Enerdata

# Training Seminar

## Evaluation of energy efficiency trends and potentials

## Grenoble, 30 January – 10 February 2006

## Introduction to end-use models

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## Content


> **End-use models : general aspects**
> Med-Pro: sectoral specifications

## Long term energy forecasting foundations - 1

- **What is « long-term »? It is the time frame necessary to study, decide, implement and pay back the investments on energy supply and energy efficiency: 20 to 30 years**

- **How to characterise « long-term »? It is a time horizon on which the weight of the past and the present situations will be small: existing facilities will have mostly disappear or will be marginal, technology might have completely changed, economic and social structures might have been deeply transformed**



## Long term energy forecasting foundations - 2

- **What are the issues of long term forecasting? The more the time frame expand, the bigger the structural transformations may become, the wider the uncertainty, the less the information on past and present is usefull for forecasting**

- **What are the methodological consequences? Explore possible futures, and not try any more to « discover » a pre-determined future; Describe these futures and the paths to them, and not extrapolate past trends any more; answer to « what if? » questions, and not try to say « what will happen »any more**

## Basic structure and formalisation of energy demand

- **Disaggregated analytical models, based on homogeneous demand modules :** Energy end-uses (heating, cooking,…), transport modes (cars, planes,…), industrial processes

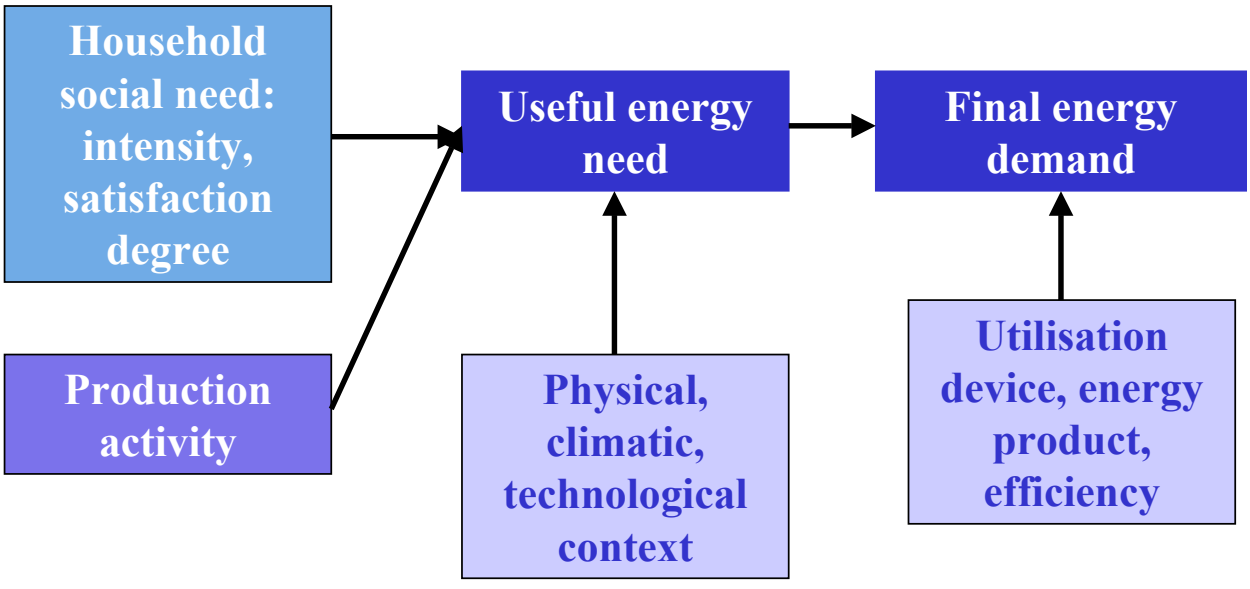
- **Final energy demand calculated by aggregation :** sectoral demand = sum of sectoral modules ($E_S = \Sigma E_{S,I}$), total demand = sum of sectoral demand ($E = \Sigma E_S$)

- **Engineer 's calculation for module 's demand :** socio-economic indicator for needs or activities ($I_{S,I}$) X specific useful energy need ($BS_{S,I}$) X energy market shares ($PM_{S,I,E}$) / efficencies ($R_{S,I,E}$)

