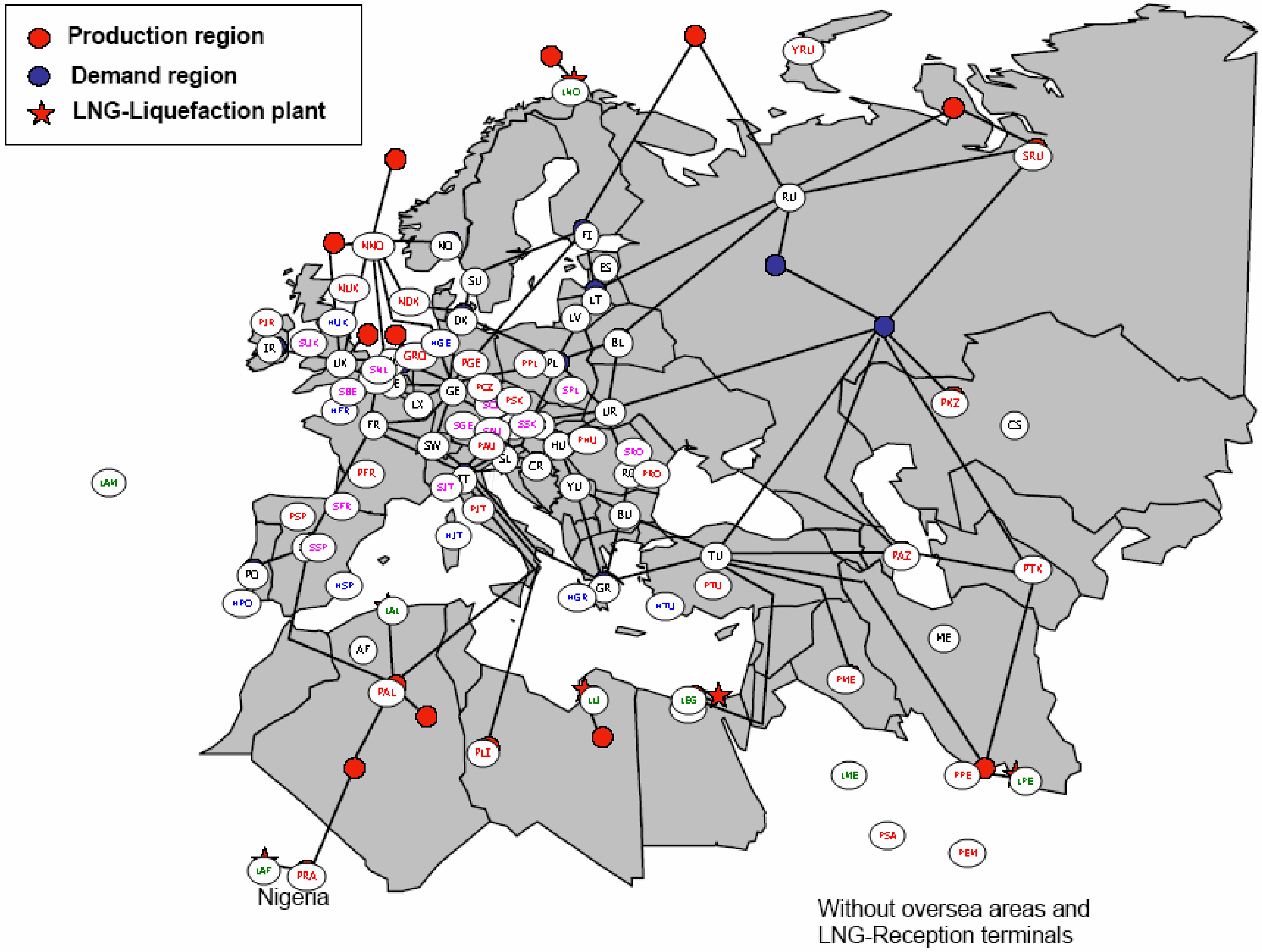
[1] Imports and exports of electricity are carried out between utilities of the countries involved.

