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AFD AGENCE FRANÇAISE DE DÉVELOPPEMENT

CONUEE Comisión Nacional para el Uso Eficiente de la Energía

ADEME Agence de l'Environnement et de la Maîtrise de l'Energie

MedPro overview

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Outline

1. **MedPro and other models**
2. MedPro characteristics
3. Use of MedPro: examples
4. Annex: comparison MedPro, LEAP and MAED

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Long-term energy demand evaluation

- Evaluating long–term energy demand usually relates to the **final energy demand, i.**e. the demand coming from end-use sectors, such as industry, transport, residential, services (public and commercial sector) and agriculture**.**

- The **primary energy demand** (also called by IEA the Total Primary Energy Supply, TPES) represents the total energy demand of the country, i.e. the total quantity of gas, oil, coal, lignite, biomass, hydro and other primary energy sources used in the country. It is equal to the final energy demand plus the demand for **power generation** and other energy transformations ➔ planning **primary energy demand** relates to both **supply and demand**.

Long-term energy demand : final vs primary energy demand

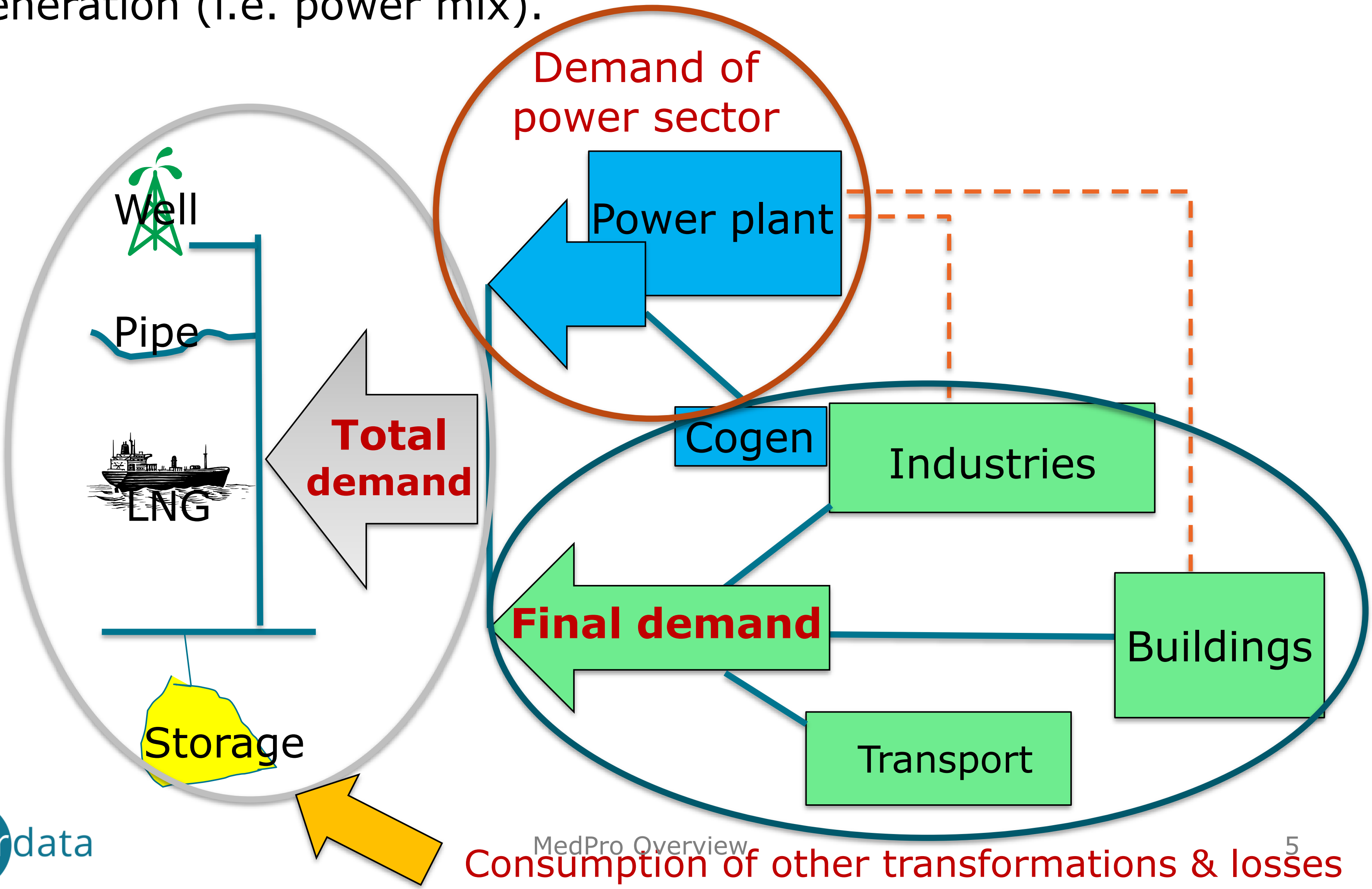
- Long-term **final energy demand** depends on changes in:
  - economic activity (GDP and its structure),
  - lifestyles (the equipment used by households),
  - energy efficiency of technologies, buildings and equipment, and thus on energy efficiency policy & measures.

- Long-term **primary energy demand** depends mainly on the **power mix**.

- In each case the drivers are different… and thus the models are different ➔ here the focus is on **final demand models**

Example: total gas demand

Total gas demand = final gas demand + demand of gas for energy transformations, and mainly the amount of gas used for electricity generation (i.e. power mix).