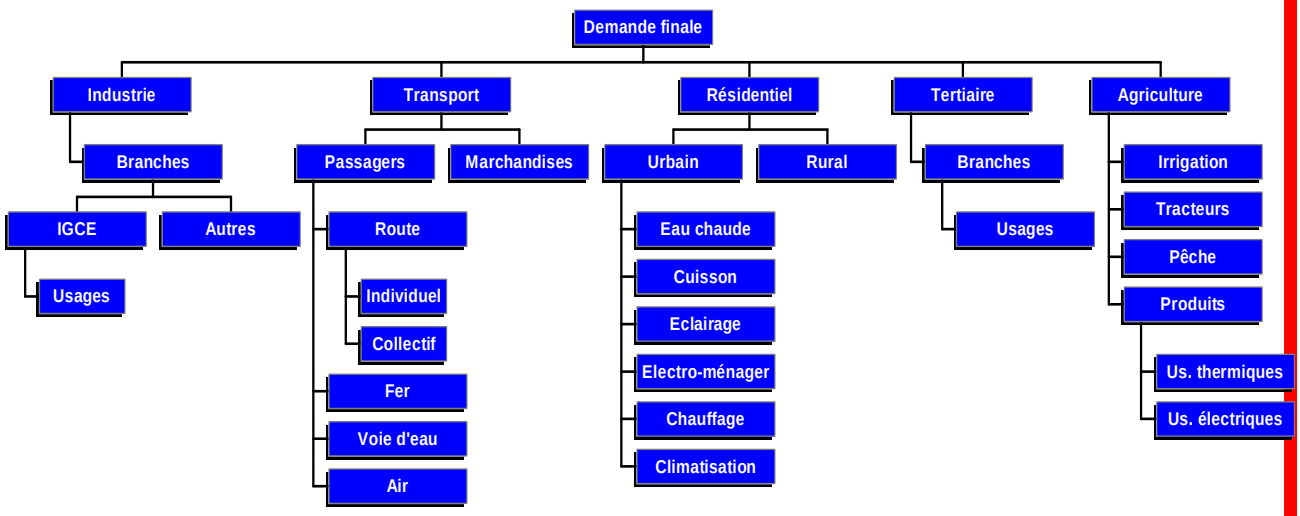
$$E_{S,I} = I_{S,I} \times BS_{S,I} \times PM_{S,I,E} / R_{S,I,E}$$



## Techno-economic (end-use) models : conceptual scheme



# Techno-economic (end-use) models: general architecture






## Accounting for time and dynamic dimension

- **Socio-economic indicators are assumed or simulated :** Time trends, econometric relations with macro-economic or sectoral variables; assumptions on economic growth and demography
- **Specific useful energy needs are deducted from technological assumptions or simulated :** equipment stock dynamic simulation (cars, dwellings, appliances) technical choice optimisation; assumptions on technical specifications of new eqipment
- **Market shares are assumed or simulated :** penetration rate based on relative prices; assumptions on strategic energies, on efficiencies

## Advantages and drawbacks

- **Advantages :** Transparency; possibility to account for structural changes in the economy and the society, for technological innovations, for strategic supply options, for energy efficiency targets and means; non determined by past evolutions

- **Drawbacks and limits:** multidisciplinary data requirements, increasing with the disaggregation level; multiplicity of assumptions which have to be consistent among themselves; lack of a formal macro-economic consistency framework



## Data requirements (1/2)

- **Energy balances and sectoral energy consumption accounts :** the energy balance is the accounting framework of energy flows, where final energy consumption are captured; sectoral energy accounts are breakdowns of final consumptions according to demand modules, but they do not reveal the actual demand

- **Indicators for socio-economic needs and production activities are part of ususal statistics :** the choice for indicators is partly determined by the available national statistics on industry, transport, habitat, agriculture, sometimes by surveys and censuses

## Data requirements(2/2)

- **Data on specific energy requirements are in technical documentation or provided by surveys :** Manufacturers use to provide test data on the energy specifications of their products; regulations sometimes address directly energy specifications and constraints of some equipment; surveys provide data on specific consumption in actual conditions of utilisation; cross country transposition is sometimes possible

- **Once the relative efficencies among energy products are given, market shares are deducted from sectoral energy consumption accounts :** relative efficiencies account for consumption differences for a same energy service



## Assumptions and scenarios (1/2)

- **A fact: the further the time horizon, the bigger the uncertainty, the more necessary the assumptions :** to make an assumption, it means that it is not possible to reduce the uncertainty because a lack of knowledge, or to use this uncertainty to assess the degrees of freedom; in the long term, our knowledge is weak and the degrees of freedom numerous

- **A necessity: consistent assumptions :** only globally consistent assumptions allow the model to describe a possible future relevant for decision making; consistency should be achieved on economic, technical and political aspects

## Assumptions and scenarios (2/2)

- **A method, the scenarios:** a scenario design obeys to precise rules aiming at reinforcing as much as possible assumptions consistency; the « base » of the scenario is a hierarchical structure among all variables on which assumptions are made, which are linked through causal and association relations; a scenario is a combination of assumptions on these variables, accounting for the interrelations among them, and telling a « story »

- **An illusion, the most likely :** it is not possible to give a probability to events which cannot be mastered; looking for the most probable means not accepting the diversity of possible futures; pre-determination of the decision