Source: PRIMES NTUA

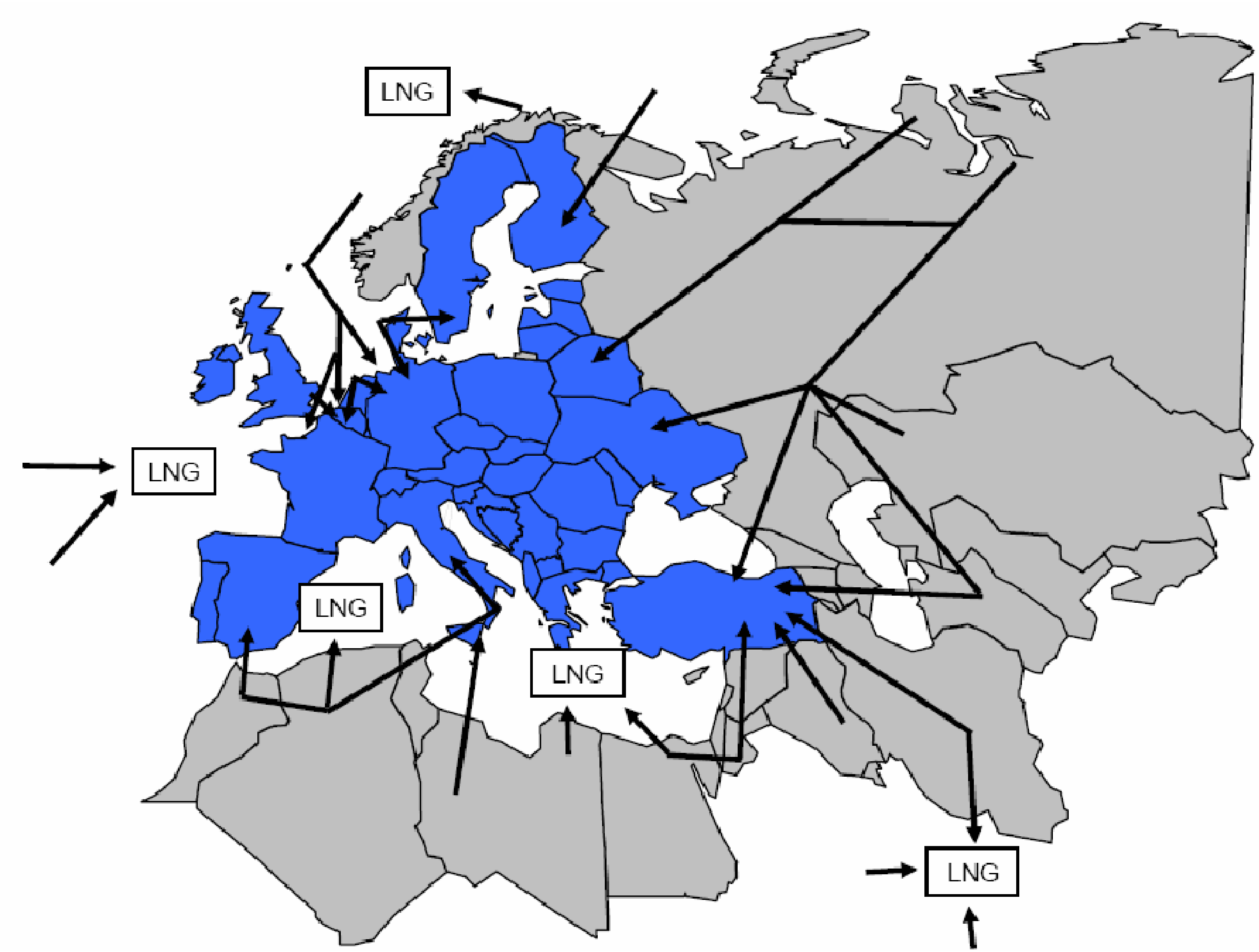
Fuel Constraints

	2000	2005	2010	2015	2020	2025	2030
Potential Fuel Consumption in Power and Steam Generation (ktoe)							
Hard Coal Imported	3069	4604	6906	13812	20717	31076	46614
Hard Coal Domestic	0	0	0	0	0	0	0
Lignite, peat etc.	20	0	0	0	0	0	0
Fuel Oil	494	544	1088	3807	3883	4272	4485
Diesel Oil	23	25	38	75	90	108	130
Natural Gas Base or Medium Load	3791	7583	13270	23222	40638	50798	60957
Natural Gas for Peak Load	151	758	834	917	1009	1110	1221
Nuclear Fuel	12421	11730	11930	11930	11930	11930	0
Biomass old or new energy crops	0	1289	1481	1536	1589	1641	1692
Waste (solid or gas)	533	433	571	569	566	562	556
Hydrogen liquefied (in fuel cells)	0	0	0	0	20000	20000	20000
Methanol (in fuel cells)	0	0	0	0	20000	20000	20000
By-products from industrial processes (derived gas)	768	642	631	579	585	569	549
Minimum Fuel Consumption in Power and Steam generation (ktoe)							
Hard Coal Imported	3066	0	0	0	0	0	0
Hard Coal Domestic	0	0	0	0	0	0	0
Lignite, peat etc.	20	0	0	0	0	0	0
Fuel Oil	494	0	0	0	0	0	0
Diesel Oil	23	23	24	24	25	25	26
Natural Gas Base or Medium Load	3788	0	0	0	0	0	0
Natural Gas for Peak Load	150	0	0	0	0	0	0
Nuclear Fuel	12421	11718	0	0	0	0	0
Biomass old or new energy crops	0	421	444	462	480	497	514
Waste (solid or gas)	533	182	223	222	221	219	217
Hydrogen liquefied (in fuel cells)	0	0	0	0	0	0	0
Methanol (in fuel cells)	0	0	0	0	0	0	0
By-products from industrial processes (derived gas)	767	546	536	492	492	483	467
Contracted Fuel quantities by generator (ktoe)							
Utilities							
Natural gas	2949	590	0	0	0	0	0
Domestic coal	0	0	0	0	0	0	0
Domestic lignite	0	0	0	0	0	0	0
Industrial generators							
Natural gas	557	111	0	0	0	0	0
Domestic coal	0	0	0	0	0	0	0
Domestic lignite	20	0	0	0	0	0	0
Other generators							
Natural gas	15	15	15	15	15	15	15
Domestic coal	0	0	0	0	0	0	0
Domestic lignite	0	0	0	0	0	0	0
Upper variance limit for contracted fuel quantities (ratio to contracted quantity)							
Utilities							
Natural gas	1.1	1.1	1.1	1.1	1.1	1.1	1.1
Domestic coal	1.1	1.1	1.1	1.1	1.1	1.1	1.1
Domestic lignite	1.1	1.1	1.1	1.1	1.1	1.1	1.1
Industrial generators							
Natural gas	1.1	1.1	1.1	1.1	1.1	1.1	1.1
Domestic coal	1.1	1.1	1.1	1.1	1.1	1.1	1.1
Domestic lignite	1.1	1.1	1.1	1.1	1.1	1.1	1.1
Other generators							
Natural gas	1.1	1.1	1.1	1.1	1.1	1.1	1.1
Domestic coal	1.1	1.1	1.1	1.1	1.1	1.1	1.1
Domestic lignite	1.1	1.1	1.1	1.1	1.1	1.1	1.1
Lower variance limit for contracted fuel quantities (ratio to contracted quantity)							
Utilities							
Natural gas	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Domestic coal	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Domestic lignite	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Industrial generators							
Natural gas	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Domestic coal	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Domestic lignite	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Other generators							
Natural gas	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Domestic coal	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Domestic lignite	0.3	0.3	0.3	0.3	0.3	0.3	0.3

