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Characteristics of the Model MEDEE-S and its correspondance in the industry sector to the data availability in African countries.

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A study for:

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## 1. Introduction and Background of the Project

The United Nations Industrial Development Organization (UNIDO) entrusted the consultant with contract number CLT 85/297 dated december 19, 1985 to carry out a survey on

> 'Charcteristics of the model MEDEE-S and its correspondance in the industry sector to the data availability in African countries'

The aim of the project is to present and describe the features of the MEDEE-S model and to point to correspondences between characteristics of the industrial sector considered in the model and the information system existent in African countries.

The Institut des Etudes Juridiques et Economique (IEJE), Grenoble, France, assessed traditional econometric energy demand forecasting methods, identified by that some limitations of such types of approaches, and commenced in 1974 to develop a new methodology to forecast energy demand called the MEDEE approach (MEDEE is the acronym for Modele d'Evolution de la Demande Energie). Whereas traditional econometric models mostly explain the development of energy demand in terms of macro-economic aggregates, the MEDEE approach takes into account explicitly the direct and indirect determinants of this demand at a disaggregate level: social, economic and technical determinants mostly measured in physical units.

The MEDEE family encompasses three different models: MEDEE-2, MEDEE-3, and MEDEE-S, developed for application in countries with different level of industrialization.

The MEDEE-2 model focuses predominantly on the calculation of energy demand for a given year and pays less attention on the development mechanisms of the energy demand determinants. MEDEE-2 is an accounting model allowing for the automatic calculation of detailed energy balances per sector, per end-use and per energy form from the projection of social, economic and technical indicators. The advantages of this model are its simplicity, its transparency and its educational value. However, the great number of exogenous variables required point to the model's limits, especially in the case for developing countries. This model has been used by the energy modelling group of the International Institut for Applied Systems Analysis (IIASA).

In the more ambitious MEDEE-3 model, energy demand is broken down to the greatest extent possible, taking into account existing information and the relevance of the disaggregation. This disaggregation is designed in order to study energy consumption categories (or modules) which are relatively homogenous in terms of the behaviour of the actors. The level of disaggregation is limited by the need to represent relevant groups, in terms of energy consumption. The calculation of the development of energy demand at the level of each module is undertaken in MEDEE-3 on the basis of accounting identities for the initial year and on simulation methods for the development of economic activities and social needs. This model was developed to fit into the model system of the Commission of the European Communities (CEC) in between a macro-economic and an energy supply model.

The experiences made with the implementation of MEDEE-2 and MEDEE-3 for developing countries made plain the limitations of this models for developing countries. Some limiting facts can be summarized as follows:

- The level of disaggregation does not take into account the heterogenities common to developing countries. The energy consumption pattern, as far as quantity and structure are concerned, are characterized by considerable differences between social groups.This refers mainly to differences between rural and urban population.

- The models include a considerable number of variables which are of no importance for the majority of developing countries.

- The fact that some scenario assumptions -though not formally interrelated in the model- are not independent from each other raises the question of consistency. It would be necessary to introduce some additional relations in order to obtain consistency of the underlying assumptions.

Therefore, in order to provide a suitable tool to developing countries planning bodies, the MEDEE-S model was developed.

MEDEE-S is a simulation model determining sectoral energy demand on the final energy level (respectively useful energy level) and the fuel mix. The accounting equations combine economic activities and socio-economic parameters to derive end-use energy demand per sector.

The models of the MEDEE famility were conceived to help in the elaboration of energy policies. They aim to associate useful and final energy profiles to major hypothesis concerning the economic and social development.

## 2. The MEDEE-S Model

### 2.1 Principle Charcteristics

In designing MEDEE-S, the following objectives were kept in mind:

- to reflect structural changes affecting long-term energy demand by disaggregating the social, economic, and technological system so as to be able to take these changes explicitly into account,

- to identify the energy spectrum of each final energy form, and

- to keep the model easily adaptable to countries with different economic, social, and energy systems.

The originality of MEDEE-S vis-a-vis other energy demand models is mainly to be seen in two facts, namely

- the disaggregation of energy demand into homogeneous categories, and

- the classification of model determinants into exogenous determinants and scenario variables.

The disaggregation of energy consumption into categories depends above all on the objectives pursued by the modeler and on the data availability. In MEDEE-S, a procedure is implemented that determines energy consumption for every category specified.

The determinants chosen as scenario elements are those the evolution of which can not be extrapolated from past trends because of possible structural changes in energy demand and socio-economic growth. The evolution of these factors are specified in scenarios. The exogenous determinants encompass those factors which are difficult to model but for which the long-term evolution can be adjusted suitably from past trends.

Whenever possible, energy demand is calculated in terms of useful energy for each end-use category. Each useful energy demand is then converted into final energy taking into account the market penetration of each form of energy and the end-use efficiencies of each form.

MEDEE-S is driven by a set of determining elements, the evolution of which is defined in a scenario. The core of the scenario is a complete characterization pattern of the country under study, complemented by technological parameters, the evolution of which is specified in a way consistent with the macro-economic assumptions behind the scenario.

### 2.2 The Structure of the Model

The MEDEE-S model opts for a breakdown into five sub-systems: industry, households, tertiary sector, transport and agriculture. The disaggregation of the MEDEE-S into sub-systems and homogeneous modules is presented in table 1 and subsequently described.

Table 1 Structure of the MEDEE-S model

| Basic modules | Additive modules |
|---|---|
| Industry (for each sector and usage) | |
| - specific electricity<br>- thermal uses<br>- motor fuel | - metal industry<br>- large energy consumers |
| Households (rural and urban per class of income) | |
| - cooking and other thermal uses<br>- lighting and specific electricity | - heating<br>- warm water<br>- electrical appliances<br>- air-conditioning |
| Tertiary (analysis by subsector) | |
| - different thermal uses<br>- specific electricity | - heating<br>- air-conditioning<br>- public lighting |
| Transport | |
| - passenger transport<br>- goods transport<br>- international transport | - urban transport |
| Agriculture (global analysis or analysis by equipment used) | |

Each module has been developed in a similar way: End-use categories have been identified by taking explicitly into account the major social, economic, technological, and policy changes that can appear over the long-term and affect energy consumption.

a) Agriculture and fishing

The main uses of energy considered in this sector are mechanical energy for irrigation and traction, propulsion energy for fishing boats and, in certain countries, energy used for conservation and drying of agricultural products. The development of energy consumption in agriculture is closely linked to the development of farming technology. Therefore in agriculture a distinction has to be made between traditional subsistence and modern intensive farming.

The sub-model agriculture renders the determination of final energy possible in two different ways. In a 'simple' approach energy consumption is determined by linking agricultural production in terms of value added and energy intensity per value added, whereby energy is not treated as an integrated whole but distinguished into three energies: fossil fuels, electricity and other fuels.

The second approach differentiates between four types of energy uses:

- motive power for soil cultivation and transportation of agricultural products,

- motive power for fishing,

- irrigation and water pumps, and

- thermal uses.