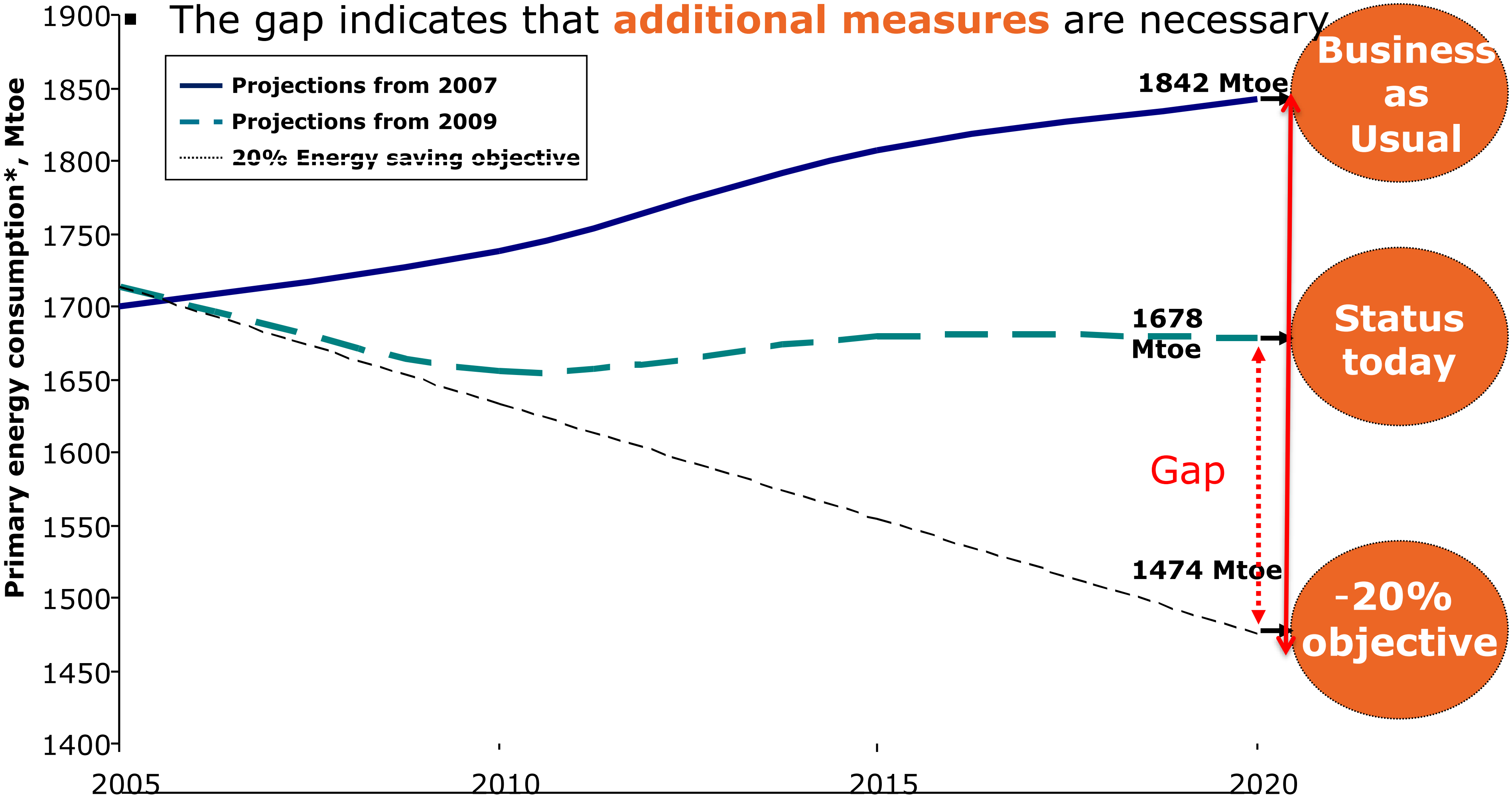
Final energy demand assessment: a growing role of policies

Energy demand planning is not only to forecast final energy demand but above all to assess the impact of policies, in particular:

- The effect of existing energy efficiency policy measures, and in particular regulations with long lasting effect.
- The impact of alternative energy efficiency measures on demand to define future targets or to see how far the country is compared to the target set.
- The CO_2 saving options on the demand side, as energy efficiency generally represents more than 50% of the required abatement in carbon emissions.

Impact of energy efficiency policies: case of EU

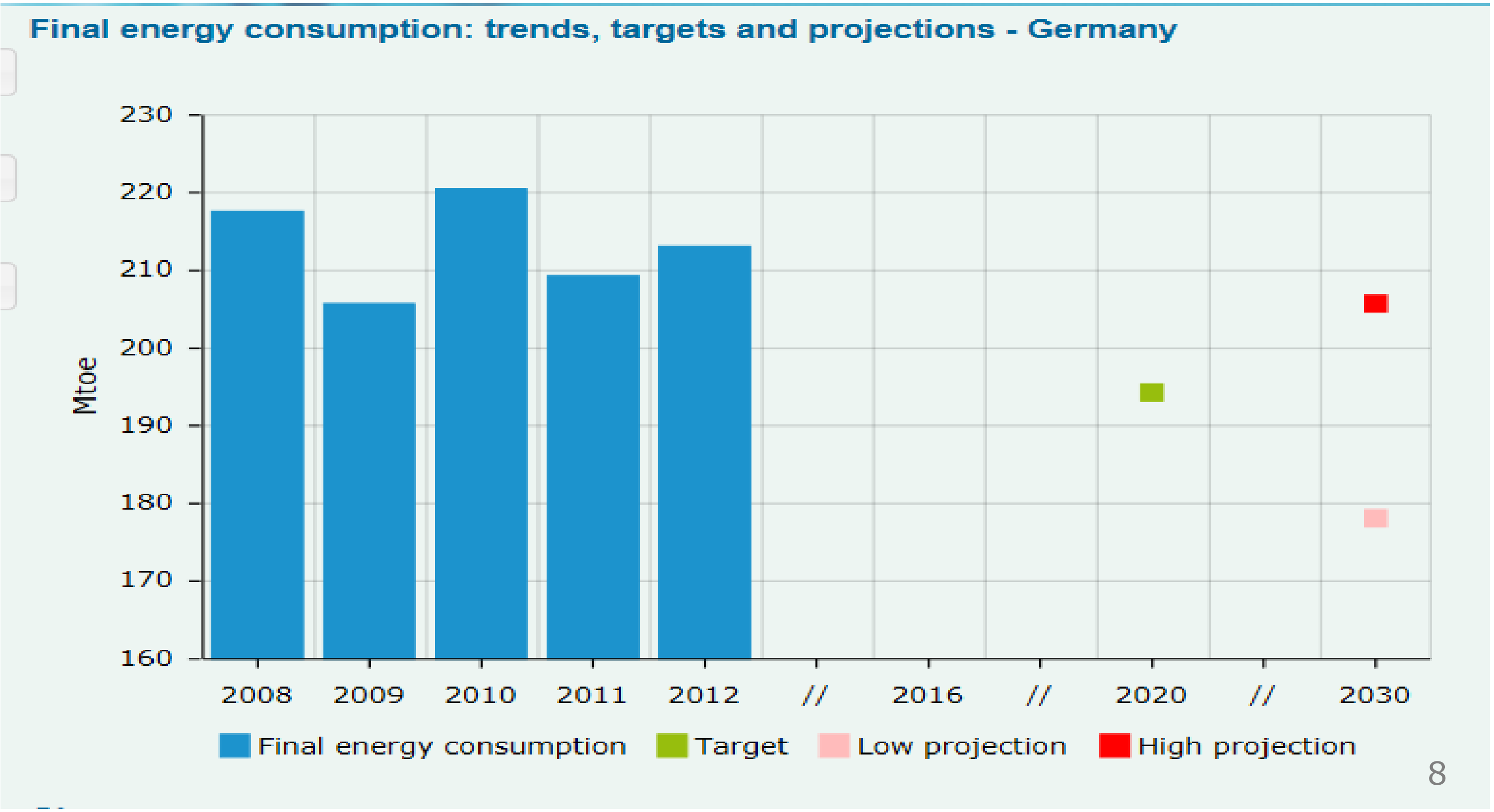
- 2020 target: **20%** energy saving **target** for 2020 vs BaU projection made in 2007
- The gap indicates that **additional measures** are necessary