The Gas Market Network in Primes



Without oversea areas and
LNG-Reception terminals


LNG
LNG
LNG
LNG
LNG

Major European Commission Publications prepared with PRIMES

1683-142X

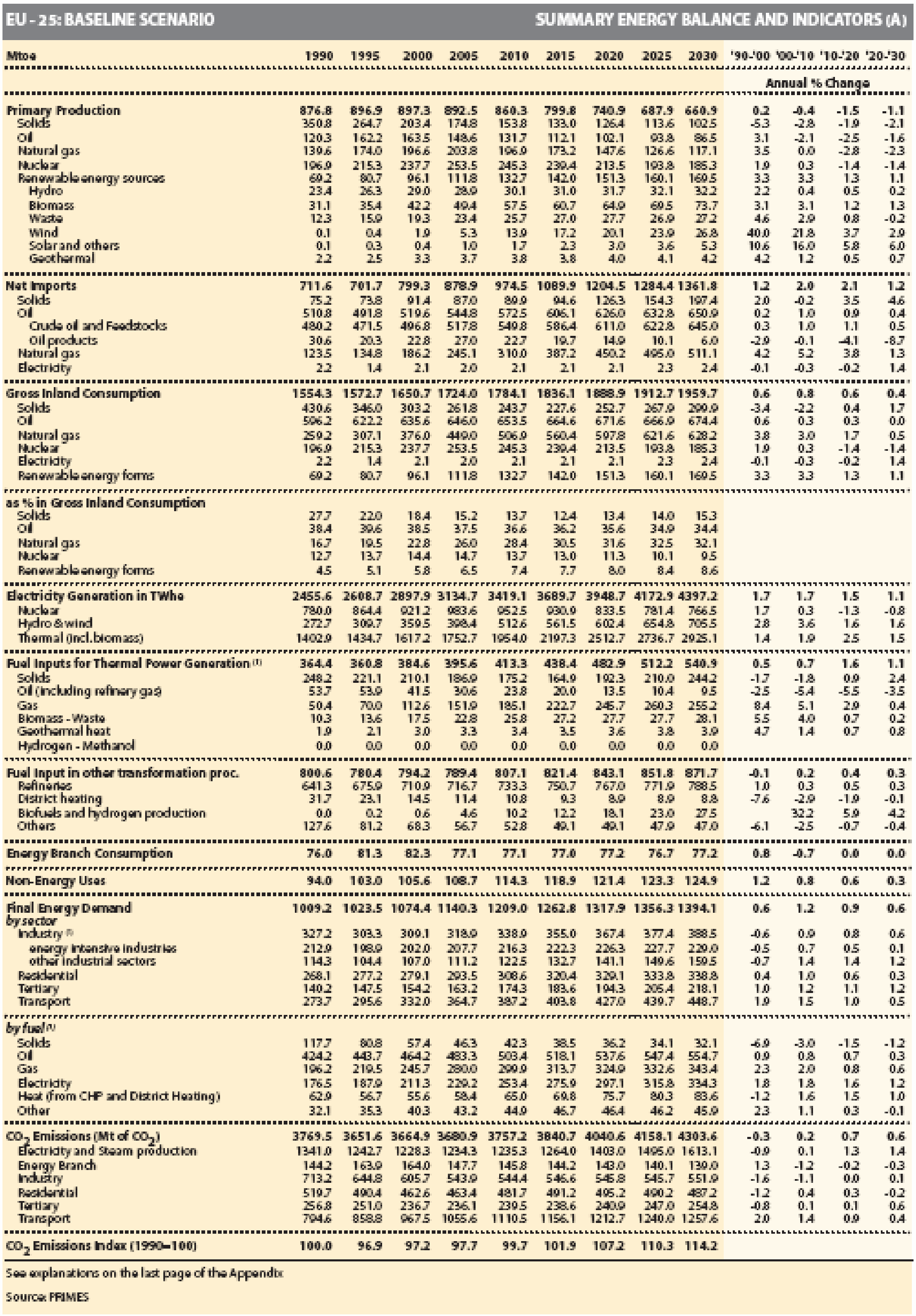
EUROPEAN
ENERGY AND TRANSPORT

Trends to 2030

EUROPEAN ENERGY AND TRANSPORT — TRENDS TO 2030

JANUARY 2003

EUROPEAN
COMMISSION



EU - 25: BASELINE SCENARIO **SUMMARY ENERGY BALANCE AND INDICATORS (A)**

Mtoe	1990	1995	2000	2005	2010	2015	2020	2025	2030	'90-'00	'00-'10	'10-'20	'20-'30
										Annual % Change			
Primary Production	876.8	896.9	897.3	892.5	860.3	799.8	740.9	687.9	660.9	0.2	-0.4	-1.5	-1.1
Solids	350.8	264.7	203.4	174.8	153.8	133.0	126.4	113.6	102.5	-5.3	-2.8	-1.9	-2.1
Oil	120.3	162.2	163.5	148.6	131.7	112.1	102.1	93.8	86.5	3.1	-2.1	-2.5	-1.6
Natural gas	139.6	174.0	196.6	203.8	196.9	173.2	147.6	126.6	117.1	3.5	0.0	-2.8	-2.3
Nuclear	196.9	215.3	237.7	253.5	245.3	239.4	213.5	193.8	185.3	1.9	0.3	-1.4	-1.4
Renewable energy sources	69.2	80.7	96.1	111.8	132.7	142.0	151.3	160.1	169.5	3.3	3.3	1.3	1.1
Hydro	23.4	26.3	29.0	28.9	30.1	31.0	31.7	32.1	32.2	2.2	0.4	0.5	0.2
Biomass	31.1	35.4	42.2	49.4	57.5	60.7	64.9	69.5	73.7	3.1	3.1	1.2	1.3
Waste	12.3	15.9	19.3	23.4	25.7	27.0	27.7	26.9	27.2	4.6	2.9	0.8	-0.2
Wind	0.1	0.4	1.9	5.3	13.9	17.2	20.1	23.9	26.8	40.0	21.8	3.7	2.9
Solar and others	0.1	0.3	0.4	1.0	1.7	2.3	3.0	3.6	5.3	10.6	16.0	5.8	6.0
Geothermal	2.2	2.5	3.3	3.7	3.8	3.8	4.0	4.1	4.2	4.2	1.2	0.5	0.7
Net Imports	711.6	701.7	799.3	878.9	974.5	1089.9	1204.5	1284.4	1361.8	1.2	2.0	2.1	1.2
Solids	75.2	73.8	91.4	87.0	89.9	94.6	126.3	154.3	197.4	2.0	-0.2	3.5	4.6
Oil	510.8	491.8	519.6	544.8	572.5	606.1	626.0	632.8	650.9	0.2	1.0	0.9	0.4
Crude oil and Feedstocks	480.2	471.5	496.8	517.8	549.8	586.4	611.0	622.8	645.0	0.3	1.0	1.1	0.5
Oil products	30.6	20.3	22.8	27.0	22.7	19.7	14.9	10.1	6.0	-2.9	-0.1	-4.1	-8.7
Natural gas	123.5	134.8	186.2	245.1	310.0	387.2	450.2	495.0	511.1	4.2	5.2	3.8	1.3
Electricity	2.2	1.4	2.1	2.0	2.1	2.1	2.1	2.3	2.4	-0.1	-0.3	-0.2	1.4
Gross Inland Consumption	1554.3	1572.7	1650.7	1724.0	1784.1	1836.1	1888.9	1912.7	1959.7	0.6	0.8	0.6	0.4
Solids	430.6	346.0	303.2	261.8	243.7	227.6	252.7	267.9	299.9	-3.4	-2.2	0.4	1.7
Oil	596.2	622.2	635.6	646.0	653.5	664.6	671.6	666.9	674.4	0.6	0.3	0.3	0.0
Natural gas	259.2	307.1	376.0	449.0	506.9	560.4	597.8	621.6	628.2	3.8	3.0	1.7	0.5
Nuclear	196.9	215.3	237.7	253.5	245.3	239.4	213.5	193.8	185.3	1.9	0.3	-1.4	-1.4
Electricity	2.2	1.4	2.1	2.0	2.1	2.1	2.1	2.3	2.4	-0.1	-0.3	-0.2	1.4
Renewable energy forms	69.2	80.7	96.1	111.8	132.7	142.0	151.3	160.1	169.5	3.3	3.3	1.3	1.1
as % in Gross Inland Consumption													
Solids	27.7	22.0	18.4	15.2	13.7	12.4	13.4	14.0	15.3				
Oil	38.4	39.6	38.5	37.5	36.6	36.2	35.6	34.9	34.4				
Natural gas	16.7	19.5	22.8	26.0	28.4	30.5	31.6	32.5	32.1				
Nuclear	12.7	13.7	14.4	14.7	13.7	13.0	11.3	10.1	9.5				
Renewable energy forms	4.5	5.1	5.8	6.5	7.4	7.7	8.0	8.4	8.6				
Electricity Generation in TWhe	2455.6	2608.7	2897.9	3134.7	3419.1	3689.7	3948.7	4172.9	4397.2	1.7	1.7	1.5	1.1
Nuclear	780.0	864.4	921.2	983.6	952.5	930.9	833.5	781.4	766.5	1.7	0.3	-1.3	-0.8
Hydro & wind	272.7	309.7	359.5	398.4	512.6	561.5	602.4	654.8	705.5	2.8	3.6	1.6	1.6