The energy consumption in each use is characterized by the equipment utilized and the specific unitary energy consumption, for instance in the case of irrigation, a distinction is made between pumps using diesel or electricity as motive fuels.

b) Industry

The breakdown of industrial activities is undertaken on the basis of the following principles:

- identification of the main energy intensive consumers,

- analysis of the specific energy consumption per production process and the possibilities for recycling waste products,

- clustering the non-energy intensive industries in a few major characteristical categories, and

- breakdown according to major energy uses: specific uses of electricity, other mechanical uses, and thermal uses according to temperature level.

The sub-model industry specifies three modules: basic, iron and steel and large energy consumers. Both last modules are optional; they can be considered separately from the basic module or integrated, depending on the availability of information and the desirability of disagregation.

The industry sub-model is elaborated in greater detail in section 3.

c) Households

Most of the energy used in households in developing countries is for cooking. The rest of the energy used is for lighting and eventually for heating, depending on the climatic zones. However, owing to the changes in personal income, the traditional energy use pattern is subject to considerable changes and 'new' areas of energy applications will occur, such as hot water, air-conditioning, etc. As the social spectrum is broadly spread in Less Developed Countries (LDCs), different social groups are considered in order to take into account the heterogenity which is observed in life styles and the levels of satisfaction of household needs.

In the sub-model household, it is distinguished between two basic uses: cooking and lighting. However, arrangements are made to consider additionally, if required, the following uses: heating, hot water, air-conditioning and electrical household appliances. In case that the basic module is activated only, the additional uses will be aggregated into cooking and lighting depending on the fuel used. For the substitutable use of energy, energy demand is determined in terms of useful energy rather than final energy in order to consider appropriately the end-use efficiencies of the different competing fuels.

Typical for developing countries is the different energy consumption in rural and urban areas and the commercial-non commercial energy spectrum. These features are considered in the industrial sub-model of MEDEE-S in order to account for the substitution of traditional and commercial energies. In urban areas, the classification criteria are, among others, income distribution, type of dwelling, type of construction, etc. For rural areas, the sub-model permits the adequate consideration of non-commercial energies.

d) Transport

The energy demand in the transportation sector is induced by the demand for transportation. For a given transportation demand, the final energy demand depends mainly on the subject to be transported, e.g. passenger or goods, the mode of transportation and the specific energy requirements per mode of transportation. For developing countries the distinction between the transport of goods and passengers is sometimes difficult to achieve due to the fact that some of the activities are covered by vehicles used for both purposes.

Basing passenger transport on the mode of transport, it enables to characterize trends in individual mobility, to identify substitution possibilities between modes and to analyze the utilization per mode.

For the transport of goods the distinction is made on the mode of transport as well as on the distance to be covered, e.g. long- or short-distance transport.

In the sub-model transport, three types of transportation are distinguished: the domestic transport of passengers and goods, and the international transport by air and water. (A sub-module permits in addition, if required, a detailed analysis of urban passenger transport.) In the module 'domestic transport of passengers' three transportation categories are distinguished: the domestic airplane transportation, the individual and public transport. The traffic related with the different transportation categories is set in dependence on the economic activities of the sector (airplanes); the individual income and infrastructural characteristics (individual transport); and a general requirement factor (public transport). The transportation modes are characterized by the capacity (e.g. number of vehicles, number of seats in railways and airplanes), the utilisation rate (e.g. distance covered, occupancy) and the types of energies used (e.g. electricity, gasoline, diesel). The traffic is expressed in either vehicle-kilometers, seat-kilometers, or passenger-kilometers.

The energy consumption in good transportation is determined by ton-kilometers per mode of transportation, e.g. trucks, railways, barges, for long-distance transport and vehicle-kilometers for short-distance, the transportation park, the load capacity, and the specific energy requirement per mode of transportation.

e) Tertiary sector

This sector is difficult to define as it groups together a multitude of often heterogeneous activities. The module considered in MEDEE-S distinguishes between two major uses: specific electricity use, and fossil fuels for thermal uses. However, the module renders a breakdown possible into different end-use categories, such as hotels, commercial establishments, small enterprises, etc., if the data situation permits.

## 3. The Industrial Sector of MEDEE-S

The disaggregation of the MEDEE-S model into five economic sectors follows the conventions and definitions commonly in use. The industrial sector encompasses in this context the classical sub-sectors 'mining' and 'manufacturing' as well as the sector 'electricity, gas and water'. Whereas the energy consumption of the mining and manufacturing sector is analyzed and modeled, the energy consumption of the energy sector is not considered separately since it is accounted for in the conversion from final to primary energy.

Given the frame of the industrial sector, the number of sub-sectors is not fixed a priori, but kept flexible and adaptable to the situation of the country under study. However, certain odds are given in the industrial sub-model, the way, that the industrial sector is subdivided according to concentrations of energy consumption into three modules:

- basic,
- iron and steel, and
- large energy consumer.

The disaggregation has been chosen in order to simulate different alternative scenarios of energy intensive branches consistent with the long-term political strategy set for the industrialization process.

The basis for the determination of energy consumption is different for each module. In the basic module energy consumption is basically related to the economic performance (or value added) of the respective branch. In both other sectors the basic element are physical units of production.

### 3.1 The Basic Module

#### 3.1.1 The Determinants of the Module

For each branch of the basic module, energy consumption is determined homogenously at the final (or useful) energy level. The core elements of the equations that calculate energy consumption per sub-sector, are the economic performance per sub-sector (value added), the energy intensity and structural and technical indices.

The energy intensity is a measure to determine specific unitary energy requirements and is derived dividing in the initial year the energy consumption of a selected branch by the respective value added.

The structural index pays regard to the effects resulting from changes in the organization of the industrial sector. These effects might emerge from political decisions to favour the development of one branch vis-a-vis another branch or dictated from the global economic situation.

The technical index takes into consideration the improvement of technical know-how and the progress of technology.

Although the distinction of both effects is difficult to make, as they overlap, but with reference to the enhance efforts undertaken in this field, respective consideration of both effects is already made in the industrial sub-model.

In order to consider the energy use in different production processes and the substitution possibilities adequately, energy consumption is not treated as a whole, but disaggregated according to the use into:

- specific electricity,

- fossil fuels, and

- energies for thermal processes.

The use of electricity and fossil fuels are bound to respective processes, e.g. electricity for the electro-chemical process and fossil fuels as motor fuels, thus representing non-substitutable energy forms. The calculation of energy consumption in these cases is carried out on the final energy level. Greater emphasis is devoted to energies for thermal use. This consumption calculation is done on the useful energy level thus offering the chances for adequate consideration of fuel substitution possibilities.

Owing to the disaggragation of energy uses, the energy intensities are changed in the following terms. For each energy use, e.g. electricity, fossil fuels and thermal use, the energy intensities are derived dividing the consumption of the respective fuels in the initial year by the value added of the industrial sub-sector under study.