## Control and interpretation of results (1/2)

- **The results of the techno-economic models : projections of useful energy, final energy demand, simulated socio-economic and technological determinants, for each module; aggregations at various levels of the final energy demand projections of the modules**

- **Results control, consistency across time, structural consistency : consistency of the forecasts with past evolutions (energy intensities, budget coefficients, structural indicators); macro-economic consistency of the demand forecasts with their implications on energy supply in the scenario**

## Control and interpretation of results (2/2)

- **An iterative process assumptions-results : feed-back on assumptions and new projections up to a globally consistent package « historical evolutions - scenario -forecasts »; interest of international comparisons**

- **A good interpretation of the projections: the projections have no meaning except within the scenario framework; none of them « tells » the future, all together frame the future; none of them tells what is the good decision to take, but all together allows for measuring the economic risks linked to the decision; a projection may be « good » and « useful » and never happen**



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Content

> End-use models : general aspects
> **Med-Pro: sectoral specifications**

## Med-Pro – Main module – energy demand forecasting

**Med-Pro, a product developped and registred by ARACADIA sarl and CLIPPER Consultants**

- **A decision-supporting tool to adress medium and long term energy planning issues**
- **Sectoral/end-use demand driven model, for energy demand and load forecast**
- **Relevant for evaluation of energy efficiency and CO2 abatement strategies**
- **On-board assistance for data input and wise use of the model**
- **Flexibility and modularity in dis-aggregation and model structure**



## MED-PRO Structure

| CORE MODEL | | OPTIONAL SUB-MODELS |
|---|---|---|
| *Minimal disaggregation* | *Optional disaggregation* | |
| INDUSTRY<br>• thermal end-uses<br>• electricity end-uses<br>• non energy uses | • industrial sub-sectors (<=6)<br>• mines and construction | • large energy consuming products (<=8)<br>.• steel |
| TRANSPORT<br>• private car<br>• public passenger<br>- road<br>- rail<br>- air<br>• freight<br>- road<br>- rail<br>- rivers and coastal<br>• international sea | • private cars by type (<=3)<br>• road passenger transportation by bus size (<=4)<br>• road freight transportation by truck size (<=4) | •motorcycles |

## MED-PRO Structure

| CORE MODEL | | OPTIONAL SUB-MODELS |
|---|---|---|
| *Minimal disaggregation* | *Optional disaggregation* | |
| **RESIDENTIAL**<br>• cooking and other thermal uses<br>• lighting and other electric uses | • urban /rural<br>• urban population by zone (<=3)<br>• rural population by zone (<=3)<br>• urban population by class (<=3)<br>• rural population by class (<=3) | • hot water<br>• space heating<br>• air conditionning<br>• electrical appliances |
| **TERTIAIRY**<br>• specific electricity end-uses, formal sector<br>• thermal end-uses, formal sector<br>• informal sector | •formal sub-sectors (<=4) | • public lighting |



## MEDPRO STRUCTURE, INPUTS and OUTPUTS

### INPUTS

**BASE YEAR DATA**

- Socio economic
  GDP, value-added, population, household, equipement ratios, employment, ...
- Technical
  Fuel efficiencies, specific consumptions

**PARAMETERS**

- Elasticities
- Logistics coefficients
- Conversion coefficients

**SCENARIO**

- Socio economic
- Demography
- Economic growth
- Industrial growth
- Energy prices
- Productivity
- Technical
- Efficiency changes
- New equipment performances
- Market shares

### MODEL'S STRUCTURE

| CORE DEMAND FORECAST MODULE | | OPTIONAL SUB-MODULES |
|---|---|---|
| *Basic dis-aggregation* | *Optional dis-aggregation* | |
| **Macro-economic consistency** | | |
| **Industry**<br>• thermal end-uses<br>• electricity end-uses<br>• non energy uses | • industrial sub-sectors<br>• construction | • energy intensive products<br>• steel |
| **Transport**<br>• private car<br>• public passenger<br>- road<br>- rail<br>- air<br>• freight<br>- road<br>- rail<br>- rivers and coastal<br>• international sea | • private cars by type<br>• road passenger by bus size<br>• road freight by truck size | •motorcycles |
| **Agriculture**<br>• tractors<br>• water pumping<br>• fishing boats<br>• thermal end-uses<br>• electricity end-uses | | • energy intensive products |
| **Residential**<br>• cooking and other thermal uses<br>• lighting and other electric uses | • urban by zone<br>• rural by zone<br>•urban by social class<br>• rural by social class | • hot water<br>• space heating<br>• air conditionning<br>• electrical appliances |
| **Tertiary**<br>• electricity end-uses<br>• thermal end-uses<br>• informal sector | • sub-sectors | • public lighting |

### OUTPUTS

**SOCIO ECONOMIC**

- Industrial output
- Vehicles stocks
- Traffics
- Dwelling stocks
- Equipment

**SPECIFIC CONSUMPTION**

- Energy intensive products
- Cars, buses, trucks
- Space heating, hot water, appliances..
- Tertiary buildings