Source: EU Commission

Final energy demand forecasts: case of Germany

- The low projection shows the impact of **existing** policies;
- The high projection corresponds to **additional** EE measures;
- The difference shows the **range of variation** of final demand in 2030, i.e. around 30 Mtoe.
- Forecasting demand is to get the range of variation of this demand according to the policies implemented, i.e. to assess the energy efficiency potential.



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Modelling approaches for demand forecasting

- Two main modelling families:

1. "**Econometric**" also called "top-down models", which are pure economic models;

2. "**Techno-economic**" or "bottom-up" models, which model demand at a disaggregated level by end-use or sub-sector (also called "end-use" models or "engineering" models).

Principle of econometric models

- Econometric models are usually expressed in **logarithm** to introduce coefficients of **elasticities** that are quite meaningful :

ln **E** = **A** ln **Y** + **B** ln **P + k**

with: **E**: energy demand (ex oil, gas,…)

Y: GDP (or other macro economic indicators);

P: energy price;

A: income elasticity (A=0.8 means that if GDP grows by 1%, energy demand grows by 0.8%);

B: price elasticity (B is negative; e.g. B=-0.2 means that if price increases by 1%, energy demand decreases by 0.8%).

Most common econometric models: dynamic models

- Dynamic models add a lag (E-1) to account for the **inertia of consumers** to changes in activity or price with a distinction between **short-term** reaction (i.e. next year) and l**ong-term** reactions (e.g. 3 years).

$$\ln \mathbf{E} = \mathbf{A} \ln \mathbf{Y} + \mathbf{B} \ln \mathbf{P} + \mathbf{C} \ln \mathbf{E\text{-}1} + \mathbf{k}$$

with: **E**: energy demand (ex oil, gas,…)

A: Short term income elasticity

B: Short term price elasticity

A/(1-C): long term income elasticity

B/(1-C): long term price elasticity

Accounting of technological progress and energy efficiency

- In econometric models, **energy efficiency** is implicitly accounted for by the price elasticity, even for regulations.
- Models can be refined by adding a technological trend**,** deemed to account for the impact of regulations and technological improvements (i.e. diffusion of more efficient electrical appliances or cars…) and that can be derived from a more detailed model.

$$\ln \mathbf{E} = \mathbf{A} \ln \mathbf{Y} + \mathbf{B} \ln \mathbf{P} + \mathbf{C} \ln \mathbf{E\text{-}1} + \mathbf{Dt}$$

With: D trend coefficient

Econometric models: strengths and weaknesses

- **Strengths**
  - Very robust as long as there are only minor changes in policies and economic structures (BaU) as econometric relations are calibrated on statistics.
  - Very well equipped to assess price related issues, including taxation.
- **Weaknesses**
  - They are too much dependant on historical trends… and the future is often very different, because of changes in policies
  - They are very poor to assess the impact of:
    - Non-price policy measures (regulations, incentives,…) that will strongly affect energy performance , mainly for new buildings, new equipment;Technological changes
    - Changes in lifestyles and economic structures
- **Conclusions**
  - Mainly relevant for short term projections.
  - Their reliability models decreases rapidly as the time-horizon increases.

Overview of techno-economic models

- Energy demand is simulated **at a detailed level:** by sub-sector, end-use, transport mode ➔ total demand is the sum of demand by sub-sector. This is why they are also called "bottom-up" models.

- Energy demand is not only a function of economic variables, but also of the equipment and technologies used, so as to be able to take into account the impact of energy efficiency policies;

- **Technological change**, driven by autonomous trends or policies, is thus a key component of these models ➔ this implies to characterize the energy efficiency policy context in a scenario (i.e. energy efficiency policy scenario).

- Examples of techno-economic models: MedPro, LEAP, or MAED.

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Techno-economic models: energy efficiency scenario for households

- For the household sector, the energy efficiency policy scenario would specify for instance:
  - When will be updated the next building standard and at which level?
  - What will be the policy vis a vis incandescent lamps (phasing out?)?
  - How will change the minimum efficiency standards for refrigerators air conditioners?
  - Will there be a support policy for some efficient technology (e.g. solar water heater, condensing boiler)
  - etc.

Energy demand forecasting: techno-economic tools have become the reference

- The scope and requirements of demand forecasting have become broader, because of **reporting** requirements at the international/ regional level on the impact of policies implemented (e.g. UNFCCC, EU Commission for EU countries) as well at national level (monitoring of national targets)

- Econometric models cannot give answers as to the impact of existing and future energy efficiency policy on demand or CO_2 emissions.

- This techno-economic models have become now the reference tools used by most Energy Ministries, in charge of energy policy.

Techno -economic models: strengths and weakness

- **Strengths**
  - They are well adapted to simulate the impact of alternative energy efficiency policies, which is a requirement at the international/ regional level (e.g. UNFCCC, EU Commission for EU countries) as well at national level (monitoring of national targets)
  - For that reason these models have become now the reference tools used by most Energy Ministries/ Administrations, as well as energy companies.