The mathematical linkage of the elements previously introduced (value added, energy intensity per energy use, structural and technical indices), determine the energy consumption per energy use in one sector for the initial year.

Predominantly the facts that the traditional structure of the industry in LDC's is quite vulnerable to global upheavals and the industrialization process is not yet terminated, made plain that value added cannot be extrapolated from past trends Therefore, the evolution of value added per sub-sector is treated as scenario variable. The structural and technical indices are treated as scenario variables as well.

### 3.1.2 Penetration of Energies in Thermal Processes

To consider in an appropriate way the substitution possibilities of energies in thermal processes, two alternative approaches are implemented in the industrial sub-model:

- the penetration of energies in dependence of the temperature level but independent of branches, and

- penetration of energies per sub-sector but independent of the temperature level.

a) Penetration of energies in dependence of temperature level but independent of branches

The analysis of energy needs on temperature levels is indispensable if the penetration of new energies substituting for fossil fuels are to be considered appropriately.

In the basic module of MEDEE-S, three temperature levels are considered for each branch:

- low temperature,

- medium temperature, and

- high temperature.

The consumption of energy in low and medium temperature processes is mainly required for the production of warm water and steam. The energy used for high temperature processes corresponds to the direct use of energy in ovens.

The penetration rate of new energies and technologies on each temperature level has a twin effect on the energy mix of the sub-sector under study, the first calls for the replacement of fossil fuels by new energies or techniques, the second leads to a reshuffling of the remaining 'traditional' fuels.

The sub-module considers five different new energies and technologies, each characterized by the temparature level for which a penetration is conceivable during the next twenty to thirty years:

- low temperature level
  . direct electricity use
  . heat pumps
  . solar energy
  . district heat
  . co-generation

- medium temperature level
  . direct electricity use
  . heat pumps
  . district heat
  . co-generation

- high temperature level
  . direct electricity use

The penetration rate of each new energy and technology on the specific temperature level is specified in a scenario.

The reshuffling of the remaining traditional energies (or the penetration of selected traditional energies) is undertaken on the following basis:

- For selected traditional energies which are considered important for the future energy mix of the country under study, the rate of penetration is subject to scenario specifications.

- For those fuels not substitutable by new energies (and technologies) and not considered important for future use, the rate of penetration is oriented on the share of these fuels in the initial year.

b) Penetration of energies per sub-sector but independent of the temperature

Owing to the fact that quite often information with regard to energy consumption on different temperature levels is limited available in LDC's, the sub-module has the option to determine useful energy demand per sub-sector independent from the temperature level. The underlying mathematical calculation per branch relates value added, useful energy intensity and structural and technical indices in order to derive useful energy consumption.

## 3.2 The Iron and Steel Module

The energy consumption in the iron and steel sector is calculated on the basis of physical units. The module considers three production processes:

- production of cast-iron in blast-furnaces,

- production by direct reduction, and

- scrap-iron melting in electric ovens.

The central element for the calculation of energy consumption is the volume of steel production which can be modelled either on the basis of domestic demand for steel or is treated as scenario variable.

The energy consumption for each process is derived linking the specific unitary energy requirements per unit of steel production and the volume of steel produced. The evolution of the distribution of steel production among the production processes is determined in scenarios in order to pay respective attention to future industry policies. The evolution of the specific energy requirements per unit of steel are determined endogenously on the basis of the structural and technical indices as defined in the basic module. Specific emphasis is devoted to coke in blast furnaces, substitutive fuels for coke and gas injection for the direct reduction process which are treated as scenario variables.

## 3.3 The Large Energy Consumer-Module

Here, as well as in the basic module, the number of sub-sectors is not defined a priori but kept flexible to the industrial system of the country under study.

Likewise to the iron and steel industry, the central elements of the sub-sectors are physical units of production which are either treated as scenario variables or determined on the basis of consumption requirements
For the calculation of energy demand, three energy uses are considered·

- specific electricity use,
- non energy uses, and
- thermal use.

In case of specific electricity and non-energy use, final energy demand is derived by linking the specific consumption of this fuels per production process to the amounts produced.

The energy demand in thermal uses is calculated on the useful energy basis, split according to the energies used and converted into final energy.

The penetration rate of new energies and technologies is modelled in the same way as described in section 3.1.2.

## 4. Information Systems of African Countries

Lately, the Special Advisory Group for Energy of the United Nations Industrial Development Organization (SAGE/UNIDO) carried out a state-of-the-art survey on the information systems and prospects of the energy and industry sector in African countries.

The results are documented in a report entitled 'Information survey for a study of the present and future energy situation in Africa and its implication for the industrial development'.

As it is stated in the report: 'In order ...to initiate Integrated Energy/Industrial Planning activities it is essential that specific energy and non energy data ... are available. These data should cover the energy system itself and its interactions with the other determinants of the national development'.

In order to systemize the available information and place them in a format suitable for energy and industry policy projects, UNIDO developped a basic information sheet which is presented in table 2.

International organizations, e.g. United Nations Statistical Office, World Bank, International Atomic Energy Agency, to name a few, provide useful information on the energy, economic and, to a certain extent, socio-economic system of sub-Saharian countries. However, the information is often incomplete and not compatible. Whereas on the macro level (that is for the economy: Gross National or Domestic Product, imports, exports, gross fixed capital formation, etc.; and for the energy sector: production, imports, exports, refinery output, electricity parameters, etc.), the data situation appear to be sufficient for gross analyses, it is mostly inadequate on the micro level (e.g. for the energy sector: consumption per sector and fuel type; for the economy: income distribution according to social classes). The situation might be gradually different if national sources are considered as sometimes information is collected and processed by individual independent national organizations but not channeled to the respective national or international statistical bureaus. Information of the socio-economy (e.g. fuel preferences for cooking, occupancy ratio in public transportation, etc.), however, are generally difficult to retrieve from either sources.

The UNIDO report displays in the respect an illustrative example: The United Nations Yearbook of Industrial Statistics provides specific information about the nature and importance of industrial activities carried out in countries. But the unsatisfactory reporting practice of countries render a fragmentary picture of commodity production (table 3).

## 4. Conclusive Remarks

Although the MEDEE-S model is kept simple and transparent in structure, the amount of data required for successful usage of the model seem not to match with the general information pattern existent in most of sub-Saharian countries let alone the more specific information on the industry and the socio-economy. A further problem is to be seen in the focus of the industrial sub-module on large energy intensive industries whereas the core of the industrial structure in sub-Saharian countries consists of small-scale industries and 'one-man' enterprises.

Therefore, in case that models like MEDEE-S are considered an appropriate tool to determine energy consumption in sub-Saharian countries, special emphasis should be devoted to

- the adaptation of the model on local facts, and

- the improvement of the information system.

In order to avoid an academic exercise, a country should be selected as case example.