Thermal (incl.biomass)	1402.9	1434.7	1617.2	1752.7	1954.0	2197.3	2512.7	2736.7	2925.1	1.4	1.9	2.5	1.5
Fuel Inputs for Thermal Power Generation (1)	364.4	360.8	384.6	395.6	413.3	438.4	482.9	512.2	540.9	0.5	0.7	1.6	1.1
Solids	248.2	221.1	210.1	186.9	175.2	164.9	192.3	210.0	244.2	-1.7	-1.8	0.9	2.4
Oil (including refinery gas)	53.7	53.9	41.5	30.6	23.8	20.0	13.5	10.4	9.5	-2.5	-5.4	-5.5	-3.5
Gas	50.4	70.0	112.6	151.9	185.1	222.7	245.7	260.3	255.2	8.4	5.1	2.9	0.4
Biomass - Waste	10.3	13.6	17.5	22.8	25.8	27.2	27.7	27.7	28.1	5.5	4.0	0.7	0.2
Geothermal heat	1.9	2.1	3.0	3.3	3.4	3.5	3.6	3.8	3.9	4.7	1.4	0.7	0.8
Hydrogen - Methanol	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0				
Fuel Input in other transformation proc.	800.6	780.4	794.2	789.4	807.1	821.4	843.1	851.8	871.7	-0.1	0.2	0.4	0.3
Refineries	641.3	675.9	710.9	716.7	733.3	750.7	767.0	771.9	788.5	1.0	0.3	0.5	0.3
District heating	31.7	23.1	14.5	11.4	10.8	9.3	8.9	8.9	8.8	-7.6	-2.9	-1.9	-0.1
Biofuels and hydrogen production	0.0	0.2	0.6	4.6	10.2	12.2	18.1	23.0	27.5		32.2	5.9	4.2
Others	127.6	81.2	68.3	56.7	52.8	49.1	49.1	47.9	47.0	-6.1	-2.5	-0.7	-0.4
Energy Branch Consumption	76.0	81.3	82.3	77.1	77.1	77.0	77.2	76.7	77.2	0.8	-0.7	0.0	0.0
Non-Energy Uses	94.0	103.0	105.6	108.7	114.3	118.9	121.4	123.3	124.9	1.2	0.8	0.6	0.3
Final Energy Demand	1009.2	1023.5	1074.4	1140.3	1209.0	1262.8	1317.9	1356.3	1394.1	0.6	1.2	0.9	0.6
by sector													
Industry (2)	327.2	303.3	309.1	318.9	338.9	355.0	367.4	377.4	388.5	-0.6	0.9	0.8	0.6
energy intensive industries	212.9	198.9	202.0	207.7	216.3	222.3	226.3	227.7	229.0	-0.5	0.7	0.5	0.1
other industrial sectors	114.3	104.4	107.0	111.2	122.5	132.7	141.1	149.6	159.5	-0.7	1.4	1.4	1.2
Residential	268.1	277.2	279.1	293.5	308.6	320.4	329.1	333.8	338.8	0.4	1.0	0.6	0.3
Tertiary	140.2	147.5	154.2	163.2	174.3	183.6	194.3	205.4	218.1	1.0	1.2	1.1	1.2
Transport	273.7	295.6	332.0	364.7	387.2	403.8	427.0	439.7	448.7	1.9	1.5	1.0	0.5
by fuel (3)													
Solids	117.7	80.8	57.4	46.3	42.3	38.5	36.2	34.1	32.1	-6.9	-3.0	-1.5	-1.2
Oil	424.2	443.7	464.2	483.3	503.4	518.1	537.6	547.4	554.7	0.9	0.8	0.7	0.3
Gas	196.2	219.5	245.7	280.0	299.9	313.7	324.9	332.6	343.4	2.3	2.0	0.8	0.6
Electricity	176.5	187.9	211.3	229.2	253.4	275.9	297.1	315.8	334.3	1.8	1.8	1.6	1.2
Heat (from CHP and District Heating)	62.9	56.7	55.6	58.4	65.0	69.8	75.7	80.3	83.6	-1.2	1.6	1.5	1.0
Other	32.1	35.3	40.3	43.2	44.9	46.7	46.4	46.2	45.9	2.3	1.1	0.3	-0.1
CO_2 Emissions (Mt of CO_2)	3769.5	3651.6	3664.9	3680.9	3757.2	3840.7	4040.6	4158.1	4303.6	-0.3	0.2	0.7	0.6
Electricity and Steam production	1341.0	1242.7	1228.3	1234.3	1235.3	1264.0	1403.0	1495.0	1613.1	-0.9	0.1	1.3	1.4
Energy Branch	144.2	163.9	164.0	147.7	145.8	144.2	143.0	140.1	139.0	1.3	-1.2	-0.2	-0.3
Industry	713.2	644.8	605.7	543.9	544.4	546.6	545.8	545.7	551.9	-1.6	-1.1	0.0	0.1
Residential	519.7	490.4	462.6	463.4	481.7	491.2	495.2	490.2	487.2	-1.2	0.4	0.3	-0.2
Tertiary	256.8	251.0	236.7	236.1	239.5	238.6	240.9	247.0	254.8	-0.8	0.1	0.1	0.6
Transport	794.6	858.8	967.5	1055.6	1110.5	1156.1	1212.7	1240.0	1257.6	2.0	1.4	0.9	0.4
CO_2 Emissions Index (1990=100)	100.0	96.9	97.2	97.7	99.7	101.9	107.2	110.3	114.2				