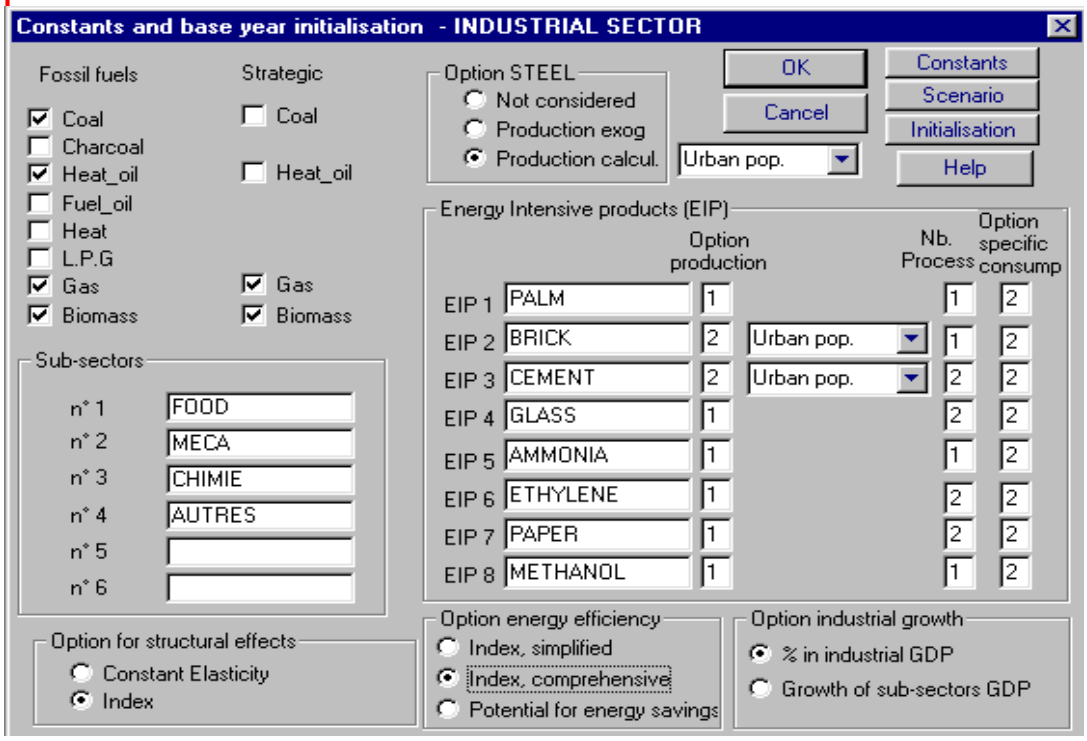
**DEMAND by ENERGY**

- Industry, by branches
- branchTransport, by modes,vehicles
- Household, by uses
- Tertiary , by uses
- Agriculture , by use