Table 2

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BASIC INFORMATION

REQUIRED FOR ENERGY-INDUSTRY STUDIES

I. Population

1. National statistics for the last decade
   - a. Population, distribution in rural and urban areas
   - b. Official population projections up to 2000
   - c. Total labor force
   - d. Labor force in industry
2. Regional distribution and population density

II. Economic Information from National Accounts

1. Gross Domestic Product (GDP) in constant prices;
2. GDP originating in Agriculture
3. GDP originating in Mining and Quarrying
4. GDP originating in Manufacturing
5. GDP originating in Construction
6. GDP originating in Electricity and Gas (Utilities);
7. GDP originating in Services
8. Exchange rates

III. Energy balance data

1. Househould energy consumption
2. Transport Energy consumption
3. Agriculture Energy consumption
4. Production of commercial and traditional energy
5. Energy import and exports
6. Efficiences of the energy transformation centers, e.g. refineries, conventional power plants, charcoal plants, losses, etc.

IV. Energy resources.

(Table 2 continues on next page)

(Table 2 continuation)

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V. <u>Industry related information</u>

A. Basic data

1. Output of:

   a) Energy intensive products (compatible with 6 digits ISIC based code) in tones per year and/or value added, e.g.:

      - steel (steel ignots ISIC 371016, 371017);
      - non-ferrous metals (primary copper ISIC 3720041, primary aluminium ISIC 3720221, primary zink ISIC 3720431);
      - non-metalic mineral products (quicklime ISIC 369201, cement ISIC 369204)
      - pulp and paper products (pulp sulfite ISIC 341110, pulp sulfate ISIC 341113);
      - chemicals (amonia ISIC 351158, caustic soda ISIC 351159, calcium carbide ISIC 351173, methanol ISIC 351121, acetylene ISIC 351105, nitrogenous fertilizers ISIC 351201)
      - textiles;
      - food-processing;
      - others.

2. Growth rate indexes for the sectors and commodities as of above.

3. Sectorial consumption of final energy forms, e.g. coal, natural gas, residual oil, electricity, bagasse, etc. based on national statistics or surveys.

B. Additional indicators

1. Energy intensities of the produced commodities,expressed either as ratio of the total energy per ton of output ( value added ) or as ratio of liquid fuels, electricity, and solid fuels per ton output (value added ).

3. Types of technologies used in the production of energy intensive commodities, e.g. iron, cement, etc.

4. Specific plans for new capacities in each industrial sector .

5. Structure of production and estimated output of the small and rural enterprises, their geographical distribution and the energy inputs used.

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Table 3

| COUNTRY (Commodity / ISIC code) | Cotton yarn 321109 | Cotton fabric 321128 | Acetilene 351105 | Nitrogenous fertiliser 351201 | Super phosphates 351204 | Building bricks 369101 | Cement 369204 | Soap 352301 | Crude steel ignots 371019 |
|---|---|---|---|---|---|---|---|---|---|
| Angola | | | | | | | | | |
| Benin | | | | | | | yes | | yes |
| Burundi | | | | | | | part. | | |
| Cameroon | | | part. | part | part. | | yes | yes | |
| Cape Verde | | | | | | | yes | yes | |
| Centr.Afr.Rep. | | yes | | | | | yes | | |
| Chad | | yes | | | | | | | |
| Congo | | | yes | | | | yes | yes | |
| Eq.Guinea | | | | | | | | | |
| Ethiopia | yes | yes | | | yes | | yes | yes | |
| Gabon | | | part. | | | | yes | yes | |
| Gambia | | | | | | | yes | | |
| Ghana | | yes | | | | | | yes | |
| Guinea | | | | | | | | | |
| Guinea Bissau | | | | | | | | | |
| Ivory Coast | part. | part. | part. | yes | yes | part | yes | part | |
| Kenya | yes | yes | | | | yes | yes | yes | |
| Liberia | | | | | | | yes | part. | |
| Madagascar | | yes | part. | | | | yes | yes | |
| Malawi | | | | | | | yes | | |
| Mali | | | | | | | yes | part. | |
| Mauritius | | | | yes | | | | | |
| Mozambique | | | part. | yes | yes | | yes | part. | |
| Namibia | | | | | | | | | |
| Niger | | yes | | | | yes | yes | yes | |
| Nigeria | part. | part. | | | yes | | yes | part. | yes |
| Rwanda | | | | | | | | part. | |
| Senegal | yes | yes | yes | yes | yes | | yes | yes | |
| Seychelles | | | | | | | | part. | |
| Sierra Leone | | | | | | | | | |
| Sudan | | | | | | | yes | part. | |
| Swaziland | | part. | | | | | | | |
| Tanzania | | yes | | yes | | | yes | part | |
| Togo | | part. | | | | yes | yes | | |
| Uganda | | yes | | | yes | | yes | yes | yes |
| Upper Volta | yes | | | | | yes | | yes | |
| Zaire | | yes | part. | | | | yes | part. | |
| Zambia | | yes | yes | yes | | | yes | yes | |
| Zimbabwe | | | | yes | yes | yes | yes | | yes |

Source: UN Yearbook of Industrial Statistics 1981 Edition

Table 12. UN-Reporting practice for the energy intensive products
yes - uninterrupted time series
part.- interrupted time series

# APPENDIX

1) The equations of the industrial sub-model in MEDEE-S

2) List of variables of the industry sector in MEDEE-S

3) Bibliography

# The equations of the industrial sub-model in MEDEE-S

A - Le sous modèle de base

La variable de commande "NSUBST" définit le nombre de branches considérées dans le secteur industriel.

Trois usages sont distingués : carburants ; usages spécifiques de l'électricité ; usages thermiques concurrentiels.

1 - Carburants :

$$mfman = \sum_{isub} mfbyin\ (isub) \times mfcyin \times stmfcy(isub) \times ysubst\ (isub)/u$$

avec :
mfman : demande totale de carburant pour l'industrie (unité du modèle)
mfbyin (isub): contenu énergétique ($10^3$ kcal/$VA) pour l'usage "carburants" pour l'année de base et la branche isub

(mfbyin (isub) = ffbyin (isub) x (pmfin (isub), avec :
ffbyin(isub): contenu énergétique "combustibles + carburants"
pmfin (isub): part des carburants dans le total "combustibles carburants" pour la branche isub.

stcyimf (isub) : indice d'évolution par branche du contenu énergétique pour l'usage "carburants" (mesure l'évolution tendancielle et intègre les substitutions électricité/carburants pour la force motrice).

mfcyin : taux d'économies d'énergie pour les usages carburants (mesure en indice) ; représente l'évolution liée au progrés technique ("effet technique") non prise en compte par l'effet de structure stmfcy

ysubst (isub) : valeur ajoutée de la branche isub ($10^9$)

u : coefficient de passage à l'unité du modèle.