- **Weaknesses**
  - They are quite demanding in data, which however maybe collected for other purposes

- **Conclusions**
  - These models are well adapted for long-term forecasts.

Example of techno -economic models

MedPro

- Belongs to the MEDEE family of models developed under different names since the mid-70s
- Developed by Enerdata

MAED

- Belongs to the family of MEDEE models, such as MedPro
- Adapted in the 80s from the MEDEE2 model and further developed by IAEA staff and consultants

LEAP

- Originally created in 1980
- Developed by the Stockholm Environment Institute (SEI)

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MedPro: origins and uses

- MedPro has been already used under different versions in 60 countries in Europe, Asia, Latin America and Africa, in about 100 demand forecasting studies, to provide long-term final energy demand forecasts at national or regional level by energy companies, Ministries or agencies.

- It is regularly used in France by the Energy Ministry and ADEME, the national energy efficiency agency. It is now also used by GRT-Gaz (gas transmission company) for long term gas demand. It is presently used to asses the energy efficiency potential and policies in Mexico, Spain, Turkey, Morocco and Tunisia, as well as in several French regions.

MedPro: objectives

- In addition to demand forecasts, MedPro can also produce GHG forecasts; in that case, projections of power mix have to be provided from other models or studies to add to the GHG emissions of final consumers the emissions from the power sector.

- MedPro can also produce load curve from the detailed projections by end-use and sector, considering the load profile of each of them:
  - In that case MedPro converts the final electricity demand in kWh in a demand in kW.
  - The detailed projection in kW by hour and season are added to get the load curve projection.
  - Results can be used to supply a power model (e.g. WASP from IAEA)

MEDPRO model: flexible structure

- MedPro is characterized by a flexible disaggregation and modelling options that the user can select easily through the so- called "command variables ", during the "configuration" of the model .
- To some extent, the user can easily design its model to fit its priority, the study focus and the data availability.

Flexible disaggregation level

- By branch
- By end-use
- By vehicle (cars, bus…)
- By zone
- …

Modelling options

- Number of vehicles
- Production of energy intensive industries
- Building stock
- …

MEDPRO model: flexible disaggregation

Transport | **Industry** | **Households** | **Services** | **Agriculture**

Transport
- Passenger, freight
- By mode
- By type of vehicles

Industry

EIP (steel, cement…; branches (chemicals, food, …)

Households
- Cooking
- Hot water
- Heating
- AC
- Lighting
- Appliance

Services
- Branch (offices, hospitals)
- End-use (thermal electric)
- Public lighting

Agriculture
- Tractors, pumps…

Some limits are given to the possibilities of disaggregation, based on the experience of using such models to help the user and avoid to combine too many possibilities and have to handle too many data.

EIP: Energy intensive products

MEDPRO model: modeling options

To project the development of some key energy demand drivers (number of cars, production of energy intensive products, etc…), alternative options are proposed :

- First between an exogenous or endogenous approach:
  - ✓ Exogenous to make use of existing studies;
  - ✓ Endogenous to increase the macro-economic consistency, if no exogenous projections are available.
- Secondly between different endogenous modeling (e.g. car stock link to household income or to annual car sales, with car sales either exogenous or linked to Income)

MEDPRO model: inputs data

MedPro input data are made of three kinds:

- “Constant”: describes the situation at base year;
- “Exogenous”: describes the trend for variables for which the projection is well known and not dependent on a scenario;
- “Scenario“: describes the trend for variables for which the projection is dependent:
  - ✓ Either on the economic scenario;
  - ✓ Or on the energy scenario (energy efficiency, fuel mix).
- Exogeneous and scenario variables are defined for the projection years

MEDPRO model: outputs

- MedPro provides above all detailed projections by sub-sector (end-use for households and services, branch in industry and services, or mode of transport) and by energy type .

- It also provides projections of socio- economic drivers (production in industry, employment in services, stock of appliances for households, number of vehicles and traffic in transport).

- Finally different types of energy indicators are calculated: specific consumption (per branch, appliance, transport mode, energy intensities (by main sector), energy market share, budget coefficients, CO_2 emissions.

MedPro model: inputs and outputs

Inputs

Socio-economic scenario

- GDP, population, value added, energy prices, productivity …

Energy efficiency scenario

- Energy efficiency trends , new equipment performance, renovation…

Transport Industry Households Services Agriculture

Outputs

Demand by energy

Socio-economics

- Industry output
- Vehicle/appliance stock, traffic…

Specific consumption

- By EIP,
- vehicles,
- end-use, appliances…

Indicators

- Energy intensity
- Energy expenses
- CO_2 emissions

EIP: Energy intensive products

MEDPRO model: modeling principles

For each sub-sector (end-use for households and services, branch in industry and services, or mode of transport), the energy demand is a function of three types of drivers:

