Can a TIMES model be substituted for an Economic Dispatch model? – Insights from a Swiss TIMES electricity model
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Presentation outline

- Swiss power sector overview
- Development of Swiss TIMES electricity model
- Key assumptions
- Preliminary results
- Modelling/calibration issues
- Conclusions
- Future direction
Swiss power sector

Electricity generation mix (2008)

- Annual average growth of 1.7% over the past ten years
- Self sufficiency in annual electricity generation, but still dependent on imported electricity for seasonal demand
- Limiting growth in electricity demand to < 5% from 2000 level - +12.1%
- Renewable electricity production of 1% of 2000 level (0.5 TWh) - +0.44 TWh

Swiss power sector

Challenges

- Carbon reduction targets of 10% by 2010 (& 80% by 2050) from 1990 level - 1.6%
- Retirement of the exiting nuclear reactors and filling the supply gap - political uncertainty over new investment / possible life extension of nuclear reactors
- Discussions on new natural gas plant or distributed CHP - ongoing consultation of carbon offset policy
- Uncertainties in future growth of electricity demand - due to uncertainties in uptake of energy efficiency on the demand side
- Revenue from electricity trading - Uncertainty in electricity market development in neighbouring countries over low carbon
Electricity load curves (2008)

- Weekly demand pattern

Seasonal: Weekdays

Seasonal: Saturdays

Seasonal: Sundays

Developments of Swiss TIMES electricity model

Model (version 3.0) overview

- Long time horizon (2000-2100) with a combination of 2, 5, 10 and 20 years time steps
- 204 annual time slices with an hourly diurnal timeslice [Began with 36 annual time slices (Sept – Jan 10)]
- Five electricity demand sectors
- Calibrated to
  - electricity generation and fuel data for years 2000-2008 within 3%
  - near term forecast of electricity generation till 2015
  - all existing technology stock with retirement schedule
  - electric load curve for year 2008 (??)
- Large scale hydro/nuclear plants are characterised at plant level based on historical data
- Four country specific interconnectors with their seasonal AF
- A range of new technologies with technical and cost characteristics, including lead time for construction
- Preliminary results for core scenarios and a number of sensitivity analyses focusing on uncertainties of new technologies of strategically importance
Developments of Swiss TIMES electricity model

Data sources
(Caveat: So far the focus has been on model methodology and structure. Input data to be updated!)

- Calibration
  - Various publications of SOFE
    - Schweizerische Gesamtenergiestatistik, Elektrizitätsstatistik, Statistik der Wasserkraftanlagen, Thermische Stromproduktion inklusive Wärmekraftkoppelung,
  - FOEN
    - Swiss communication to UNFCCC
  - European Network of Transmission System Operators for Electricity
    - Load curves, electricity trading, ....

- Energy resources
  - Fossil/nuclear fuel prices
    - PSI Technology Assessment group (to be updated to new Dataset)
  - Renewable energy potential
    - Renewable energy map of SATW (Swiss Academy of Engineering Sciences)

- Technology data
  - PSI Technology Assessment group (Axpo)

- Electricity demand projection
  - Indirectly linked to drivers in the Energy perspective 2035

Key assumptions

- Electricity demand of 250 PJ in 2050 and 280 PJ in 2100 (Vs. 210 PJ in 2010)
- Reserve margin of 30% and T&D loss of 7%
- Discount rate of 10%
- Costs in 2005 Swiss Francs (CHF\textsubscript{2005}) [1\$ \sim 1.1 \text{ CHF}\textsubscript{2010}/1.25 \text{ CHF}\textsubscript{2005}]
- Hydro power is maintained at today’s level independent of their cost
- Nuclear is limited to 5 GW by 2050 and 8 GW by 2100 (vs. today’s level of 3 GW)
- Electricity imports/exports are constrained to the last ten years’ average
- Imported electricity is assumed as ‘zero’ carbon
- Time depended import/export costs for electricity during weekdays (linked to gradient of demand curve)
- Renewable potentials are based on technical potential
- Seasonal AF for solar PV based on sunshine hours. No seasonal AF included for other renewable energy sources
- Distributed generation is not modelled
- No credit for heat from CHP
Key assumptions

Reference energy system

Electricity generation technologies data

<table>
<thead>
<tr>
<th>Resources</th>
<th>Cost (CHF/kW/GJ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas</td>
<td>6.2 - 10.5</td>
</tr>
<tr>
<td>Oil</td>
<td>8 - 13.5</td>
</tr>
<tr>
<td>Coal</td>
<td>2.5 - 2.6</td>
</tr>
<tr>
<td>ELC Import</td>
<td>15.78 - 26.72</td>
</tr>
<tr>
<td>ELC Export</td>
<td>11 - 18.7</td>
</tr>
<tr>
<td>Wood</td>
<td>9.7 - 8.5</td>
</tr>
</tbody>
</table>
Preliminary results

Core scenarios
1. **BASE**: Business as usual (without coal)
2. **CO2_S**: Stabilizing CO$_2$ at 2000 level by 2050 and beyond* (excluded)
3. **CO2_Z**: Zero carbon electricity by 2050 and beyond