2 - Usages spécifiques de l'électricité :

$$elsman = \sum_{isub} elbyin\ (isub) \times elcyin \times stelcy\ (isub) \times ysubst\ (isub)$$

avec :

- elsman : demande totale d'électricité à usages spécifiques pour le secteur industriel (TWh)
- elbyin (isub) : contenu énergétique (kWH/$VA) pour les usages spécifiques de l'électricité pour l'année de base et la branche isub
- stelcy : indice d'évolution par branche du contenu énergétique pour les usages spécifiques de l'électricité (mesure l'évolution tendanciell
- elcyin : taux "d'économies d'énergie" pour les usages spécifiques de l'électricité (mesuré en indice) ; représente l'évolution liée au progrés technique ("effet technique") en sus de la tendance prise en compte par stelcy

3 - Usages thermiques concurrentiels :

Sources d'énergie considérées :

- combustibles (par type)
- énergies et techniques nouvelles
  - électricité
  - pompe à chaleur
  - solaire
  - production combinée
  - réseau de chaleur (géothermie, rejets thermiques...)

Deux cas de calcul : selon que les pénétrations des différentes sources d'énergie sont définies :

- par niveau de température (BT : basse température ; MT : moyenne température ; HT : haute température) et indépendemment de la branche (moyenne tous secteurs)
- par branche

L'utilisateur définit pour la variable de commande OPIND le cas de calcul choisi :

OPIND = 1 : niveau de température (variante 1)

OPIND = 2 : secteur (variante 2)

La demande est d'abord calculée en énergie utile (demande totale), puis ventilée entre les différentes sources et enfin transformée en énergie finale.

### 3.1 - Calcul de l'énergie utile totale

OPIND = 1 : variante 1 "pénétration par niveaux de température"

Trois niveaux de température sont considérés, repérés par l'indice "iproc" (iproc = 1 Basse Température ; iproc = 2 Moyenne température...)

$$\text{usindp (iproc)} = \sum_{\text{isub}} (\text{thbyin (isub)} \times \text{thcyin} \times \text{stthcy (isub)} \times \text{ysubst(isub)} \times (\text{pusind (isud , iproc)}/u)$$

avec :

| | |
|---|---|
| usindp (iproc) | : demande totale d'énergie utile par niveau de température iproc (unité modèle) |
| thbyin (isub) | : contenu énergétique pour les usages thermiques pour l'année de base et la branche isub (énergie utile) |

thbyin (isub) = ffbyin (isub) x (1-pmfin (isub)) x rend x effpro (iproc)

avec :

| | |
|---|---|
| ffbyin (isub) | : contenu énergétique "combustibles + carburants" pour l'année de base("énergie finale) |
| pmfin (isub) | : part des carburants dans ffbyin (isub) (année initiale) |
| effpro (iproc) | : indice relatif du rendement des combustibles pour le niveau de température iproc par rapport au niveau de température de référence choisi par l'utilisateur (=1 par définition pour le niveau de température de référence); ce coefficient permet de calculer un rendement par niveau de température à partir du rendement efcbby (icomb) défini comme référence |
| rend | : rendement moyen des combustibles pour l'année de base |

$$rend = \sum_{icomb} pcbby\ (icomb) \times efcbby\ icomb$$

efcbby (icomb) : rendement du combustible icomb pour le niveau de température de référence

pcbby (icomb) : part du combustible icomb pour l'année de base

thcyin : indice d'évolution technique du contenu énergétique (mesure les économies d'énergie

stthcy (isub) : indice d'effet de structure de l'évolution du contenu énergétique pour les usages thermiques (mesure l'évolution tendancielle

ysubst (isub) : valeur ajoutée de la branche isub

pusind (isub,iproc) : par des usages selon niveau de température iproc dans la branche isub

$$\sum_{iproc} pusind\ (isub,\ proc) = 1$$

$$usind = \sum_{iproc} usindp\ (iproc)$$

usind : demande totale d'énergie utile pour les usages thermiques concurrentiels dans l'industrie (unité du modèle)

<u>OPIND = 2</u> : Variante 2 "pénétration par branche"

$$usindp\ (isub) = thbyin\ (isub) \times thcyin \times stthcy\ (isub) \times ysubst\ (isub)/u$$

<u>avec</u> : usindp (isub) : demande totale d'énergie utile pour la branche isub

thbyin (isub) : contenu énergétique pour les usages thermiques pour l'année de base et la branche isub (énergie utile)

$$thbyin\ (isub) = ffbyin\ (isub) \times (1-pmfin\ (isub)) \times rend\_su\ (isub)$$

<u>avec</u> : rendsu (isub) : rendement moyen des combustibles dans le branche isub

$$usind = \sum_{isub} usindp\ (isub)$$

## 3.2 Partage de l'énergie utile entre les différentes sources d'énergie

La pénétration des énergies et techniques nouvelles est définie par scénario ; la part globale des combustibles est calculée par différence (part non couvert par les énergies et techniques nouvelles)

### 3.2.1 Part des énergies et techniques nouvelles

OPIND = 1 : variante 1 "pénétration par niveau de température"

- électricité : une variable de scénario (elpind) par niveau de température :
  pelind (iproc) = elpind (iproc), iproc = 1, 2, 3

- pompe à chaleur : une variable de scénario : hpi
  phpind (1) = hpi (BT)
  (2) = hpi (MT)
  (3) = 0 (HT)

- réseau de chaleur : une variable de scénario : idh
  pdhind (1) = idh
  - idh
  0

- solaire : pssind (1) = splt x fids
  (2) = 0
  (3) = 0

- production combinée : une variable de scénario : icogen
  pcgind (1) = icogen
  (2) = icogen
  (3) = 0

<u>OPIND = 2</u> : variante 2 "pénétration par branche"

L'utilisateur définit par les variables de commandes :

- nsubel et lsubel,
- nsubss et lsubss,
- nsubcg et lsubcg,

respectivement le nombre et la liste des branches où pénètrent :

- l'électricité
- le solaire et les pompes à chaleur,
- la production combinée et les réseaux de chaleur.

le modèle lit :

- pelind (isub) , $\forall$ isub $\in$ esubel
- phpind (isub) , $\forall$ isub $\in$ esubss
  pssind (isub)
- pcgind (isub) , $\forall$ isub $\in$ lsubcg
  pdhind (isub)

### 3.2.2 <u>Calcul de la contribution des combustibles</u>

remarque : calcul commun aux deux variantes et qui porte sur l'indice itrav

itrav $\in$ (1, nproc) si OPIND = 1
itrav $\in$ (1, nsubst) si OPIND = 2

<u>Part globale des combustibles</u> :

pffind (itrav) = 1 - (pelind (itrav) + phpind (itrav) + pssind (itrav) + pcgind (itrav) + pdhind (itrav))

Partition entre les différents combustibles considérés

La partition pour chaque année de calcul est réalisée sur la base de deux éléments :

- la structure initiale (définie en énergie finale, pour simplifier l'entrée des données)

  OPIND = 1 : structure par combustible

  OPIND = 2 : structure par combustible et par branche

- la part définie par scénario des combustibles stratégiques (énergie utile)

La contribution des combustibles stratégiques est donc définie par une variable de scénario ; celle des combustibles secondaires est calculée par solde et en transportant la structure initiale des combustibles résiduels (voir figure 4 du papier de description de ce sous-modèle)

OPIND = 1 :

La structure initiale est définie par combustible et en énergie finale : pcbby[1] (icomb)

On transforme cette structure en une structure en énergie utile :

$$\text{pcbby 1 (icomb)} = \frac{\text{pcbby 1 (icomb) x efcbby (icomb)}}{\sum_{\text{icomb}} \text{pcbby 1 (icomb) x efcbby (icomb)}}$$

avec : efcbby (icomb) : rendement du combustible icomb pour l'année de base

OPIND = 2

La structure initiale est définie par combustible et par branche en énergie finale : pcbby 2 (icomb, isub)

On réalise la même opération de transformation .

