A comparison of modelling tools for energy planning

Sara Ben Amer-Allam, sbea@dtu.dk
Per Sieverts Nielsen, pernn@dtu.dk

CITIES 3rd General Consortium Meeting
24th May 2016, DTU Lyngby, Denmark
Contents

1. What is energy planning?
2. Energy system models
3. Selected modelling tools
4. Technical/scientific aspects
5. Practical aspects
6. Choosing a relevant tool
7. Conclusions
What is energy planning?

• “The process of developing long-range policies to help guide the future of a local, national, regional or even the global energy system” (Wikipedia)

• Incorporates: energy policy, energy economics, engineering, social science

• Focuses on: sustainability, resilience, flexibility, efficiency, affordability etc.
Energy system models

Fig. 1 Energy flows in an energy system model

Fig. 2 Partial-equilibrium resources, storage & conversion methods, demand points

Fig. 3 Exogenous energy demand

Econometric models → Future energy demand → Energy models
Energy system models (2)

• Utilize:
  – mathematical programming (depicting the energy quantities flow)
  – engineering process analysis (technically detailed description of energy technologies)
  – econometrics (demands, behavioural aspects) (Rath-Nagel & Voss 1981)
Selected modelling tools (commonly used in Denmark)
Balmorel

Versatile model for analysing electricity and combined heat and power sectors in a regional or (inter)national perspective

Used by e.g. Technical University of Denmark (DTU), Danish Energy Association, Ea Energy Analyses, China National Renewable Energy Centre (CNREC)

Available at: http://eabalmorel.dk/
Deterministic input/output tool for optimising the operation of a given energy system

Used by e.g. Aalborg University, PlanEnergi

Available at: http://www.energyplan.eu/
Modelling software package for combined techno-economic design, analysis, and optimisation of energy projects

Used by e.g. PlanEnergi and several Danish district heating companies

Available at: http://www.emd.dk/
Sifre

Mixed-integer linear optimization tool simulating energy flows and energy prices in all sectors of the specified energy system in discrete time steps

Developed and used by the Danish TSO Energinet.dk and external collaborators

Expected to be available online
IEA ETSAP (Energy Technology Systems Analysis Program)-TIMES model developed by DTU for Denmark

Includes all sectors in the Danish energy system, finds least cost pathways to targets for renewables or emission reduction, links to Geographic Information System (GIS) data

Used by DTU and Danish Energy Agency

ETSAP-TIMES is developed by IEA community
## Technical/scientific overview

<table>
<thead>
<tr>
<th>Tool</th>
<th>Optimization type</th>
<th>Implementation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Balmorel</td>
<td>Investment optimization</td>
<td>Programming in GAMS, solvers e.g. CPLEX</td>
</tr>
<tr>
<td>EnergyPLAN</td>
<td>Operation optimization</td>
<td>Delphi Pascal</td>
</tr>
<tr>
<td>energyPRO</td>
<td>Optimization: user-defined or auto-calculated operation strategy</td>
<td>Delphi</td>
</tr>
<tr>
<td>Sifre</td>
<td>Operation optimization</td>
<td>Mixed-integer linear programming (MILP) in C#</td>
</tr>
<tr>
<td>TIMES/TIMES-DK</td>
<td>Investment optimization</td>
<td>GAMS programming, VEDA front- and back-end, Excel</td>
</tr>
</tbody>
</table>
## Technical/scientific overview (2)

<table>
<thead>
<tr>
<th>Tool</th>
<th>Sectoral representation</th>
<th>E.g. issues solved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Balmorel</td>
<td>Electricity + heat (+ EVs)</td>
<td>Electricity markets; expansion of DH; role of demand response</td>
</tr>
<tr>
<td>EnergyPLAN</td>
<td>Electricity+heat+transport</td>
<td>100% RES energy systems, energy storage; national energy strategies</td>
</tr>
<tr>
<td>energyPRO</td>
<td>Flexible: electricity + heat,</td>
<td>CHP plants participating in the spot market; compressed-air energy storage</td>
</tr>
<tr>
<td></td>
<td>(transport as &quot;energy plant&quot;)</td>
<td></td>
</tr>
<tr>
<td>Sifre</td>
<td>Electricity+heat+transport+gas</td>
<td>Electrolysis and biomass conversion scenarios for Sønderborg, Denmark</td>
</tr>
<tr>
<td>TIMES/TIMES-DK</td>
<td>Electricity+heat+transport</td>
<td>TIMES: Future role of hydrogen; regional energy strategies and many more...</td>
</tr>
</tbody>
</table>
## Practical overview

<table>
<thead>
<tr>
<th>Tool</th>
<th>Cost</th>
<th>User interface</th>
<th>Access to the code</th>
<th>Computational time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Balmorel</td>
<td>Free tool, commercial GAMS license</td>
<td>N</td>
<td>Y</td>
<td>Long (if all Nordic system modelled hourly)</td>
</tr>
<tr>
<td>EnergyPLAN</td>
<td>Free</td>
<td>Y</td>
<td>N</td>
<td>Short</td>
</tr>
<tr>
<td>energyPRO</td>
<td>Commercial</td>
<td>Y</td>
<td>N</td>
<td>Short (increases if large model)</td>
</tr>
<tr>
<td>Sifre</td>
<td>Internal – expected to be free?</td>
<td>Y</td>
<td>N</td>
<td>Short (runs at Energinet’s servers)</td>
</tr>
<tr>
<td>TIMES</td>
<td>Free model generator, commercial GAMS &amp; VEDA license</td>
<td>Y</td>
<td>Y/N</td>
<td>Short (time-slices)</td>
</tr>
</tbody>
</table>
Guiding questions for tool choice

• **Who is the tool addressed for?**
  – Public: has to be (made) available online
  – Project participants: online availability not a requirement

• **Who are the project participants?**
  – Researchers
  – Non-researchers with some energy knowledge (e.g. utilities, municipalities)
  – Non-researchers with no energy knowledge

• **How much time is planned for learning the tool (from non-user to confident user)?**
  – Up to a man-month?
  – Longer?
Guiding questions for tool choice (2)

• How much time is planned in the project for modelling?
  – up to 3 man-months
  – more than 3 man-months

• What kind of analysis is required?
  – operation optimization
  – investment optimization

• Is access to the source code required?

• Should the tool link with GIS?
Conclusions

• Energy planning
  – process of developing future energy policies, focusing on: sustainability, resilience, flexibility, efficiency, affordability...
  – energy system modelling allows developing techno-economic scenarios for energy planning facilitation

• Both technical/methodological and practical aspects can affect the usefulness of the tool

• Energy system models/modelling tools
  – all are flexible enough for many applications
  – each has it’s strengths and weaknesses = some more suitable for selected research questions than others
Conclusions (2)

• Main differences:
  – Balmorel and TIMES-DK are investment and operation optimization tools; Sifre, energyPRO and EnergyPLAN are operation optimization tools
  – Various sectoral and technology representation

• Main **aspects to consider** before choosing the tool:
  – Project participants
  – Preparation and modelling time available
  – Type of analysis
Available Energy System Used

Questions?