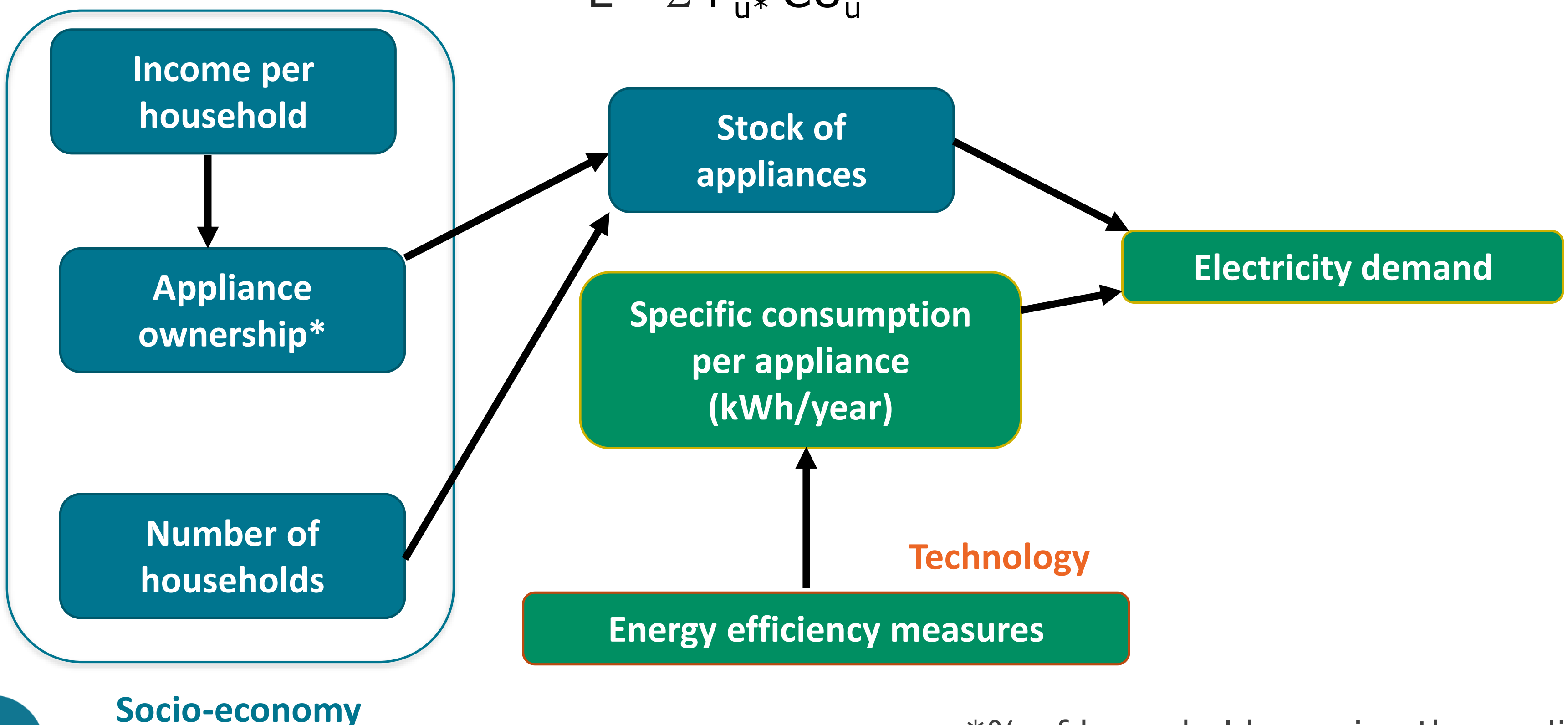
- A level of activity (e.g. production , number of appliance or vehicles ➔ a socio-economic variable.
- An indicator capturing technical change, and mainly energy efficiency progress;
- An indicator of fuel mix (except for captive use of electricity).

MedPro: example of household electrical appliances

For captive uses (e.g.. electrical appliances), households demand E is simulated at the level of different appliances, as a function of:

- The number of households with equipment P_u
- A specific consumption per equipment (CU_u in kWh/appliance), changes of which depends on technological trends and policies.

$$E = \sum P_{u*} CU_u$$



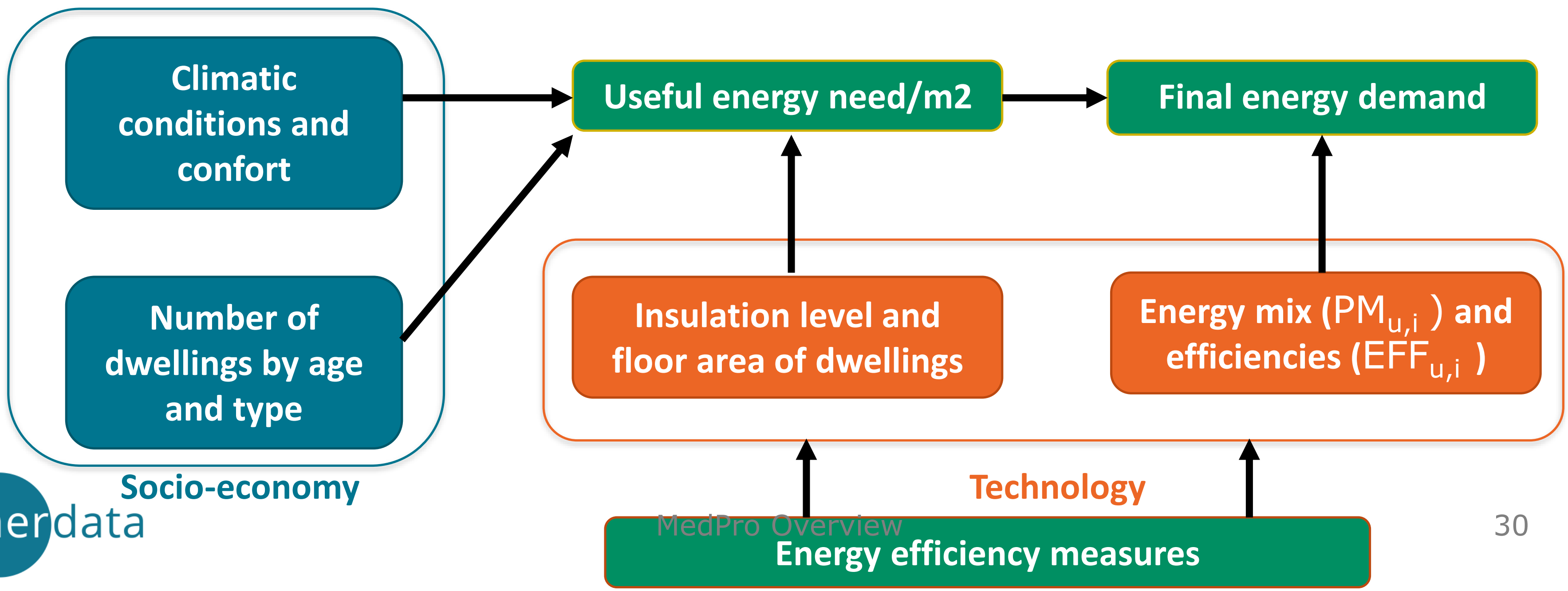
*% of households owning the appliance

MedPro: case of thermal uses for households

For end-uses with fuel substitution between energy/technologies with different efficiencies (e.g. cooking), calculation of demand in 2 steps:

- In useful energy as above (CUU_u)
- In final energy by accounting of the market shares of the different energy/technology i ($PM_{u,i}$) and their end-use efficiencies ($EFF_{u,i}$)

$$E = \Sigma\, P_{u} * CUU_u * PM_{u,i} / EFF_{u,i}$$



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MedPro model: some general features:
1. Change over time

- Change over time is often defined by an index, equal to 1 the base year:
  - ✓ This is often the case for accounting for energy efficiency: a value of 0.85 in year t will mean a 15% energy efficiency improvement between base year and t;

- Change over time may also be defined by a growth rate over a period:
  - ✓ The value at t corresponds to the average annual variation between t-1 and t.