L'opération de partition est la même pour les deux cas de calcul*. La part des combustibles stratégiques pcbcy (icomb, itrav) est une variable de scénario pour toute valeur de icomb correspondant à un combustible stratégique

on lit donc pcbcy (icomb, itrav), variable de scénario, $\forall$ icomb $\in$ lcbsn. Soit lcbcte la liste des combustibles secondaires, la part totale des combustibles secondaires s'écrit :

$$pcte = 1 - \sum_{icomb} pcbcy\ (icomb,\ itrav),\ icomb \in lcbsn$$

On calcul alors la part de chaque combustible secondaire de la manière suivante**:

$$pcby\ (icomb,\ itrav) = pcte \times \frac{pcbby\ 1\ (icomb,\ itrav)}{\sum_{icomb \in lcbcte} pcbby\ 1\ (icomb,\ itrav)}$$

* l'indice de calcul "itrav" représente tantôt 'iproc" (OPIND = 1), tantôt "isub" (OPIND = 2)

** pour la variante 1 (OPIND = 1) cette part n'est pas fonction de itrav et l'on calcul directement pcby (icomb)

### 3.3 Calcul de l'énergie finale

Le calcul est commun aux deux variantes avec l'indice de travail itrav

itrav $\in$ (1, nproc) si OPIND = 1
itrav $\in$ (1, nsubst) si OPIND = 2

Production combinée

cogsub (itrav) = pcgind (itrav) x usindp (itrav)
cgelsu (itrav) = cogsub (itrav)/helrat

avec : helrat : ratio entre la vapeur produite par cogénération et l'électricité autoproduite (sans dimension)

Electricité

elhsub (itrav) = - cgelsu (itrav) + (pelind (itrav) + phpind (itrav)/hpi) x (usindp (itrav)

avec : effhpi : coefficient de performance des pompes à chaleur par rapport au rendement de l'électricité.

cgelsu (itrav): électricité générée par la production combinée.

Réseau de chaleur

dhsub (itrav) = pdhind (itrav) x usindp (itrav)

Solaire

solsub (itrav) = pssind (itrav) x usindp (itrav)

Combustibles

énergie utile totale

ffusub (itrav) = cogsub (itrav) + pffind (itrav) x usindp (itrav)

partage des combustibles, passage à l'énergie finale

OPIND = 1

ffcbsu (icomb, itrav) = ffusub (itrav) x pcbcy (icomb, itrav)/(efcbby (icomb)
(efcbcy x effpro (itrav))

OPIND = 2

ffcbsu (icomb, itrav) = ffusub (itrav) x pcbcy (icomb, itrav)/(efcbby (icomb)
(efcbcy)

$$\text{ffsub (itrav)} = \sum_{\text{icomb}} \text{ffcbsu (icomb, itrav)}$$

$$\text{ffcomb (icomb)} = \sum_{\text{itrav}} \text{ffcbsu (icomb, itrav)}$$

4 - Matières premières

Ce calcul ne doit tenir compte que des usages non énergétiques non couvert par les sous-modèles annexes) fdman = feedby x feedcy x yind

avec : feedby : contenu énergétique pour les matières premières pour l'année de base ($10^3$ kcal/\$VA)

feedcy : indice d'évolution du contenu énergétique

yind : valeur ajoutée industrielle ($10^9$ \$)

5 - Agrégats

$$\text{elhman} = \sum_{\text{itrav}} \text{elhsub (itrav)}$$

(demande en électricité pour usages thermiques dans le secteur industriel)

$$\text{dhman} = \sum_{\text{itrav}} \text{dhsub (itrav)}$$

(demande totale pour les réseaux de chaleur)

$$\text{solman} = \sum_{\text{itrav}} \text{solsub (itrav)}$$

(demande totale pour les systèmes solaires)

$$\text{ffman} = \sum_{\text{itrav}} \text{ffsub (itrav)}$$

(demande totale en combustibles)

elman = elhman + elsman x 0,86/u

(demande totale en électricité)

thman = elhman + dhman + solman + ffman

(demande totale pour usages thermiques)

finman = mfman + elsman x 0,86/u + thman

(demande totale pour le module de base du secteur industriel)

## B - Sous modèle annexe :"Industries grosses consommatrices d'énergie"

La variable de commande NBIGCE indique le nombre de produits gros consommateurs d'énergie considérés.

### 1 - Détermination de la production

Pour chaque produit, il est possible de choisir entre deux variantes de calcul définies par la variable de commande OPIGCE

- OPIGCE = 1 : la production est donnée directement par scénario
- OPIGCE = 2 : la production est déduite de la consommation et d'un taux d'importation du produit ; la consommation est calculée à partir de la consommation du produit pour l'année de base, et de l'évolution d'agrégats macro-économiques.

Calcul de la consommation :

consgc (iprod) = cbyrgc (iprod) x ccyrgc (iprod) x coefva

avec :

| | | |
|---|---|---|
| consgc (iprod) | : | consommation totale du produit iprod ($10^6$) |
| cbyrgc (iprod) | : | consommation du produit iprod, pour l'année de base et par unité de coefva |
| ccyrgc (iprod) | : | indice d'évolution de cbyrgc (iprod) |
| coefva | : | agrégat macro-économique qui peut être choisi parmi les éléments suivants et selon la variable de commande igceva |

igceva = 1 : y (PIB)
= 2 : po (population)
= 3 : y/po
= 4 : yagri (valeur ajoutée pour l'agriculture)
= 5 : ybuild (valeur ajoutée pour la construction)

Déduction de la production

prodgc (iprod) = consgc (iprod) x (1 - impgc (iprod))

avec : prodgc (iprod) : production du produit iprod ($10^6$t)

impgc (iprod) : taux d'importation du produit iprod

2 - Partition de la production par procédés :

Pour chaque produit, un ou deux procédés* de fabrication peuvent être considérés auxquels seront affectés des consommations spécifiques d'énergie propres. La variable de commande nprogc indique le nombre de procédés retenus.

nprogc (iprod) = 1 : pproc (1) = prodgc (iprod)

pproc (2) = 0

nprogc (iprod) = 1 : pproc (1) = prodgc (iprod) x prolgc (iprod)

pproc (2) = prodgc (iprod) x (1-prolgc (iprod))

avec : pproc (iproc) : production du produit par le procédé iproc ($10^6$t)

prolgc (iprod) : part de la production du produit iprod assurée par le procédé 1

3 - Calcul de la demande :