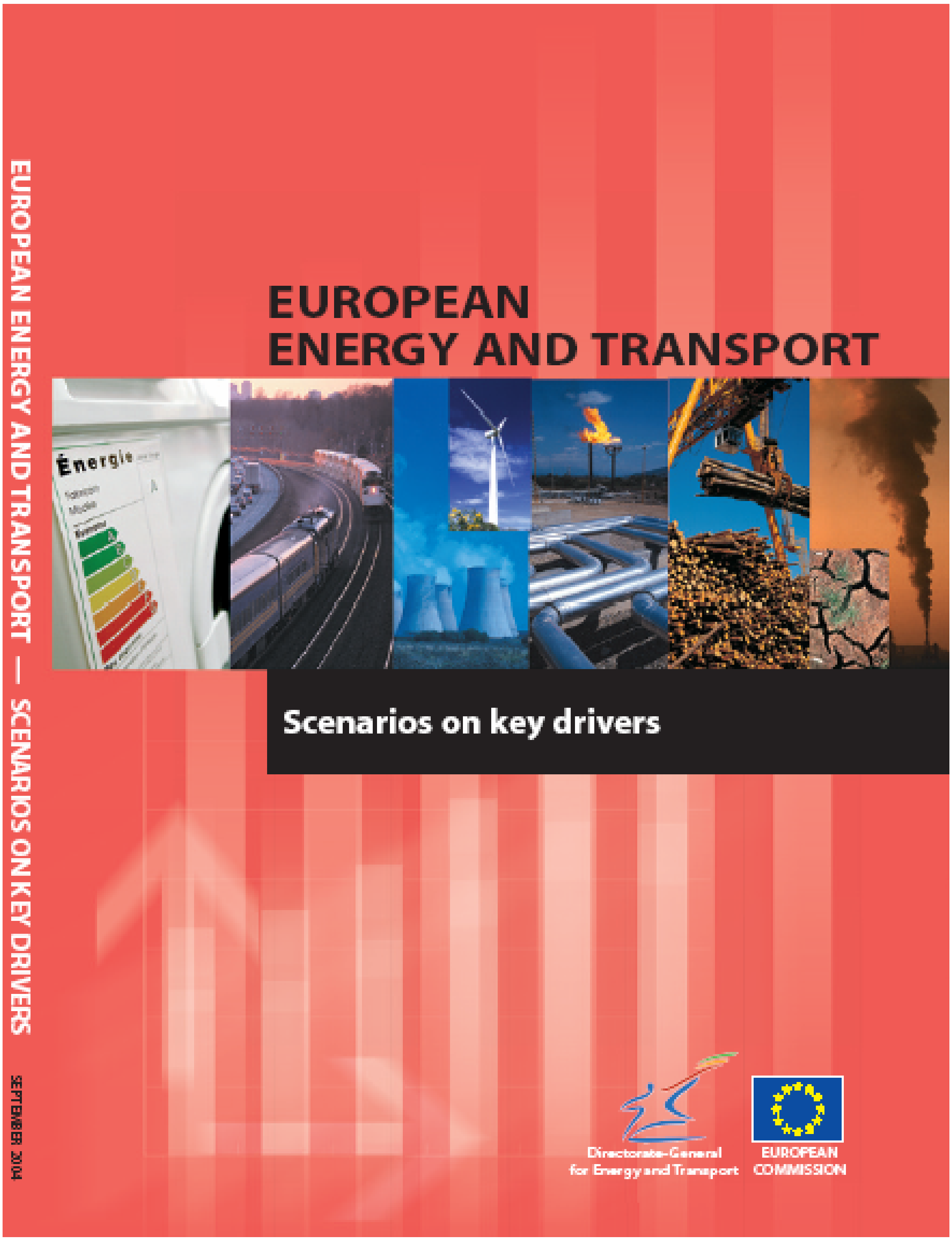
See explanations on the last page of the Appendix