MedPro model: some general features:
2. Modeling of economic variables

- Change in the stock of appliances and vehicles or in traffics is linked to a macro-economic variable (e.g. GDP), through an elasticity coefficient ;

- For instance, the freight traffic is driven by an elasticity to the GDP. The elasticity coefficient A is defined as :

Traffic (2020) = Traffic (2015) x (1 + agr GDP x A)^(1/5)

With A = agr freight traffic / agr GDP

- In the BaU, the elasticity mainly relies on historical trend, while in an energy efficiency scenario it is adapted to reflect new policies (e.g. from other countries for instance)

agr: average annual growth rate

MedPro model: some general features

3. Modeling energy efficiency :separation between new stock and existing stock

To account for the efficiency standards for new construction, new appliances or new vehicles, which may be reinforced in the future, and the possibilities of renovation for buildings, MedPro

- separates the new stock from the existing stock ;
- the stock of buildings can even be broken down into homogenous categories:
  - different ages of dwellings (corresponding to the various implementation of building standards) to account for different energy efficiency performances;
  - occupancy status (owner vs renter for dwellings), to account for different investment behaviours on energy efficiency ;

MedPro model: some general features

4. Change in fuel mix

- Energy market shares are specified in the scenarios for a limited number of fuels called "strategic fuels", selected by the user in the model configuration:
  - ✓ For households and transport, market shares are always defined in % of user using a given fuel (i.e. households, vehicles), and not as a % of consumption.
  - ✓ Depending on the sector, it may apply to the total stock of the new stock only (e.g. cars), depending on whether consumers can or not easily change of fuels.
- For the other fuels (i.e. non strategic), their market share among non strategic fuels is assumed to remain the same as in base year.

MedPro model: some general features

4. Change in fuel mix (cont'd): example

- Let us assume that for households, strategic fuels are wood and natural gas.
- Share of strategic fuels in the future are exogenous (in red)
- Share of other fuels are calculated endogenously

Fuels	Base year	2030
Wood	20%	15%
LPG	70%	67.5%
Gas	2%	10%
Kerosene	8%	7.5%

- Share of LPG in 2030 = 70%/(100%-20%-2%) *(100%-12%-8%)=90%*75%=67.5% (rounded)

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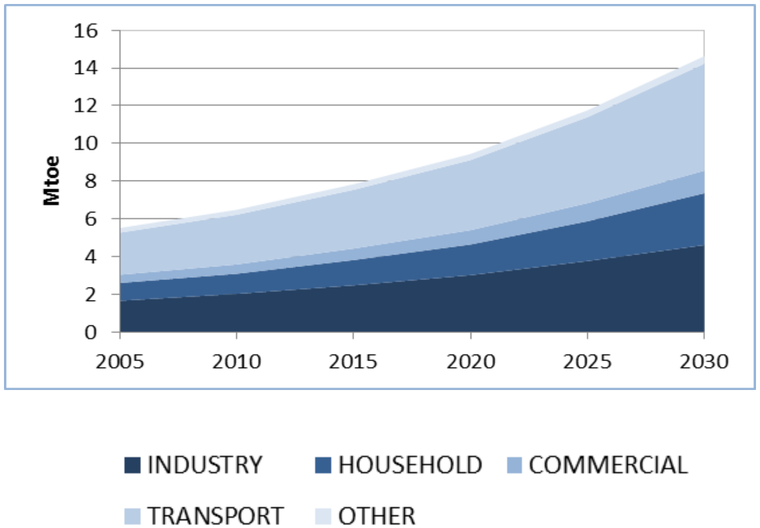
Use of MedPro for energy demand forecasting

MedPro is usually used :

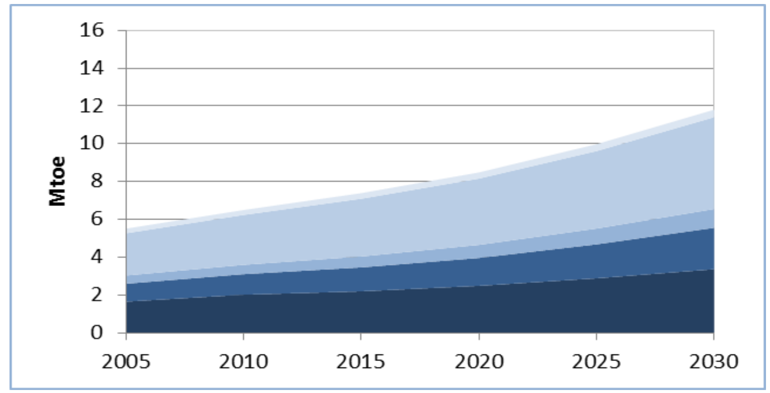
- To produce reference demand forecasts showing the impact on energy demand of current energy efficiency and GHG policies for a given socio economic development ("base-line” or BaU).
- To evaluate the change induced by energy efficiency and GHG measures and to derive by difference with the "base-line‟ the existing potential for energy efficiency improvements.

Use of MedPro to assess the impact of energy efficiency measures

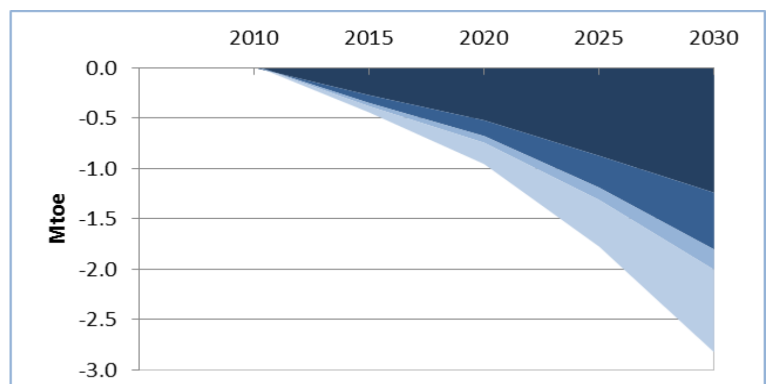
Reference scenario



Efficiency scenario



Energy savings



- In the reference scenario, energy demand is growing to 15 Mtoe.
- In the efficiency scenario, energy demand would only reach 12 Mtoe ➔ 3 Mtoe reduction (or savings).
- Industry accounts for almost half of these energy savings.

