NATIONAL TECHNICAL UNIVERSITY OF ATHENS

European Commission Joule-III Programme

The *PRIMES* Energy System Model

Summary Description

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The PRIMES Energy System Model

History

The development of the PRIMES energy system model has been supported by a series of research programmes of the European Commission. The model has been successfully peer reviewed by the European Commission in 1997-1998.

The construction of the PRIMES energy model started in 1993 and from the beginning the aim was 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 markets analysis tool including the relationships between energy policy and technology assessment. The need to represent the growing process of market liberalisation, also motivated PRIMES and other modellers to adopt market-oriented modelling approaches giving rise to models often called “new generation models” like in the US the models IFFS and NEMS (US/DOE).

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 the negotiation phase for the Kyoto conference for climate change. The current version of the model (version 2 of PRIMES) formulated as a non-linear mixed complementarity (MCP) problem and solved under GAMS/CPLEX/PATH is fully operational and calibrated on 1995 data-set for all European Union member states. During the 1998-1999 period, version 2 of PRIMES has been used to prepare the European Union Energy and Emissions Outlook for the Shared Analysis project of the European Commission, DG XVII. It has been also extensively used for DG Environment and started to be used at government level in the EU.

Scope and Objectives

PRIMES is a modelling system that simulates a market equilibrium solution for energy supply and demand in the European Union (EU) member states. The model determines the equilibrium by finding the prices of each energy form such that the quantity producers find best to supply match 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 also represent 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.

PRIMES 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
- energy trade and EU energy provision
- 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 price. 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, as well as 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 selects the technology of the energy equipment on an economic basis and 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, 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, including the most expedient regional structure. The electricity module covers the whole Europe, while representing chronological load curves and dispatching at the national level. The natural gas market also expands over the whole Europe. However, coal supply, refineries and demand operate at the national level. Furthermore, the modularity allows any single sector or group of sectors to be run independently for stand alone analysis.

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. Also, the model fully integrates the national within the multinational energy system (for oil refinery, gas supply to Europe and generation and trade of electricity).

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. Primary energy supply, for example coal and lignite supply curves, has, on the other hand, a national-specific character. Finally, energy savings, technology progress in power generation, abatement technologies, renewables and alternative fuels (biomass, methanol, hydrogen) are determined at each country-specific energy system.

Cost evaluation modules and price-setting mechanisms are at the core of the model. The formers are attached to each energy supply module. The cost module considers total revenue requirements of the sector (based on total costs and other accounting costs) and allocates payments over the consumers, according to a general Ramsey pricing rules (parameters are user selected). The pricing parameters reflect alternative industrial economic circumstances and are linked to marginal and average values from the sector's optimisation. For example, these rules consider a peak-synchronisation characterisation of consumers or average cost rating of energy demand by consumers. The allocation of payments is further determined, by also considering eventual 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 cost-effective technology solutions.

In addition, market related factors, as represented within the optimisation modules, can 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 parameters, as for example by varying the discount rates with the consumer size.

Policy parameters can of course change the optimality conditions and influence technology choice and penetration. The model can in addition simulate accompanying policies that aim at structural improvements that may maximise the effects of policy measures. For example, true cost pricing, removal of barriers, new funding mechanisms etc. can be reflected to changes of parameters that will influence technology choices and penetration.

Environment

The mechanisms relating pollution with energy activities, also involving pollution abatement choices, are fully integrated into PRIMES. The optimisation modules 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 and can also be accompanied with policy aiming at structural change. Finally, a module computes dispersion and deposition of emitted pollutants.

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

1. Regulation by sector (in the form of a constraint of emissions by sector);
2. Regulation by country (in the form of a global constraint taking into account emissions

from all modules);

3. 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);
4. Pollution permits. A separate market for pollution permits is implemented in the model. The different sectors can therefore trade (sell or buy) permits based on their initial endowment;
5. 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. Taxes, excise, VAT, carbon 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 treated.

Other economic instruments, like the tradable emission rights (pollution permits) are also 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 and binding within the optimisation modules. The model can evaluate the effectiveness and compute proxies to the shadow cost 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, although involving higher costs for the consumer. In such cases, voluntary agreements are possible when deviations are threatened by the risk of considerably higher costs. PRIMES has not such a mechanism built in. However, 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.

