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Influence of long term electricity sector developments in Europe on the Swiss electricity system: Risks and opportunities for electricity trading
Outline

• Introduction
• Objectives
• CROSSTEM model
• Scenarios
• Preliminary results
• Issues and Challenges
• Outlook
Introduction

- Electricity accounts for one quarter of Swiss energy demand
- Large differences in seasonal output, seasonal demand.
- Creates seasonal dependence on electricity import.

Electricity generation mix 2010

Future of Electricity sector

- Nuclear phase out – No replacement of existing Nuclear power plants at the end of their lifetime. Last power plant off grid by 2034.
- The Swiss Energy Strategy (SES) 2050
- Uncertainty regarding future supply options – A combination of gas based generation, renewables and electricity imports are mentioned.
Future of Electricity sector – Tradeoffs

Developments in Europe
- Integration of intermittent Renewables
- Nuclear phase-out?
- CO$_2$ emission targets
- Gas imports

Supply Security

Electricity Supply Options
- Gas
- Renewables
- Import

Cost of Supply
- Cost implications of renewable / low carbon policy
- Revenue from trade

Balancing supply and demand
- Intermittent nature of renewables
- Electricity imports

Climate change
- CO2 emission targets
- Expansion of Gas plants
Model Features

- Single region model
- Time horizon: 2000 – 2100 in 18 time periods
- An hourly timeslice (288 timeslices)
- Characterization of about 140 technologies and over 40 energy and emission commodities

Key Parameters

- Exogenous electricity demand for the future
- Range of primary energy resources
- Electricity import and export from four countries

R Kannan & H. Turton (2011) - Documentation on the development of the Swiss TIMES electricity model
Available at http://energyeconomics.web.psi.ch/Publications/Other_Reports/PSI-Bericht%2011-03.pdf
Objectives

- Analyse developments in the neighbouring countries – Germany (DE), Austria (AT), France (FR) and Italy (IT)
- Quantify the extent to which these developments affect the Swiss electricity sector
- Can Switzerland depend on imported electricity?
• **CROSs** border Swiss TIMES Electricity Model
• Extension of the STEM-E model to include the four neighbouring countries
• Time horizon: 2000 – 2050 in 14 unequal time periods
• An hourly timeslice (288 timeslices)
• Detailed reference electricity system with resource supply, renewable potentials and demands for 5 countries
• Calibrated for electricity demand and supply data between 2000-2010
• Endogenous electricity import / export based on costs and technical characteristics
3 Scenarios selected for Analysis

- **Base (BASE)** – No specific constraints on technology choice, nor any emission targets, Swiss BAU CO2 tax applied,

- **Low Carbon (LC)** – A cap on the total CO$_2$ emission from electricity generation is applied across all regions. Level of decarbonisation to reach 60% of 1990 levels by 2030, 98% by 2050$^1$.

- **Renewable Scenario (REN)** – A minimum of 20% of the CROSSTEM demand is to be met by renewable sources by 2020$^2$, 40% by 2050.
  - Excluding hydro!

Key assumptions

- Nuclear phase-out in Switzerland and Germany has been assumed. Only France will continue with its nuclear program.
- Electricity demand obtained from GEMINI-E3, a dynamic recursive CGE model.
- Renewable potential in accordance with various national and European studies.
- CCS potential implemented based on European studies.
- Self Sufficiency constraint: no net import/export for future years for all countries except LC scenario!
- Trade with “fringe regions”: enable or disable? If enabled, then historical maximum values set as upper bounds.