**INDICATORS**

- Energy intensity
- Income elasticity
- Energy expenses
- CO2 emissions

# Calibrating the structure of Med-Pro: example of industry





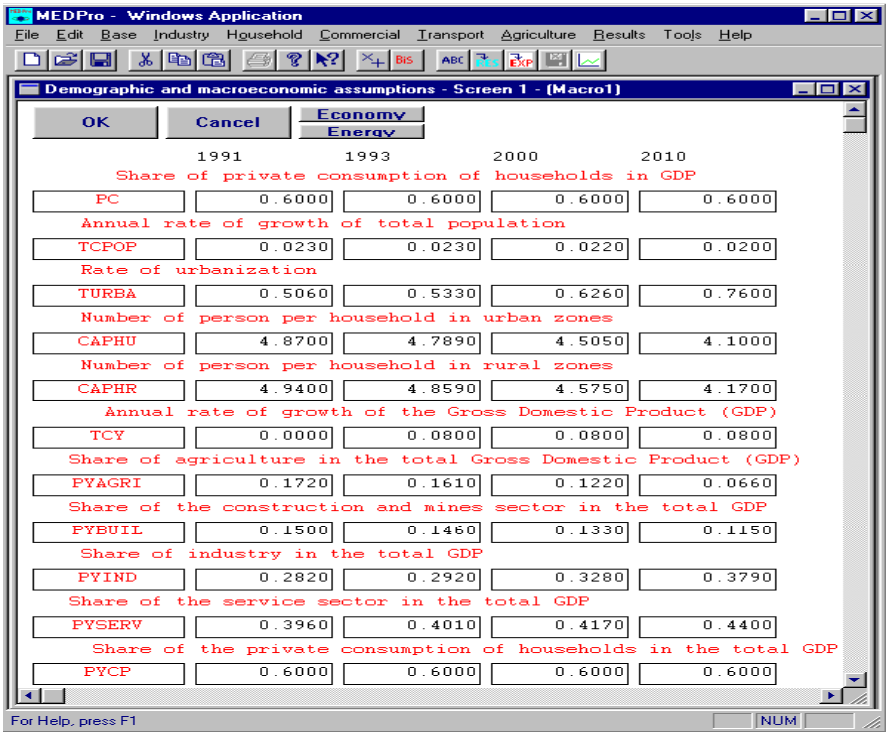

# Input data: sectoral account , example of industry

Sectoral energy consumption account - INDUSTRY

OK Cancel

| | Coal | Charcoal | Heat_oil | Fuel_oil | Heat | L.P.G | Gas | Biomass | Electric | |
|---|---|---|---|---|---|---|---|---|---|---|
| TOTAL_I | 0.610 | 0.000 | 2.720 | 0.000 | 0.000 | 0.000 | 0.650 | 1.950 | 1.000 | TOTAL_I |
| CONSTRUCTIOI | 0.000 | 0.000 | 0.690 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.150 | CONSTRUCTION_I |
| STEEL | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | STEEL |
| MANUFACTUR_I | 0.610 | 0.000 | 2.030 | 0.000 | 0.000 | 0.000 | 0.650 | 1.950 | 0.850 | MANUFACTUR_I |
| FOOD | 0.000 | 0.000 | 0.620 | 0.000 | 0.000 | 0.000 | 0.000 | 1.800 | 0.170 | FOOD |
| palm | 0.000 | 0.000 | 0.170 | 0.000 | 0.000 | 0.000 | 0.000 | 1.700 | 0.050 | palm |
| MECA | 0.000 | 0.000 | 0.090 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.150 | MECA |
| CHIMIE | 0.000 | 0.000 | 0.020 | 0.000 | 0.000 | 0.000 | 0.440 | 0.100 | 0.320 | CHIMIE |
| ammonia | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.170 | 0.000 | 0.060 | ammonia |
| ethylene | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | ethylene |
| methanol | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.270 | 0.000 | 0.000 | methanol |
| AUTRES | 0.610 | 0.000 | 1.300 | 0.000 | 0.000 | 0.000 | 0.210 | 0.050 | 0.210 | AUTRES |
| brick | 0.000 | 0.000 | 0.110 | 0.000 | 0.050 | 0.000 | 0.000 | 0.050 | 0.010 | brick |
| cement | 0.440 | 0.000 | 0.510 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.070 | cement |
| glass | 0.000 | 0.000 | 0.120 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.020 | glass |
| paper | 0.000 | 0.000 | 0.020 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.010 | paper |
| UNIT_COEF_I | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | UNIT_COEF_I |

# Input data: scenario assumptions , example






# Results , example, industry

| Ktoe/year | *2000* | 2000 | 2010 | 2020 | 2030 | *2010-2000* | *2030-2000* |
|---|---|---|---|---|---|---|---|
| AGRO-ALIMENTAIRE | *114* | 114 | 170 | 231 | 309 | *4,1%* | *3,4%* |
| dont Sucre | | 29 | 29 | 29 | 29 | | |
| TEXTILE | *46* | 46 | 99 | 182 | 277 | *7,9%* | *6,2%* |
| MECANIQUE | *227* | 227 | 324 | 729 | 1105 | *3,6%* | *5,4%* |
| dont acier | | 127 | 136 | 387 | 601 | | |
| CHIMIQUE/MINES | *318* | 318 | 405 | 783 | 980 | *2,5%* | *3,8%* |
| dont Phosphates | | 110 | 110 | 110 | 110 | | |
| Engrais | | 104 | 104 | 322 | 322 | | |
| MATERIAUX | *944* | 944 | 1210 | 1430 | 1675 | *2,5%* | *1,9%* |
| dont Ciment | | 607 | 723 | 875 | 1038 | | |
| Verre | | 18 | 26 | 39 | 57 | | |
| DIVERS | *109* | 109 | 226 | 344 | 464 | *7,6%* | *4,9%* |
| dont Papier | | 28 | 30 | 53 | 78 | | |
| Total | *1758* | 1758 | 2434 | 3699 | 4811 | *3,3%* | *3,4%* |