Demand-side Management and Integrated Resource Planning is also another example for which the model is not entirely sufficient. PRIMES, being explicit in technology representations, includes electricity consumption technologies and uses in all consumption modules. To each use, the model associates generic load patterns, the aggregation of which over the consumers' electricity uses gives the load shape faced by electricity generation. A DSM measure can be simulated by a change either in the shape or the area (efficiency) of a particular electricity use. This will alter the optimality conditions of electricity generation and will probably imply cost savings. Externally to the model, the analyst has to evaluate implementation costs of the measure and allocate the bearing of the costs between the consumer and the generator. In such a way, he can carry out cost-benefit analysis to evaluate DSM measures. The concept of Integrated Resource Planning seems now old fashioned within the on going liberalisation of markets[1]. At the energy system level, PRIMES is a complete

[1] If the concept is limited to the obligation of generators to do IRP, instead of the society.

tool for IRP evaluations, but the model is totally inadequate if IRP is to be carried out at the generator level.

To study the general issue of internalisation of externalities one has to use an accounting framework for externalities[2], consider internalisation through economic instruments (thus compare them for effectiveness, as mentioned before) or define a regulation scheme that will oblige the actors to take into account external costs. Total cost pricing was recently brought up in the debate as a means to regulate decision-making. Total cost (that is including external costs) can be imposed in all optimisation modules of PRIMES. This will influence technology choice and pricing throughout the system.

The PRIMES Model Application for the European Union

Model Nomenclature

Regions: 15 European Union countries

Fuel types: 24 energy forms in total; Coal, Lignite and Peat, 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 and cooling are considered as a special sub-sector, which is independent of the type of dwelling. Four energy use types are defined per dwelling type.

Commercial: 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 7 sub-sectors and more than 30 end-use technology types are defined.

Industry: The industrial model separately formulates 9 industrial sectors, namely iron and steel, non ferrous, chemicals, building materials, paper and pulp, food drink tobacco, engineering, textiles, other industries 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.

Transport modes: for urban passengers car, public transport, motorcycle, non urban passengers: car, bus, rail, air, navigation; for freight transport truck, rail, air, navigation. 6 to 10 alternative technologies for each mode (car, bus, truck); more limited number of alternatives for rail, air and navigation

Supply Sectors:

Electricity production: 148 different plant types per country for the existing thermal plants; 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,

[2] For example, EXTERNE results.

interconnections, network representation; three typical companies per country; Cogeneration of power and steam, district heating

Refineries: 4 refineries with typical refinery structure; 6 typical refining units (cracking, reforming etc.)

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

Time Horizon

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

Output (Dynamic Annual Projections in Specific Units)

- Full detailed EUROSTAT Energy Balance sheets per country and per year
- Energy demand at the above mentioned classification
- Energy costs, producer and consumer prices
- Power generation park, load curves, load factors, investment and marginal costs (central systems, combined heat-power, exchanges)
- Refining units, expansion, costs
- Natural gas transport and distribution: flows, capacities, costs
- Endogenous treatment of energy savings and new technologies
- Atmospheric emissions (CO_2, NO_x, SO_2, N_2O, CH_4, VOC, PM), abatement equipment and standards

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
- European energy market integration, European networks
- Energy system implications and forecasting for the penetration of new energy technologies in energy savings, energy demand, power generation etc.
- Energy supply to Europe: dependency and vulnerability analysis for natural gas and oil.

Required Infrastructure

- Hardware: PC Pentium with Windows '95 or Alpha Digital Equipment running NT-Windows with 128MB RAM or higher
- Software: GAMS Ver. 2.25 with PATH solver and Cplex (or OSL)
- MS EXCEL ver. 7.0 or later

The Power and Steam Generation Sub Model of PRIMES

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 emergence 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. On the contrary, the previous version of PRIMES has considered a separation between centralised electricity and the independent production of steam and electricity, the latter being modelled within the demand sub-models of PRIMES. That design has put more emphasis on the self-supply character of cogeneration, since such a situation has prevailed in the market for a long period of time. 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 then 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 new version of PRIMES puts emphasis on the different nature of producers that will 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 (renewables, 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 if 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 renewables, 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 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 has deprived small independent producers to enter 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.