Trois grands usages d'énergie sont considérés :

- électricité spécifique
- matières premières
- combustibles (= usages thermiques couverts par des combustibles)

* ce nombre de procédés peut facilement être augmenté

3.1 Electricité spécifique :

$$\text{elgc (iprod)} = \sum_{\text{iproc}} \text{csel (iprod, iproc)} \times \text{pproc (iproc)} \times 10^{-3}$$

avec : elgc (iprod) : consommation totale d'électricité à usage spécifique pour la fabrication du produit iprod (TWh)

csel (iprod,iproc) : consommation spécifique d'électricité pour le produit iprod, par le procédé iproc (kwh/t)

3.2 Matières Premières :

$$\text{feedgc (iprod)} = \sum_{\text{iproc}} \text{csfeed (iprod, iproc)} \times \text{pproc (iproc)} \times 10^{-3}/u$$

avec : feedgc (iprod) : demande totale de matières premières pour la fabrication du produit iprod (unité du modèle)

csfeed (iprod iproc) : consommation spécifique de matières premières pour le produit iprod, par le procédé iproc ($10^3$kcal/t)

3.3 Combustibles : (usages thermiques couverts par les combustibles)

La demande totale d'énergie thermique couverte par des combustibles est calculée en énergie utile, puis ventilée entre les différents combustibles et enfin transformée en énergie finale. Au préalable ce calcul est fait pour l'année initiale pour convertir les données exprimées en énergie finale en termes d'énergie utile ; ce calcul permet de définir la consommation en énergie utile pour l'année initiale et la contribution de chaque combustible

3.3.1 Calcul à l'année initiale

Deux variantes définies par la variable de commande OPCBBY peuvent être

Considérées :

- OPCBBY = 1 : la structure initiale des combustibles utilisée dans le sous-modèle de base est reprise. Cette structure définie dans ce fichier a été transformée dans le sous-modèle de base en une structure en énergie utile.

- OPCBBY = 2 : la structure initiale est spécifiée par produit ; elle est donnée en énergie finale et est transformée en une structure en énergie utile dans le sous-modèle.

Les deux variantes visent à tenir compte des différents niveaux de connaissance des consommations par branche industrielle. Dans la première variante (OPCBBY = 1), on suppose que l'on ne connait pas la répartition de la consommation de combustibles par type de combustible.

Il s'agit de déterminer les variables pcbby (icomb) pour icomb = 1,... ncomb et rend, qui représentent respectivement la part (en énergie utile) du combustible icomb dans la consommation d'énergie thermique couverte par des combustibles à l'année de base et le rendement moyen tous combustibles pour l'année de base.

- OPCBBY = 1 : reprise des parts de combustibles calculées du sous-modèle de base.

  • OPIND = 1 : variante 1 "pénétration par niveaux de températures"

Les variables disponibles sont :

- pcbby 1 (icomb) pour icomb = 1,... ncomb : part du combustible icomb dans la demande (énergie utile) pour l'année de base (calculée dans le sous-modèle de base).
- efcbby (icomb) pour icomb = 1,...ncomb : rendement du combustible icomb pour l'année de base.

On calcule alors :

pcbby (icomb) = pcbby 1 (icomb)

$$\text{rend} = \sum_{\text{icomb}} \text{pcbby (icomb)} \times \text{efcbby (icomb)}$$

- OPIND = 2 : variante 2 "pénétration par branche"

Les variables disponibles sont :

- pcbby 2 (icomb, inb) pour icomb = 1, ... ncomb et isub = 1,... nsubst : part en énergie utile du combustible icomb dans la demande pour la branche isub et pour l'année de base.
- ffusub (isub) pour isub = 1, nsubst : demande en énergie thermique couverte par des combustibles pour les branches isub (énergie utile)
- efcbby (icomb), icomb = 1, ncomb

On calcul alors :

$$\text{pcbby (icomb)} = \sum_{\text{isub}} \text{pcbby 2 (icomb, isub)} \times \frac{\text{ffusub (isub)}}{\sum_{\text{isub}} \text{ffusub (isub)}}$$

$$\text{rend} = \sum_{\text{icomb}} \text{pcbby (icomb)} \times \text{efcbby (icomb)}$$

Ce calcul est mené uniquement pour l'année de base.

En particulier, ffusub représente bien dans le calcul la demande en énergie utile pour l'année de base.

- OPCBBY = 2 : une structure initiale spécifique est donnée pour le produit considéré

Les variables disponibles sont :

- pcbygc (iprod, icomb) pour icomb = 1, .. ncomb : part du combustible icomb dans la consommation de combustibles pour le produit iprod et pour l'année de base énergie finale.
- efcbby (icomb)

On calcule alors :

$$pcbby\ (icomb) = \frac{pcbygc\ (iprod,\ icomb) \times efcbby\ (icomb)}{\sum_{icomb} pcbygc\ (iprod,\ icomb) \times efcbby\ (icomb)}$$

$$rend = \sum_{icomb} pcbby\ (icomb) \times efcbby\ (icomb)$$

### 3.3.2 Calcul de la demande d'énergie thermique couverte par des combustibles (en énergie utile) :

$$ffutil\ (iprod) = \sum_{iproc} csffby\ (iprod,\ iproc) \times rend \times csffcy\ (iprod,\ iproc) \times (pproc\ (iproc) \times 10^{-3}/u$$

avec :

| | |
|---|---|
| csffby (iprod, iproc) | : consommation spécifique de combustibles pour le produit iprod pour le procédé iproc et pour l'année de base (énergie finale ; 103kcal/t) |
| rend | : rendement moyen des combustibles pour l'année de base |
| csffcy (iprod, iproc) | : indice d'évolution de la consommation spécifique csffby (iprod, iproc |
| pproc (iproc) | : production du produit iprod par le procédé iproc ($10^6$t) |
| ffutil (iprod) | : demande totale de combustibles pour la fabrication du produit iprod (unité modèle) |

### 3.3.3 Projection du partage entre les différents combustibl

Le même principe que celui adopté dans le sous-modèle de base est utilisé. Les combustibles stratégiques sont les mêmes que pour ce module.