Examples of official energy demand studies in France with MedPro

2014-2015 & 2017-2018:

- Assessment of the impact of around 40 policy measures, organized in 3 different energy efficiency scenarios to monitor the objectives of the French Energy Transition for Green Growth law and for reporting to the European Commission.

2012-2013:

- Results used to report for the 6th national communication of France to the UNFCCC.
- Reporting to the European Commission

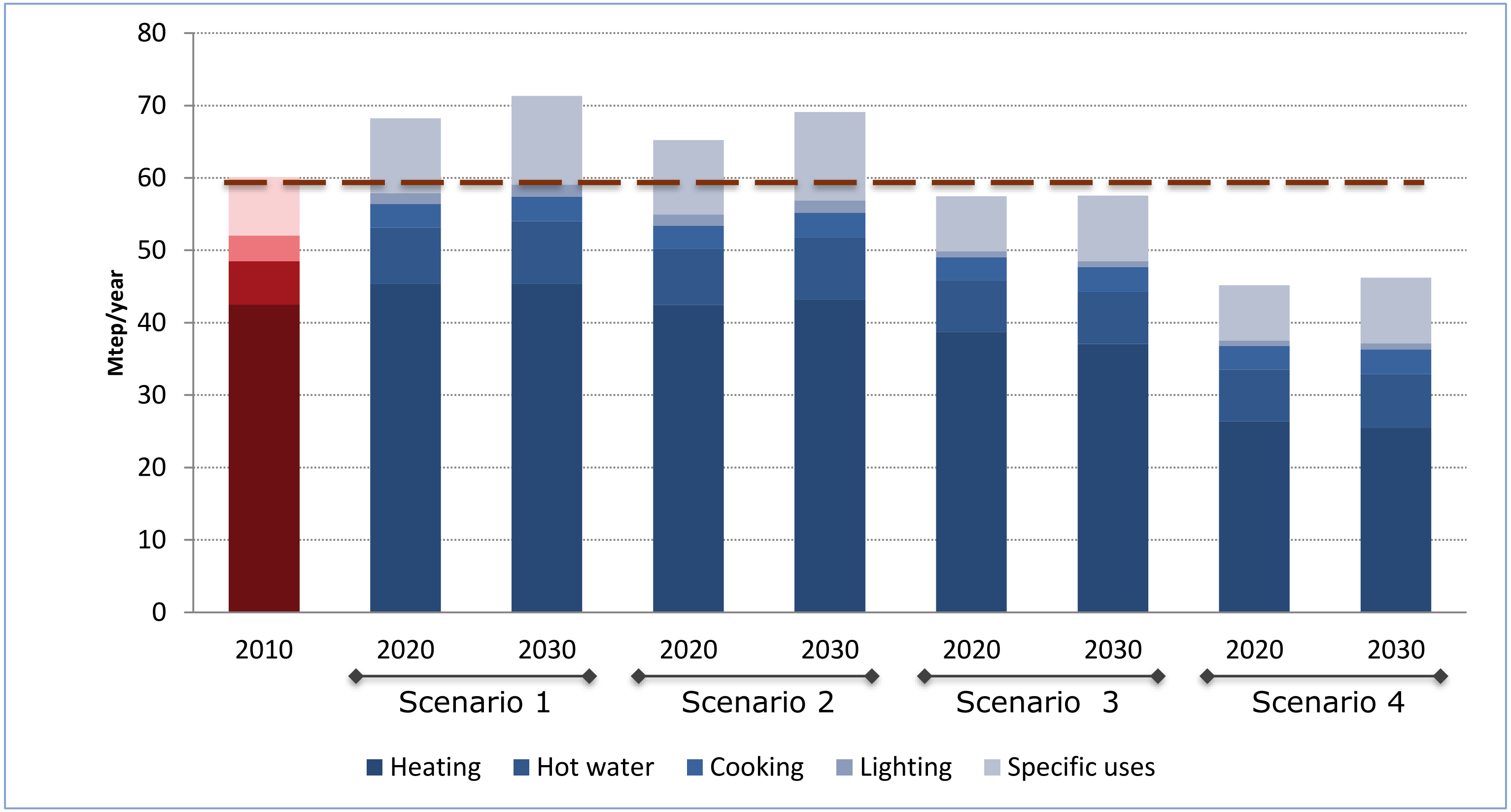
2010-2011:

- Assessment of measures and objectives of the French “Grenelle” environmental law
- Reporting to the European Commission

Impact of various EE measures : case of households in France

Each scenario considers different packages of measures

Final energy consumption by end-use for households



Examples of official energy demand studies at national level with MedPro

- **Tunisia, 2017-2018: ANME** (Energy Efficiency Agency) Modelling of the Plan and its contribution to the NDC;
- **Spain, 2017-2018: IDAE** (Energy Efficiency Agency);
- **Morocco, 2015: MEMEE** (Energy Ministry): Energy efficiency scenarios to 2030;
- **Mexico, 2017-2018: CONUEE**: BaU and energy efficiency scenario to 2050;
- **Turkey: MNER, 2016** (Energy Ministry): BaU scenario to 2030.

Building the energy efficiency scenario

- The model should be seen as an integrator of the various existing studies or expertise on the energy efficiency potential at a detailed level by sub-sector and end-use.

- To assess the detail potential of EE improvement, different approaches can be followed and combined:
  - A dialogue with stakeholders
  - Use of existing studies
  - Benchmarking of performance with country's or international best practices
  - Rely on a separate ad hoc modelling.

- Whatever the approach followed, what is important is to well document the method used and the assumptions made.

Example of a strong interaction with stakeholders

- In France, official demand forecasting studies are done in a very interactive way involving various types of stakeholders.

- The technical work is sub-contracted but the whole supervision, the scenarios definition and the validation of results are under the responsibility of the Ministry.

- Scenarios are defined in interaction with a large number of stakeholders (other Ministries, public institutions, industry associations, researchers and NGOs) during sectoral workshops (macro economy, industry, buildings, transport, agriculture).