## Results , example, transport

### 14.1 Traffics

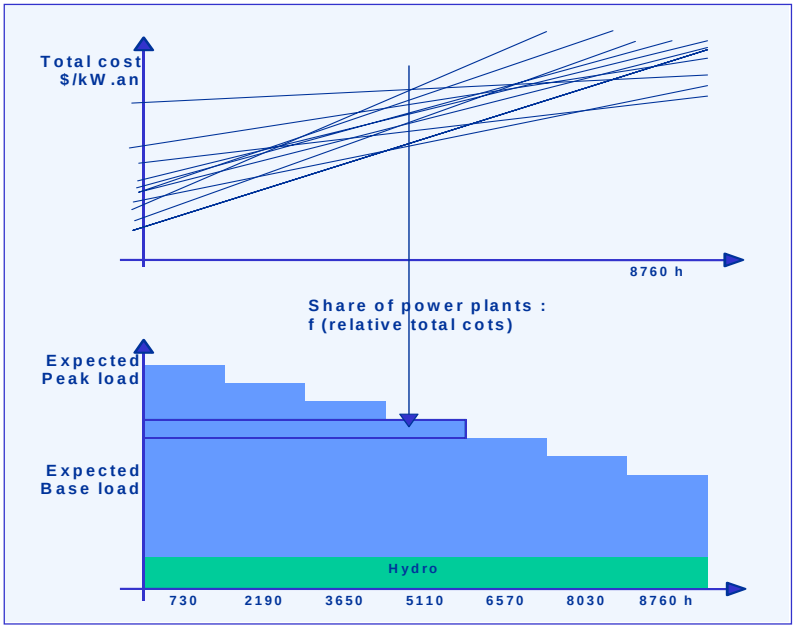
| | | 2000 | 2010 | 2020 | 2030 | 2010-2000 | 2030-2000 |
|---|---|---|---|---|---|---|---|
| **Road** | | | | | | | |
| Cars | Gvkm | 7,0 | 11 | 20 | 52 | 5,1% | 6,9% |
| Freight | Gtkm | 8 | 15 | 22 | 31 | 5,8% | 4,5% |
| Bus-taxis | Gpkm | 19 | 25 | 31 | 37 | 2,8% | 2,2% |
| **Rail** | | | | | | | |
| Passengers | Gpkm | 1,3 | 1,9 | 2,5 | 3,0 | 4,0% | 3,0% |
| Freight | Gtkm | 2,3 | 2,3 | 2,3 | 2,3 | 0,0% | 0,0% |
| **Waterways** | Gtkm | 0 | 0 | 0 | 0 | | |



## Med-Load :characteristics

- **A decision-supporting tool to adress medium and long term electricity investment planning issues**
- **Sectoral/end-use model, for load curve and load duration curve**
- **Feeds electricity generation investment optimization model**
- **Relevant for evaluation of optimal mix of power plants**
- **Designed for professionals of utilities, consulting and energy companies**
- **On-board assistance for data input and wise use of the model**

# Med-Load :rationale for investment planning






# Med-Load :specific inputs

**definitions of the daily time slices (up to 24) and of the seasonal periods (up to 12) ;**

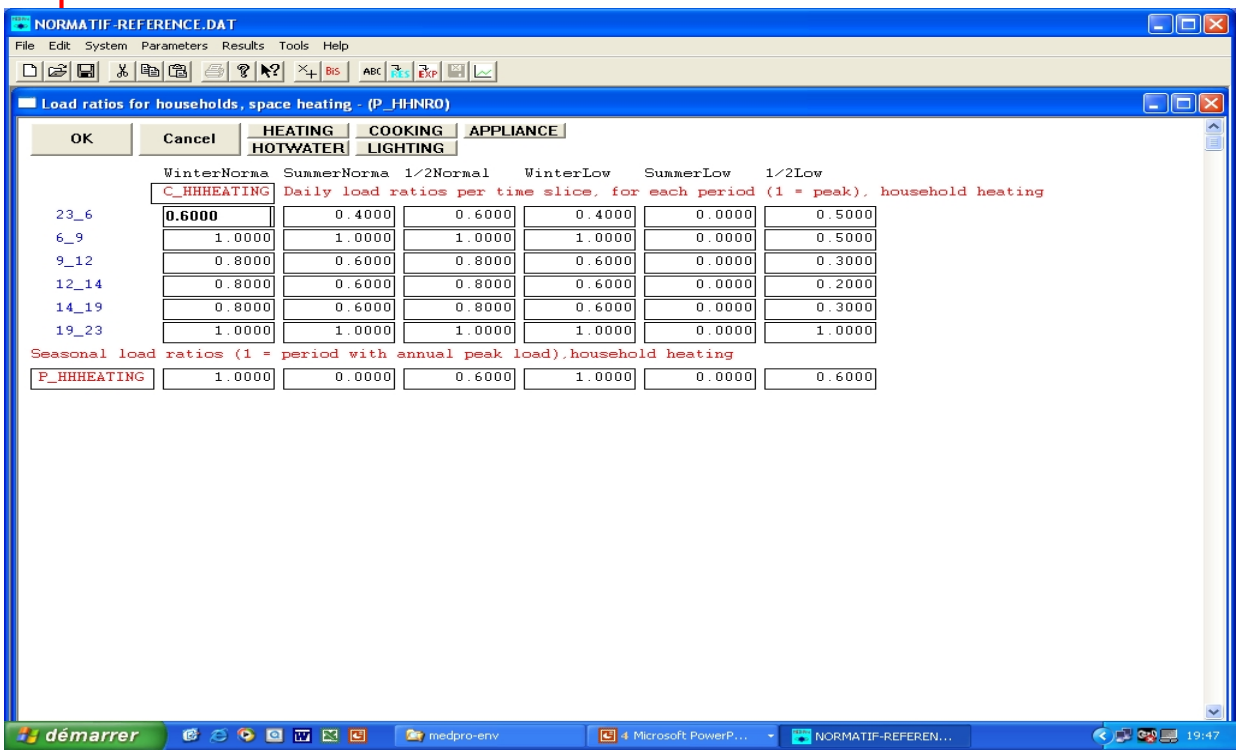
**duration of the defined daily time slices (hours per day) and seasonal periods (days per year) ;**