Sensitivities
1a. **B_NoNuc**: BASE without new nuclear plants
1b. **B_RNW**: BASE Renewable only (without new nuclear, coal, gas plants and 'limited' import of electricity*)
1c. **B_Coal**: BASE with coal plants (excluded)
3a. **Z_NoNuc**: CO2_Z scenario without any new nuclear
3b. **Z_RNW**: CO2_Z scenario with renewable only (without any new nuclear and limited import of electricity)

* CO$_2$ emissions from waste incineration and biomass are not accounted!
** Electricity import limited to 30% of total demand by 2050 and 35% in 2100
Preliminary results

Electricity generation mix

Electricity generation mix:

Electricity trade balance

Electricity trade:
Preliminary results

Electricity dispatch: Base Winter Weekdays

- BASE (2000): WIN-WK
- BASE (2020): WIN-WK
- BASE (2050): WIN-WK
- BASE (2100): WIN-WK

Electricity dispatch: Base Summer Weekdays

- BASE (2000): SUM-WK
- BASE (2020): SUM-WK
- BASE (2050): SUM-WK
- BASE (2100): SUM-WK
Preliminary results

Electricity dispatch: Z_RNW Winter Weekdays

Electricity dispatch: Z_RNW Summer Weekdays
Preliminary results

Electricity dispatch: Z_RNW Saturdays

Preliminary results

Issues with calibration and electricity balance
Preliminary results

Electricity supply and demand balance (over production)

Electricity over production

<table>
<thead>
<tr>
<th>Year</th>
<th>2000</th>
<th>2020</th>
<th>2050</th>
<th>2100</th>
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<tbody>
<tr>
<td>Base</td>
<td>0%</td>
<td>2%</td>
<td>4%</td>
<td>6%</td>
</tr>
<tr>
<td>B_NoNuc</td>
<td>0%</td>
<td>2%</td>
<td>4%</td>
<td>6%</td>
</tr>
<tr>
<td>B_RNW</td>
<td>0%</td>
<td>2%</td>
<td>4%</td>
<td>6%</td>
</tr>
<tr>
<td>CO2_Z</td>
<td>0%</td>
<td>2%</td>
<td>4%</td>
<td>6%</td>
</tr>
<tr>
<td>Z_NoNuc</td>
<td>0%</td>
<td>2%</td>
<td>4%</td>
<td>6%</td>
</tr>
<tr>
<td>Z_RNW</td>
<td>0%</td>
<td>2%</td>
<td>4%</td>
<td>6%</td>
</tr>
</tbody>
</table>

Electricity expansion plan

Installed Capacity:

Renewable Capacity:
Preliminary results

Renewable electricity generation vs. capacity in Z_RNW

Renewable electricity generation:

- Biogas
- Waste
- Wood
- Wind
- Solar
- Geothermal

Renewable Capacity:

- 2030
- 2050
- 2100

Electricity system cost

Undiscounted energy system cost:

- Salvage
- Decommissioning
- Resource
- Variable O&M
- Fixed O&M
- Capital

*Resource costs includes electricity trade balance
Preliminary results

CO₂ emission and marginal cost

<table>
<thead>
<tr>
<th>Year</th>
<th>Base</th>
<th>B_NoNuc</th>
<th>B_RNW</th>
<th>CO2_Z</th>
<th>Z_NoNuc</th>
<th>Z_RNW</th>
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<tbody>
<tr>
<td>2030</td>
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<tr>
<td>2100</td>
<td></td>
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</table>

CO₂ emissions

Marginal cost of CO₂

Modelling and calibration issues

- Inadequate data on power plant operational schedule for calibration to an hourly level
- Absence of seasonal AF for other renewable technologies (e.g. wind has been chosen as a base load plant within its AF)
- Difficulties in calibrating to electricity trading (price vs. cost) and discrepancies in data sources
- Storage (STG) process in TIMES vs. reality \(\text{(energy flow without any activity)}\)
- Processing of model results and understanding at an hourly level (>100'000 data points), e.g. unknown drivers in certain timeslices
- Electricity supply/demand balance \(\text{(excess production in some period)}\)
- Input data handling (e.g. large rows of data for solar AF)
Conclusions

- Nuclear seems cost-effective in BASE scenario, but construction time delays the deployment in medium terms
  - In absence of nuclear, gas becomes cost effective
  - Coal is the most cost-effective option
- Renewable scenario almost meets the low carbon objectives
- Without imported electricity, meeting zero carbon objective is technically not feasible
- While comparing marginal cost, caution with other constraint (e.g. marginal cost of carbon vs. renewable constraints)
- Hourly timeslice provides additional insights on operation of power plants, though the role of storage to be addressed
- There is no parameters for system reliability if TIMES were to be compared to an electricity despatch model
- Extension to other energy supply and end use sectors would enhance modelling framework and enable better understanding of power plant operation

Future direction

- To update input data:
  - Technology data, electricity demand projection, fossil fuel price (July 10)
- Implementation of AF for all renewable resources
- Introduction of electricity import/ export regions with their electricity demand profile
- Make necessary changes to storage technologies
- Implementation of all electricity policy, e.g. feed-in tariff
- Implementation of CCS (CARMA - Carbon Management in power generation project)
- Moving from electricity model to energy system model: Developing a Swiss TIMES Energy System Model (STEM) for transition scenario analysis - SOFE funded project (2010-2013)