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.

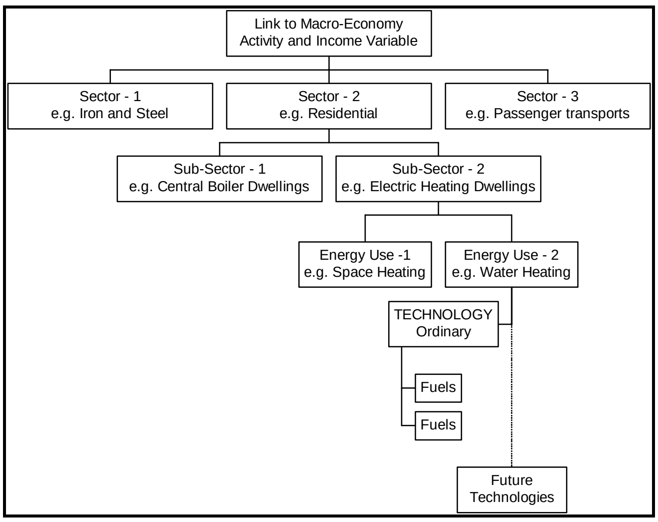
Decision-making by electric utilities (or steam producers) may be considered in three different, yet interrelated, problems:

- 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, which is close to average cost pricing, and we interpret this choice as representative of both the regulated monopoly and the monopolistic competition market regimes.

General Structure of 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.



The data that are necessary to calibrate the model for a base year (1995) and a country (all EU member-states) can be divided in the following categories.

- Macro-economic data that correspond to demographics national accounts, sectoral activity and income variables. 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 data bases MURE, IKARUS, ODYSSE 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 sells 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. The PRIMES database consists in introducing that steam (for self-consumption) in the final energy consumption tables of the balance sheets and inserting the fuels used to produce that steam in the table of transformation input and output. 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).

The fuel types are as follows:

1. Solid fuels except lignite and peat
2. Lignite and Peat
3. Residual Fuel Oil
4. Diesel Oil
5. Liquefied Petroleum Gas
6. Kerosene
7. Gasoline
8. Naphtha
9. Other oil products
10. Bio-fuels
11. Natural and derived gas
12. Thermal Solar (active)
13. Geothermal low enthalpy
14. Steam (industrial and distributed heat)
15. Electricity
16. Biomass and Waste
17. Hydrogen

Industrial Sector

The industrial sector 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 structure for the industrial sector is given below:

SECTORS	*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
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
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
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
Paper and pulp production	Chemical paper	Lighting
	Mechanical pulp and paper	Motor drives
		Pulping electric
		Refining electric
		Steam and high enthalpy heat
		Low enthalpy heat
		Pulping steam
		Drying and separation
		Refining steam

SECTORS	*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
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
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
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 tertiary sector comprises of 4 sectors. 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 is as follows:

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

SECTORS		*ENERGY USES*	*ENERGY TECHNOLOGIES*
Services			
	Offices and Services	Lighting	Lighting
		Space heating	Electric heating/cooling
		Air conditioning	Gas heating/cooling
		Electrical uses	Boiler heating/cooling
		Water heating	District heating
			Greenhouses
			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	Greenhouses
			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	Greenhouses
			Electrical equipment

Residential Sector

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:

SECTORS	*HOUSEHOLD TYPES*	*ENERGY USES*
Dwellings	1. Central boiler households that may also use gas connected to the central boiler (flats)	Space heating
	2. Households with mainly electric heating equipment (non partially heated)	Cooking
	3. Households with direct gas equipment for heating (direct gas for flats and gas for individual houses)	Water heating
	4. Households connected to district heating	Air conditioning
	5. Partially heated dwellings and agricultural households	

SECTORS	*ENERGY USES*
Electric Equipment	Washing machines
	Dish washers
	Dryers
	Lighting
	Refrigerators
	Television sets

Transport sector

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. The structure is as follows:

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