**transport-distribution losses in the electric grid for each end-use ;**

**daily and seasonal load coefficients for all end-uses ;**

**power requirement dispersion segments (up to 6) and coefficients**

# Med-Load :load coefficient by end-use, example






# Med-Load:specific outputs

**cumulative power requirements per yearly time slice, including peak power requirement ;**

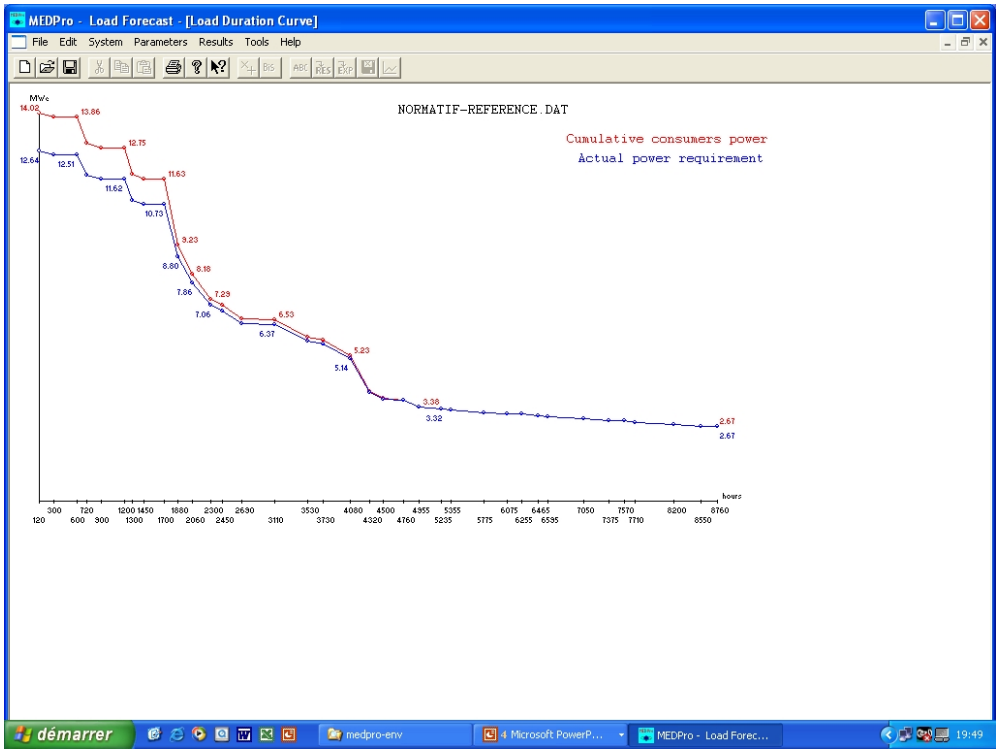
**differences in cumulative power requirements according to sorted out yearly time slices ;**

**duration of yearly time slices ;**

**power requirement duration curve (and data)**

**load duration curve (and data).**

# Med-Load:load duration curve, illustrative






# Med-Pro Environment :characteristics

- **A decision-supporting tool to adress medium and long term environment and climate change policy issues**
- **Sectoral/end-use model, for calculation of GHG and pollutants emissions**
- **Results displayed on the UNFCCC Common Reporting Format**
- **Includes the calculation/forecast of global energy balances**
- **All GHG, all sectors**
- **On-board assistance for data input and wise use of the model**

# Med-Pro Environment :specific inputs

**Production of primary energies, structure and performance of the transformation sector (electricity generation, refineries, etc…)**