Example of benchmarking

- In energy intensive industries, the energy efficiency scenario relied on a benchmarking with EU performances because a lack of national estimates :
  - Steel: Europe 2014 in 2030
  - Cement: Austria 2013 in 2030
  - Paper : Netherlands 2014 in 2030

	2014	2020	2030	2040	2050
Steel	1.00	0.98	0.95	0.92	0.89
Cement	1.00	0.97	0.91	0.85	0.80
Paper	1.00	0.97	0.91	0.91	0.91

- This approach can be now improved with a new GIZ study carried out by Bariloche for CONUEE, with a detailed assessment of measures to be implemented and their impact.

Example of external modelling: public lighting for Mexico (1/2)

- In Mexico , a programme supports municipalities to replace exiting lamps by more efficient lamps (PNEEAPM).
- Evaluation of the program implementation provides annual number of lamps replaced and average savings obtained.
- On this basis, a small model has been developed to simulate the growth in the number of lamps for public lighting (based on urban population growth, with different options as to the increase in the number of lamps replaced and the proportion between LEDs and other efficient lamps

Example of external modelling: public lighting for Mexico (2/2)

	BaU	EE	BaU	EE	BaU	EE
	number of lamps replaced		% LED		Efficiency index (MedPro input)	
2014-2020	0.5 M	0.7 M				
2020				10%	0.94	0.92
2020-2030	1 M	3 M				
2030			10%	20%	0.82	0.58
2030-2040	2 M	1.4				
2040			30%	40%	0.62	0.47
2030-2050	1.6 M					
2050			50%	100%	0.49	0.40

EE= Energy efficiency scenario

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MedPro overview

Granularity:	• Energy coverage: up to 14 (coal, charcoal, LPG, gasoline, diesel, heating oil, jet fuel, kerosene, fuel oil, natural gas, electricity, biomass, heat, solar) • Sub-sectors : up to 44 (in residential, services, industry, transport and agriculture) • Technologies: up to 40 (incl. vehicle types, process for energy intensive products in industry, appliances)
Time resolution	By period (to be defined by user)
Modelling type	Simulation; bottom-up
Energy prices	Exogenous
Emissions coverage	CO2, CH4, N20, SF6, PFC, HFC
Major outputs	Forecasts of energy demand by sector and energy, Energy balances, assessment of energy efficiency policies, emissions
Reference of users	• Public institutions and companies
Mathematical routines	Code in C
Usage conditions /	Licence

MAED overview

Granularity	▪ Energy coverage: 9 (fossil fuels, electricity, traditional fuels, biomass, heat, solar, gasoline, diesel, coal) ▪ Sub-sector: around 110 (in residential, services, industry, transport and agriculture) ▪ Technologies: around 20 (incl. vehicle types, process for energy intensive products in industry, end- uses in buildings)
Time resolution	By period (to be defined by user)
Modelling type	Bottom-up
Energy prices	No
Emissions coverage	No
Major outputs / areas of application	Forecasts of energy demand by sector and energy
Reference of users	Energy ministries and power companies in collaboration with IAEA
Mathematical routines	Excel spreadsheets with Visual Basic macros
Usage conditions /commercial	Free under agreement with IAEA

LEAP overview

Granularity	• Energy coverage: the user can edit the list of fuels • Sub-sector: the user can edit the its list. • Technologies: the user can select the list.
Time resolution	Yearly
Modelling type	Simulation; bottom-up
Energy prices	No
Emissions coverage	Yes: GHG and air pollutants
Major outputs / areas of application	Forecasts of energy demand by sector and energy, Energy balances, assessment of energy efficiency policies, emissions, Sankey diagrams
Reference of users	Public institutions and companies
Mathematical routines	Software
Usage conditions /commercial	Licence (Free to non-profit, academic and government in developing countries)

Comparison of models

5 criteria were used to compare the models:

- Flexibility
- Accessibility
- Calibration of the base year
- Demand modelling
- Consistency check of results
- Functionalities

Flexibility of models

Criteria	Med-Pro	MAED	LEAP
Demand categories	Flexible	Imposed	Flexible: to be defined by the user
Disagreg-gation of categories	Flexible from predefined options (maximum imposed)	Flexible, but limited for fossil fuels (maximum imposed)	Flexible: to be defined by the user
Dynamics of demand drivers	Flexible	No	Choice between 2 modes: activity level, technology

Accessibility

Criteria	Med-Pro	MAED	LEAP
Adaptation and competence required	Model readily available. Does not need much effort to start using it.	Model readily available	Model needs to built by the user from the beginning.
Licencing	Licensing required	Easily available under agreement with IAEA, for governments and power utilities	Available under agreement with SEI for governments and universities. Licneing for the others

Enerdata

Calibration of the base year

Data	Med-Pro	MAED	LEAP
Energy balance	Yes, internal consistency check	No	Yes
Sectoral energy accounts	Yes, consistency check: internal and with energy balance	No	No
Base year calculation	Yes, dedicated sub-model, consistency check with sectoral accounts	Yes, generic equations, no consistency check	Yes, generic equations, sum-up consistency check

Demand modelling

Relations	Med-Pro	MAED	LEAP
Modules energy accounting identities, target years	Ys, double step: useful energy, final energy; specific to modules	Double step: useful energy, final energy; specific to sectors	Double step: useful energy, final energy; specific to sectorse
Dynamics of energy demand drivers, socio-economic	Various alternative options	Mostly exogenous	Exogenous; choice among various time-related equations + exogenous parameters
Dynamics of energy demand drivers, technical	Partly specific stock-flow simulation; partly exogenous + optional time related equations	No, exogenous	Yes, partly generic stock-flow simulation; partly exogenous + optional time related equations

Consistency check of results

Data	Med-Pro	MAED	LEAP
Sectoral & global energy intensities	Yes, total energy, electricity, other energies aggregated	No	No by default
Sectoral budget coefficients	Yes	No	No by default
Structural indicators	Yes	yes	Yes (global energy balance)

Functionalities

Data	Med-Pro	MAED	LEAP
Structure design	Yes, Windows « command » screen for modules and disagregation level	Yes, choice of disagregation level, Excel file	Yes, tree organisation, choice of calculation mode (activity versus technology)
Data input	Pre-formatted user friendly dynamic Windows screen, linkage with Excel	Pre-formatted user friendly Excel data input screens	Pre-formatted user-friendly data input screens
Accessing and editing results	Pre-formatted Windows screens, access to all results, export editable excel formats	Pre-formatted Excel tables	Choice among pre-formatted tables and graphs, export pre-recorded Excel formats