Key assumptions

- **CO2 price** – Swiss BAU CO2 tax\(^5\) applied in all regions.
- **Fuel Prices** – Universal fuel prices from WEO 2010\(^6\).
- **No trade loss** – In endogenous and exogenous trade, no trade loss assumed.
- **Copper Plate regions** – No transmission lines, nor transmission costs, only interconnectors between regions

Electricity generation mix – 5 countries

Electricity generation mix: CROSSTEM

- Net Import
- Wood
- Waste & Biogas
- Wind
- Solar
- Geothermal
- Oil
- Gas-CCS
- Gas (Flex)
- Gas (CHP)
- Gas (Base)
- Coal-CCS
- Coal
- Nuclear
- Hydro (P)
- Hydro (D)
- Hydro (R)
- Pumps
- Total Demand

PI

2010 2020 2035 2050

Base BAU REN LC

Preliminary Results

PSI, 18.11.2015
CO\textsubscript{2} emissions – 5 countries

CO\textsubscript{2} emission: CROSSTEM

<table>
<thead>
<tr>
<th>Year</th>
<th>BAU</th>
<th>REN</th>
<th>LC</th>
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<tbody>
<tr>
<td>2010</td>
<td>400</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>2020</td>
<td>500</td>
<td>150</td>
<td>150</td>
</tr>
<tr>
<td>2035</td>
<td>600</td>
<td>200</td>
<td>200</td>
</tr>
<tr>
<td>2050</td>
<td>700</td>
<td>250</td>
<td>250</td>
</tr>
</tbody>
</table>

Legend:
- CH
- AT
- FR
- IT
- DE

Mt CO\textsubscript{2}
Electricity generation costs (Rp/kWh)
Load Curves

BASE – Summer Weekday - 2050
Load Curves

BASE – Summer Weekday - 2050

- **Export**: DE: SUM-WK (2035)
- **Import**: DE: SUM-WK (2050)
- **Export**: AT: SUM-WK (2050)
- **Import**: AT->DE, CH->DE, FR->DE, OT->DE
BASE – Summer Weekday - 2050

Load Curves

IT - Export

IT - Import

Export: IT: SUM-WK (2050)

FR: SUM-WK (2050)

IT - Export

IT - Import

Export: IT: SUM-WK (2050)

FR: SUM-WK (2050)

IT - Export

IT - Import

Export: IT: SUM-WK (2050)

FR: SUM-WK (2050)
Load Curves

BASE – Summer Weekday - 2050

And so on … … …
Load curves – comparison between scenarios

Switzerland – Summer Weekday - 2050

CH: SUM-WK (2050)

BASE

RENS

LC

- Pump
- Export
- Import
- Biomass
- Waste/Biogas
- Solar
- Geothermal
- Wind
- Gas (CHP)
- Gas (F)
- Gas (B)
- Nuclear
- Hydro (P)
- Hydro (D)
- Hydro (R)
- Demand (GW)
- Marginal cost
Load curves – comparison between scenarios

Switzerland – Fall Saturday - 2050

CH: FAL-SA (2050)

BASE

REN

LC

Marginal cost

Pump

Export

Import

Biomass

Waste/Biogas

Solar

Geothermal

Wind

Gas (CHP)

Gas (F)

Gas (B)

Nuclear

Hydro (P)

Hydro (D)

Hydro (R)

Demand (GW)
Conclusions

• Model over a long term horizon combined with dispatch aspect achieved.
• Quantified the developments in the neighbouring countries and its impact on the Swiss electricity sector was achieved.
• Importance of pumped storage and trade to balance load demands was analysed
• Results need to be refined - Outlook
Issues and Challenges

Model deficiencies

• Trade with Fringe countries – Enable or Disable?
• Pumped Storage – Not pumping at off-peak and discharging at peak

Modelling Challenges

• Computational time – 50 hours!!!
• Data Collection & Uncertainties – Difficulty in obtaining consistent data from certain countries. Discrepancies between different data sources
• Scenarios and Policy – No coherent story line
Outlook

• Continuous improvement of the model – update potentials, technology data, costs, calibration of model – eg. Gas plants in Switzerland
• Refinement of results
• Scenario development and implementation – Analysis of Swiss Energy Strategy in light of European developments
• Possibility for the inclusion of transmission lines
• Methods to improve computational requirements – eg. period definition
Thank you for your attention !!!
Energy Economics Group

Laboratory for Energy Systems Analysis

General Energy Research department & Nuclear Energy and Safety Research Department