SOFT LINK BETWEEN ENERGY, TECHNOLOGY AND TRANSPORT MODELS AT DIFFERENT SCALES

Raffaella Gerboni, Daniele Grosso, Andrea Carpignano, Bruno Dalla Chiara
POLITECNICO DI TORINO, Dept. of Energy and Dept. DIATI-Transport systems

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Summary

- The background
- Energy modelling
- The soft-link among tools
- Examples of modelling exercises
- Conclusions
The background

- EC Policy framework for climate and energy (2014)
  main goal: increase in the **security**, **competitiveness** and **sustainability** of the EU’s energy system and a reduction in the import dependency, with consequent environmental issues

- Transport accounts for **half of global oil consumption** and **nearly 20% of world energy use**

- Transport sector is almost based on the consumption of **one primary energy commodity**: oil (~96% in EU)
The background
The available tools

Energy analysts often make use of *energy modelling tools* that represent the energy system of a Region.

Energy modelling exercises and simulations can propose a possible evolution in time of:

- energy consumption
- mixes of different fuels
- technologies

that can be used to satisfy the required services demands.

The services demands are usually
- *exogenously* provided
- calculated making use of additional *econometric models* based on drivers (i.e. development of economic activities, demographic trends, energy prices on international markets).
Energy models

- The main aims of energy models are to:
  - forecast the future energy demand and supply, referred to a country or a region;
  - evaluate the effects of different policies and measures (scenario analysis) on the energy system;
  - quantify the impact of different targets (f.i. GHG emissions reduction, supply risk reduction) on the system;
  - compare the economic costs of alternative configurations;
  - represent supporting tools for decision-makers.
Energy models classification

- Top-down $\rightarrow$ mainly related to the General Equilibrium econometric models;
- Bottom-up $\rightarrow$ characterised by a high detail in technological description and widely used to estimate possible future configurations of an energy system
- Focus on: the bottom-up optimisation model generator named TIMES, developed by the IEA-ETSAP (Energy Technology Systems Analysis Program), which allows to build local, national or multi-regional models for estimating energy dynamics over a mid-long time horizon.
TIMES models

• In the TIMES-based models, the objective function is represented by the total cost of the energy system and the model solver finds the system configuration that corresponds to the minimum cost by making technology substitutions and taking into account both competitions:
  ▫ vertical, i.e. among different technologies inside each sector;
  ▫ horizontal, i.e. among each step of the energy chain.

• The end-use sectors in a TIMES model are agriculture, commerce and services, transport, industry, residential
Detail of the TIMES models features

- The *fuels used* are common to all the sectors and this feeds the *competition* mechanisms
- The objective function, defined for a certain region (a geographic area, with any territorial scale), can be

\[
\text{REG}_\text{OBJ}_{z,r} = \sum_{y \in (-\infty, +\infty)} \text{DISC}_{y,z} \times \left\{ \text{INVCOST}_y + \text{INVTAXSUB}_y + \text{INVDECOM}_y + \text{FIXCOST}_y + \text{FIXTAXSUB}_y + \text{VARCOST}_y + \text{ELASTCOST}_y - \text{LATEREVENUES}_y \right\} - \text{SALVAGE}_z
\]

- \( r \): model region
- \( y \): year, ranging over the set of model years (from the base year to the end of the time horizon)
- \( z \): year at the beginning of which the total system cost (i.e. the objective function) is discounted

Example of transport services demand

- The RES (Reference Energy System) of the Pan European TIMES model (PET36, a multi-regional model analysing the energy system of 36 European countries) includes 12 different energy services demands for the transport sector.

<table>
<thead>
<tr>
<th>Energy Service Demand</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aviation Generic</td>
<td>PJ</td>
</tr>
<tr>
<td>Road Bus Intercity</td>
<td>Mpass·km</td>
</tr>
<tr>
<td>Road Bus Urban</td>
<td>&quot;</td>
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<tr>
<td>Road Car Long Distance</td>
<td>&quot;</td>
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<tr>
<td>Road Car Short Distance</td>
<td>&quot;</td>
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<tr>
<td>Road Freight</td>
<td>Mtonn·km</td>
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<tr>
<td>Road Moto</td>
<td>Mpass·km</td>
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<tr>
<td>Navigation Generic</td>
<td>PJ</td>
</tr>
<tr>
<td>Navigation Generic Bunker</td>
<td>PJ</td>
</tr>
<tr>
<td>Rail Freight</td>
<td>Mtonn·km</td>
</tr>
<tr>
<td>Rail Passengers Light</td>
<td>Mpass·km</td>
</tr>
<tr>
<td>Rail Passengers Heavy</td>
<td>&quot;</td>
</tr>
</tbody>
</table>

Kanlo (2010), "Deliverable 5.1 - Description and documentation of the modelling tools", EU FP7 REACCESS project deliverable, April 2010
Example of transport technologies available

- Each of these demands can be fulfilled by several kinds of technologies, fed by one or more fuels

Kanlo (2010), “Deliverable 5.1 - Description and documentation of the modelling tools”, EU FP7 REACCESS project deliverable, April 2010
Need for soft-linking

- The choice and need for a territorial scale focus (e.g. urban) leads to an additional effort in defining efficiencies, patterns, consumption, trends in the transport sector, deriving from specific analyses including traffic modelling and modal share.
  - In particular, the level of accuracy that specific energy consumption models can achieve would be a plus to refine the efficiency parameter that characterises several processes along the path, in a well-to-wheel approach.
End point of soft link /1:
Energy consumption in land transport

• Example of specific quantification: the *Tank-to-Wheel* of a train

\[
E' \approx \frac{N_{rail} + 1}{L} \cdot \frac{v_{max}^2}{2} + B_0 + B_1 \cdot v_{aver} + B_2 \cdot v_{aver}^2 + g \cdot \frac{\Delta h}{L}
\]

• \( E' \) is the energy consumed, expressed in kJ/ (t·km),
• the first addendum indicates the load relevant to acceleration, while the remaining ones quantify the energy spent to keep the train at running speed.
End point of soft link /2: Mobility demand in land transport

- Demand of transport services required by TIMES energy models: *passengers per kilometre* or *tons per kilometre*

- It is useful for our purpose to understand the *daily mobility, besides the mode choice*.
  - e.g. daily average distances travelled by Italians range between 32.1 km and 38.7 km and are characterised by an average vehicle trip length between 4.6 and 6.2 km in urban areas and between 11.9 and 26.5 km in extra-urban area
End point of soft link /3: modal shares demand and solutions

• An additional refining option would lie in the possibility to assess recent mobility options in modal share, e.g.:
  ▫ Car-pooling → reduction of the mobility demand
  ▫ Car sharing → additional kind of demand

• Appropriate technological solution choice
Example of energy modelling results /1

- Results of a Pan European model run with a set of constraints related to the implementation of the 20-20-20 policy for EU27

![Diesel oil consumption in Italy by sector](chart.png)
Example of energy modelling results /2

- Scenario: variation of the modal fulfilment of goods transport demand (partially shifting from trucks to trains)

![Normalised diesel oil consumption in the transport sector in Italy](image)
Conclusions

• TIMES based energy models are used to forecast energy supply distribution to fulfil a services demand in a defined area. The demand is exogenously provided for the end use sectors.

• For all sectors the demand must be calculated with dedicated models and tools and this would be particularly necessary for the transport sector.

• A soft-link between energy models and transport ones could proficiently contribute also to address modal split and solutions (including new motorisations).

• New ITS are arising which could provide large quantities of reliable data.
Thanks