Source: PRIMES

EU - 25:BASELINE SCENARIO **SUMMARY ENERGY BALANCE AND INDICATORS (B)**

	1990	1995	2000	2005	2010	2015	2020	2025	2030	'90-'00	'00-'10	'10-'20	'20-'30
										Annual % Change			
Main Energy System Indicators													
Population (Million)	441.1	448.6	453.4	458.7	461.2	462.3	462.1	461.0	458.2	0.3	0.2	0.0	-0.1
GDP (in 000 MEuro'00)	7315	7817	8939	10080	11433	12887	14462	16169	18020	2.0	2.5	2.4	2.2
Gross Inl. Cons./GDP (toe/MEuro'00)	212.5	201.2	184.7	171.0	156.1	142.5	130.6	118.3	108.8	-1.4	-1.7	-1.8	-1.8
Gross Inl. Cons./Capita (toe/inhabitant)	3.5	3.5	3.6	3.8	3.9	4.0	4.1	4.1	4.3	0.3	0.6	0.6	0.5
Electricity Generated/Capita (kWh/inhabitant)	5567	5816	6391	6834	7413	7981	8545	9052	9597	1.4	1.5	1.4	1.2
Carbon intensity (t of CO_2/toe of GIC)	2.43	2.32	2.22	2.14	2.11	2.09	2.14	2.17	2.20	-0.9	-0.5	0.2	0.3
CO_2 Emissions/Capita (t of CO_2/inhabitant)	8.5	8.1	8.1	8.0	8.1	8.3	8.7	9.0	9.4	-0.6	0.1	0.7	0.7
CO_2 Emissions to GDP (t of CO_2/MEuro'00)	515.3	467.2	410.0	365.2	328.6	298.0	279.4	257.2	238.8	-2.3	-2.2	-1.6	-1.6
Import Dependancy %	44.8	43.6	47.2	49.6	53.1	57.7	61.9	65.1	67.3				
Energy intensity indicators (1990=100)													
Industry (Energy on Value added)	100.0	91.1	82.7	76.4	71.0	65.7	60.5	55.5	51.3	-1.9	-1.5	-1.6	-1.6
Residential (Energy on Private income)	100.0	98.1	85.8	80.2	74.4	68.7	63.1	57.5	52.7	-1.5	-1.4	-1.6	-1.8
Tertiary (Energy on Value added)	100.0	96.7	86.8	80.2	74.9	69.6	65.3	61.4	58.2	-1.4	-1.5	-1.4	-1.1
Transport (Energy on GDP)	100.0	101.1	99.3	96.7	90.5	83.7	78.9	72.7	66.5	-0.1	-0.9	-1.4	-1.7
Carbon Intensity indicators													
Electricity and Steam production (t of CO_2/MWh)	0.44	0.40	0.37	0.32	0.29	0.28	0.29	0.29	0.30	-1.8	-2.3	-0.2	0.4
Final energy demand (t of CO_2/toe)	2.26	2.19	2.12	2.02	1.97	1.93	1.89	1.86	1.83	-0.7	-0.7	-0.4	-0.3
Industry	2.18	2.13	1.96	1.71	1.61	1.54	1.49	1.45	1.42	-1.1	-2.0	-0.8	-0.4
Residential	1.94	1.77	1.66	1.58	1.56	1.53	1.50	1.47	1.44	-1.6	-0.6	-0.4	-0.5
Tertiary	1.83	1.70	1.54	1.45	1.37	1.30	1.24	1.20	1.17	-1.7	-1.1	-1.0	-0.6
Transport	2.90	2.91	2.91	2.89	2.87	2.86	2.84	2.82	2.80	0.0	-0.2	-0.1	-0.1
Electricity and steam generation													
Generation Capacity in GW_e		617.4	656.2	716.0	783.9	862.8	946.7	1034.3	1118.2		1.8	1.9	1.7
Nuclear		134.7	140.3	138.9	129.8	123.7	108.0	106.6	107.8		-0.8	-1.8	0.0
Hydro (pumping excluded)		93.3	96.2	101.0	104.6	107.5	109.3	111.4	112.2		0.8	0.4	0.3
Wind and solar		2.5	13.0	28.0	73.2	91.7	104.1	125.2	149.2		18.9	3.6	3.7
Thermal		386.9	406.7	448.1	476.3	539.9	625.3	691.1	749.0		1.6	2.8	1.8
of which cogeneration units		*87.3*	*103.4*	*115.2*	*129.7*	*149.8*	*168.1*	*184.2*	*198.7*		*2.3*	*2.6*	*1.7*
Open cycle(incl.biomass-waste)		343.8	335.6	324.0	270.6	210.3	175.3	151.9	147.4		-2.1	-4.2	-1.7
Supercritical Polyvalent/Clean Coal and Lignite		0.0	0.0	0.0	1.0	13.1	66.6	104.5	149.9			52.7	8.4