### 3.3.4 Passage à l'énergie finale :

ffgcpd (iprod, icomb) = ffutil x pcbgc (iprod, icomb)/(efcbby (icomb) x (efcbcy

**avec :**

| | |
|---|---|
| ffgcpd (iprod, icomb) | : demande du combustible icomb dans la fabrication du produit iprod (énergie finale, unité du modèle) |
| ffutil | : demande totale de combustibles pour la fabrication du produit iprod (énergie utile) |
| pcbgc (iprod, icomb) | : part du combustible icomb dans le total des combustibles. le produit iprod. (part d'énergie utile) |
| efcbby (icomb) | : rendement du combustible icomb pour l'année de base. |
| efcbcy | : indice d'évolution du rendement des combustibles. |

$$ffgc\ (iprod) = \sum_{icomb} ffgcpd\ (iprod,\ icomb)$$

**avec :**

| | |
|---|---|
| ffgc (iprod) | : demande totale de combustibles pour la fabrication du produit iprod (énergie finale ; unité du modèle) |

The list of variables of the industry sector in MEDEE-S

## List of variables of the MEDEE-S model

### Industry

### 1. Basic variables

#### Basic Module

| | |
|---|---|
| ELBYIN(i) | energy intensity of electricity use in sector i (electricity consumption per unit of value added, kwh/$ VA) |
| FFBYIN(i) | energy intensity of solid fuels use in sector i (consumption of solid fuesl per unit of value added, 1000 kcal/$ VA) |
| FUSIND(i,j) | Distribution of competitive thermal use per sector i and temperature level j |
| FEEDBY | energy intensity of raw materials per unit of production (1000 kcal/ton) |
| EFCBBY(icomb) | index of efficiency of solid fuel icomb |
| PCBBV1(icomb) | share of solid fuel icomb in competitive thermal use (final energy) |
| EFFPRO(j) | index of efficiency of solid fuels on temperature level j relative to the reference temperature niveau which is set equal to 1 |
| PCBBY2(icomb,i) | share of solid fuel icomb in thermal usage in sector i |

#### Iron and Steel Industry

| | |
|---|---|
| CBYRST | specific consumption of steel per unit of GNP,... |
| EISTEE | consumption of thermal energy for steel production per unit of production (1000 kcal /ton) |
| GHF | production of gas per ton of cast-iron in blast-furnace (1000 kcal/ton) |
| EIROLL | consumption of thermal energy for rolled steel per unit of production (1000 kcal/ton) |
| ELIRON | electricity consumption per unit of production in blast-furnace (kwh/ton) |
| ELROLL | electricity consumption per unit of production of rolled steel (kwh/ton) |
| EFSTBY | average efficiency of solid fuels in rolled steel production |
| PGZROL | share of gas in thermal usage for rolling |
| PFUROL | share of fuel oil in thermal usage for rolling |
| PCHROL | share of coal in thermal usage for rolling |
| PGZBOF | share of gas regarding solid fuels used for injection in blast-furnace |

| | |
|---|---|
| PFUBOF | share of fuel oil regarding solid fuels used for injection in blast-furnace |
| PCHBOF | share of coal regarding solid fuel used for injection in blast-furnace |
| ESTEEL(s) | electricity consumption per unit of steel production used in process s |

Large Energy Consumers (per product)

| | |
|---|---|
| CSFEED((iprod,j) | energy consumption of raw materials per unit of production per product iprod and temperature level j (1000 kcal/ton) |
| CSFFBY(iprod,j) | energy consumption of fossil fuels per unit of production iprod and temerature level j (1000 kcal/ton) |

case 2 of the calculation of the production (endogenous calculation):

CBYRGC(iprod) consumption of product iprod per unit of the following macro-economic aggregate igcva

igcva=1 GNP (billion $)
igcva=2 Population (million)
igcva=3 GNP/cap (1000 $/cap)
igcva=4 GNP(agriculture)/value added of the agriculture (billion $)
igcva=5 GNP(construction)/value added of the construction (billion $)

case 2 of the calculation of the initial structure of the solid fuels:

PCBYGC(iprod,icomb) structure of the motor fuels: share of solid fuel icomb on the basis of final energy

2. Exogenous variables

Basic module

| | |
|---|---|
| EFFHPI | coefficient of efficiency of heat pumps |
| FIDS | penetration rate of solar energy for thermal use |
| EFFCOG | global efficiency of cogeneration plants |
| HELRAT | rate of heat/electricity generated in combined production processes |

Iron and Steel Industry

| | |
|---|---|
| EICOK | consumption of coke per unit of cast-iron produced (ton/ton) |
| INJRAT | quantity of energy injected in blast-furnace in the form of fuel oil, gas, ....(1000 kcal /ton) |
| EIRED | consumption of gas per unit of production in the direct reduction processes (1000 kcal/ton) |
| IRONST | ratio cast-iron/steel or iron sponge/steel |

Large Energy Consumers (per product)

| | |
|---|---|
| CSEL(iprod,j) | consumption of electricity per unit of product iprod and temperature level j (kwh/ton) |

3. Scenario variables

Basic module

| | |
|---|---|
| MFCYIN | rate of savings for motor fuels |
| ELCYIN | rate of savings for electricity |
| THCYIN | rate of savings for thermal energy |
| STMFCY(i) | index of the energy content of solid fuel in sector i |
| STELCY(i) | index of the energy content of electricity in sector i |
| STTHCY(i) | index of the energy content of thermal use in sector i |
| FEEDCY | development index of the energy content of raw materials |

case 1 of calculation (if OPIND=1)

| | |
|---|---|
| HPI | penetration rate of heat pumps for thermal uses |
| IDH | penetration rate of district heat for thermal uses |
| SPLT | penetration rate of solar energy for thermal uses |
| ICOGEN | penetration rate of cogeneration heat for thermal use |
| ELPIND(j) | penetration rate of direct electricity for the thermal use at temperature level j |
| PCBCY(s,iproc) | penetration rate of strategy i of solid fuels for thermal use |

case 2 of calculation (if OPIND=2)

for each sector s into which electricity might penetrate

| | |
|---|---|
| PELIND(s) | penetration rate of electricity |

for each sector s into which solar energy or heat pumps might penetrate

| | |
|---|---|
| PSSIND(s) | penetration rate of solar energy |
| PHPIND(s) | penetration rate of heat pumps |

for each sector s into which direct heating systems might penetrate

| | |
|---|---|
| PCGIND(s) | penetration rate of the cogeneration heat |
| PDHIND(s) | penetration rate of district heating systems |

for each sector s

| | |
|---|---|
| PCBCY(s,i) | penetration rate of fossil fuel strategy s |

Iron and Steel Industry

| | |
|---|---|
| RED | share of steel production via direct reduction |
| BOF | share of steel production via blast-furnace or cast-iron processes |
| PEROL | penetration rate of electricity for production of rolled steel |

case 1 calculation of production (OPSTEE=1)

| | |
|---|---|
| PRODST | annual production of steel (million ton) |

case 2 calculation of production (OPSTEE=2)

| | |
|---|---|
| CCYRST | index of steel consumption per unit of GNP, ... |
| IMPST | import/export rate of steel as % of consumption |

Large Energy Consumers

| | |
|---|---|
| PRO1GC(iprod) | share of process 1 in the production of product iprod |
| PDIGCE(iprod) | annual production of product iprod (million ton) |
| CCYRGC(iprod) | index of CBYRGC (see earlier) |

| | |
|---|---|
| IMPGC(iprod) | share of consumption of product iprod covered by imports (or exports) |
| CSFFCY(iprod,j) | index of fossil fuel consumption per unit of product iprod and temperature level j |
| PCBGC(iprod,j) | share of strategic solid fuel icomb per product iprod and temerature level j |

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