**GHG emission factors**

**Activity forecasts for non energy sectors ;**



# Med-Pro Environment :specific outputs

**Emissions of GHG and pollutants according to Med-Pro categories**

**Emissions of GHG and pollutants according to CRF**

**Global energy balance**

# Med-Pro Environment :example of results, CRF

**TABLE 1 SECTORAL REPORT FOR ENERGY**

| SECTORAL REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES (Gg) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| GREENHOUSE GAS SOURCE AND SINK CATEGORIES (1996 IPCC GUIDELINES) | code | CO2 | CH4 | N2O | NOx | CO | NMVOC | SO2 |
| **Total Energy** | **emitotener(G,An)** | **65535,00** | **65 535,00** | **65 535,00** | **0,00** | **0,00** | **0,00** | **0,00** |
| **A Fuel Combustion Activities (Sectoral Approach)** | **emicombtot(G,An)** | **48896,10** | **0,00** | **0,00** | **0,00** | **0,00** | **0,00** | **0,00** |
| **1 Energy Industries** | **emicombtransf(G,An)** | **14605,40** | **0,00** | **0,00** | **0,00** | **0,00** | **0,00** | **0,00** |
| a Public Electricity and Heat Production | emicombelec(G,An) | 14545,53 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |
| b Petroleum Refining | emicombraf(G,An) | 59,87 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |
| c Manufacture of Solid Fuels and Other Energy Industries | emicombcms(G,An) | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |
| **2 Manufacturing Industries and Construction** | **emicombind(G,An)** | **10406,88** | **0,00** | **0,00** | **0,00** | **0,00** | **0,00** | **0,00** |
| a Iron and Steel | emicombacb(G,An) | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |
| b Branches | emicombil(x)(G,An) | | | | | | | |
| AGRO-ALIMENTAIRE | | 499,04 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |
| TEXTILE | | 227,38 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |
| MECANIQUE | | 782,61 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |
| CHIMIQUE/MINES | | 1205,61 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |
| MATERIAUX | | 1121,21 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |
| DIVERS | | 647,81 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |
| c EIP | emicombigce(y)(G,An) | | | | | | | |
| CIMENTERIE | | 2679,20 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |
| SIDERURGIE | | 2073,02 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |
| VERRERIE | | 124,47 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |
| SUCRERIE | | 89,66 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |
| PHOSPHATE | | 307,57 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |
| BASE | | 537,91 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |
| PAPIER | | 111,38 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |
| | | | | | | | | |
| **3 Transport** | **emicombtra(G,An)** | **16751,80** | **0,00** | **0,00** | **0,00** | **0,00** | **0,00** | **0,00** |
| a Civil Aviation | emicombair(G,An) | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |
| b Road Transportation | emicombrte(G,An) | 16641,75 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |
| c Railways | emicombfer(G,An) | 110,05 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |
| d Navigation | emicombnav(G,An) | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |
| e Pipeline Transport | emicombpip(G,An) | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |
| **4 Other Sectors** | **emicombret(G,An)** | **7132,02** | **0,00** | **0,00** | **0,00** | **0,00** | **0,00** | **0,00** |
| a Commercial/Institutional | emicombter(G,An) | 3435,15 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |
| b Residential | emicombres(G,An) | 3696,87 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |
| c Agriculture/Forestry/Fishing | emicombagr(G,An) | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |
| **5 Other (please specify)** | **emicombdiv(G,An)** | **0,00** | **0,00** | **0,00** | **0,00** | **0,00** | **0,00** | **0,00** |



# Med-Pro Environment :example of results, global energy balance

**2030**

| ktep | Pétrole | | Charbon | Gaz | Electricité | | | Biomasse | Chaleur | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| | Brut | Raffiné | | | Electricité | Nucléaire | Hydro | | | |
| Production | 500 | - | - | 1 000 | - | - | - | 507 | - | 1 569 |
| Imports-exports | 1 351 | 8 508 | 384 | 6 824 | - | - | - | - | - | 17 067 |
| Disponibilités | 1 851 | 8 508 | 384 | 7 824 | - | - | - | 507 | - | 19 074 |
| Raffinerie | 1 851 | 1 833 | - | - | - | - | - | - | - | 19 |
| Centrales électriques | - | 331 | - | 5 783 | 3 313 | - | - | - | - | 2 801 |
| Autres transformations | - | - | - | - | - | - | - | - | - | - |
| Pertes | - | - | - | - | 301 | - | - | - | - | 301 |
| Consommation finale | - | 10 009 | 384 | 2 026 | 3 012 | - | - | 507 | - | 15 937 |
| Industrie | - | 2 113 | 384 | 939 | 1 374 | - | - | - | - | 4 809 |
| Résidentiel | - | 833 | - | 570 | 1 003 | - | - | 507 | - | 2 913 |
| Tertiaire | - | 739 | - | 516 | 606 | - | - | - | - | 1 861 |
| Transports | - | 5 776 | - | - | 28 | - | - | - | - | 5 804 |
| Agriculture | - | - | - | - | - | - | - | - | - | - |
| Total énergétique | - | 9 460 | 384 | 2 026 | 3 012 | - | - | 507 | - | 15 387 |
| Non énergétique | - | 550 | - | - | - | - | - | - | - | 550 |