Gas Turbines Combined Cycle		20.4	47.4	95.9	169.6	263.9	318.8	365.8	384.6		13.6	6.5	1.9
Small Gas Turbines		22.0	22.8	27.0	33.9	51.3	63.3	67.5	65.8		4.1	6.4	0.4
Fuel Cells		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0				
Geothermal heat		0.7	1.0	1.2	1.2	1.2	1.3	1.3	1.4		1.6	0.7	0.8
Indicators													
Efficiency for thermal electricity production (%)		35.8	37.1	39.9	42.6	45.2	46.8	48.1	48.7				
Load factor for gross electric capacities (%)		48.2	50.4	50.0	49.8	48.8	47.6	46.1	44.9				
CHP indicator (% of electricity from CHP)		11.5	12.6	13.8	14.4	14.7	15.5	16.0	16.3				
Non fossil fuels in electricity generation (%)		46.8	46.4	46.6	45.5	43.0	38.7	36.6	35.6				
nuclear		33.1	31.8	31.4	27.9	25.2	21.1	18.7	17.4				
renewable energy forms		13.7	14.6	15.2	17.6	17.7	17.6	17.9	18.2				
of which waste		*0.9*	*1.1*	*1.3*	*1.3*	*1.3*	*1.2*	*1.0*	*1.0*				
Transport sector													
Passenger transport activity (Gpkm)	4683.8	5038.7	5519.7	5944.2	6432.8	6963.4	7509.1	8031.4	8538.9	1.7	1.5	1.6	1.3
public road transport	484.5	469.2	493.8	498.5	503.9	518.1	533.0	545.7	555.6	0.2	0.2	0.6	0.4
private cars and motorcycles	3593.6	3950.3	4291.6	4647.4	5025.6	5410.7	5788.4	6143.3	6474.5	1.8	1.6	1.4	1.1
rail transport	408.3	371.7	402.3	400.1	414.9	445.2	479.3	508.8	537.6	-0.1	0.3	1.5	1.2
aviation	168.5	215.5	298.3	360.8	448.1	546.1	661.6	783.2	917.0	5.9	4.2	4.0	3.3
inland navigation	28.9	31.9	33.6	37.3	40.4	43.3	46.8	50.4	54.1	1.5	1.8	1.5	1.5
travel per person (km per capita)	10618	11233	12174	12959	13947	15062	16249	17423	18637	1.4	1.4	1.5	1.4
Freight transport activity (Gtkm)	1762.6	1859.8	2147.6	2397.9	2689.8	3003.5	3339.0	3684.5	4042.8	2.0	2.3	2.2	1.9
trucks	1064.3	1233.6	1482.7	1711.4	1966.6	2232.5	2516.9	2818.8	3132.6	3.4	2.9	2.5	2.2
rail transport	440.2	358.0	368.0	367.3	378.3	397.3	419.9	435.5	453.2	-1.8	0.3	1.0	0.8
inland navigation	258.1	268.2	297.0	319.3	344.9	373.7	402.2	430.2	457.1	1.4	1.5	1.6	1.3
freight activity per unit of GDP (tkm/000 Euro'00)	241	238	240	238	235	233	231	228	224	0.0	-0.2	-0.2	-0.3
Energy demand in transport (Mtoe)	273.7	295.6	332.0	364.7	387.2	403.8	427.0	439.7	448.7	1.9	1.5	1.0	0.5
public road transport	7.7	6.9	7.0	7.1	7.1	7.1	7.0	6.7	6.4	-1.0	0.2	-0.3	-0.9
private cars and motorcycles	138.1	146.1	157.1	169.4	169.0	164.3	168.6	166.8	161.6	1.3	0.7	0.0	-0.4
trucks	82.9	93.2	108.5	125.1	143.8	161.1	174.5	186.8	195.5	2.7	2.9	2.0	1.1
rail transport	8.8	8.9	9.0	8.7	8.0	7.1	6.6	6.3	6.2	0.1	-1.1	-2.0	-0.5
aviation	29.1	33.8	45.1	48.5	53.0	57.4	63.3	65.7	71.2	4.5	1.6	1.8	1.2
inland navigation	7.0	6.7	5.4	5.8	6.3	6.7	7.1	7.4	7.8	-2.6	1.6	1.2	0.9
Efficiency indicator (activity related)													
passenger transport (toe/Mpkm)	39.0	38.6	39.2	39.1	36.6	33.7	32.6	30.5	28.7	0.1	-0.7	-1.2	-1.3
freight transport (toe/Mtkm)	51.7	54.4	53.8	55.3	56.3	56.3	54.7	52.9	50.5	0.4	0.5	-0.3	-0.8

Source: PRIMES



EUROPEAN ENERGY AND TRANSPORT — SCENARIOS ON KEY DRIVERS

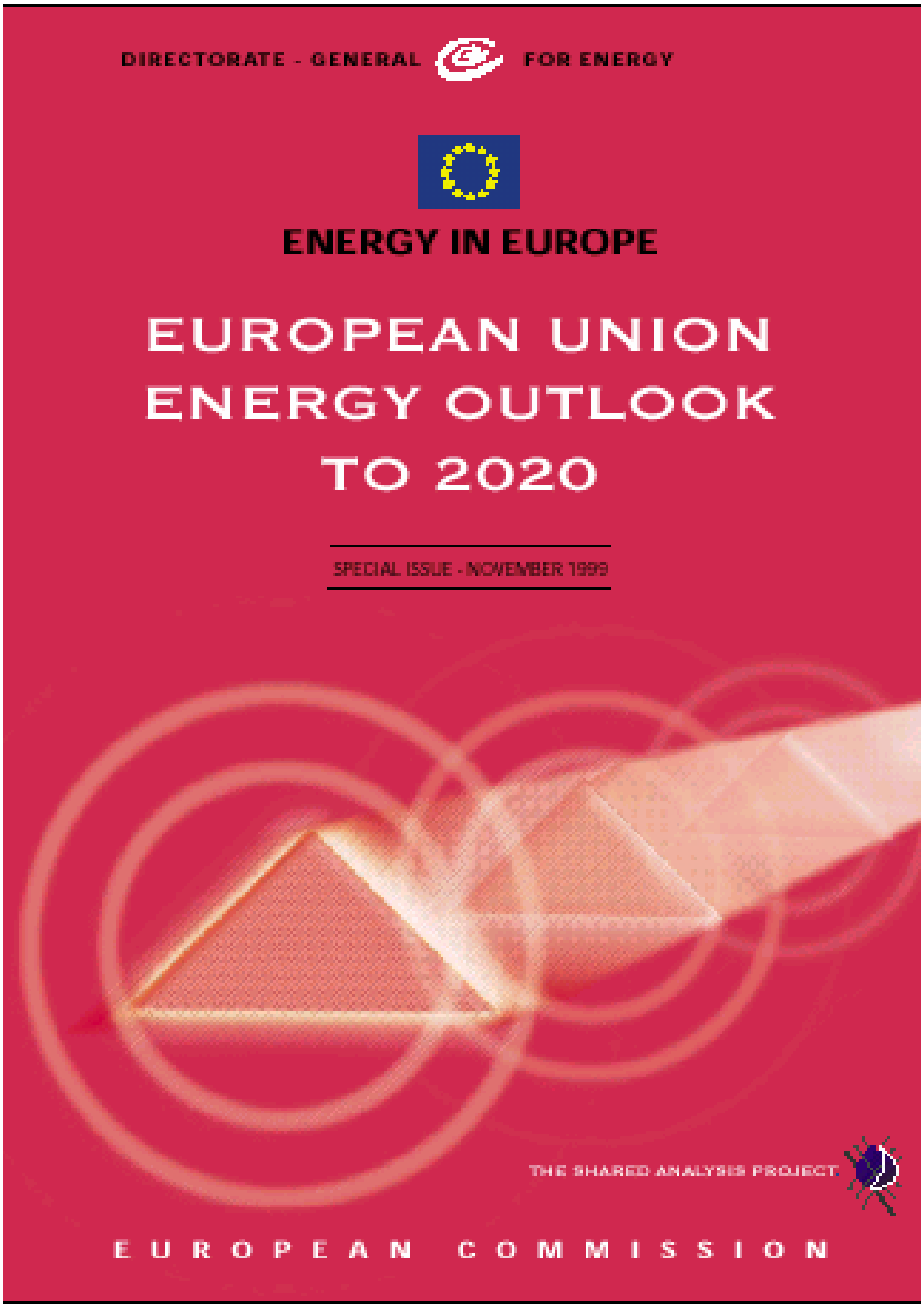
SEPTEMBER 2004

EUROPEAN
ENERGY AND TRANSPORT

Scenarios on key drivers

Directorate-General
for Energy and Transport

EUROPEAN
COMMISSION



DIRECTORATE - GENERAL FOR ENERGY

ENERGY IN EUROPE

EUROPEAN UNION
ENERGY OUTLOOK
TO 2020

SPECIAL ISSUE - NOVEMBER 1999

THE SHARED ANALYSIS PROJECT

EUROPEAN COMMISSION