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Development of the CROSSTEM model – A tool for analyzing uncertainty in the evolution of the Swiss electricity system
Outline

- Introduction – Background of Swiss Electric system
- CROSSTEM Model
- Motivation – European nuclear phase-out and its consequences
- Scenarios & Key Assumptions
- Preliminary results
- Conclusions
- Model limitations, issues and challenges
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 2012

1. “Schweizerische Elektrizitätsstatistik 2012”, BFE Bern, Okt 2013
• **Nuclear phase out** – No replacement of existing Nuclear power plants at the end of their 50 year lifetime. Last power plant off grid by 2034.

• **Ambitious carbon reduction targets**

• **Uncertainty in electricity demand** – The Swiss Energy Strategy 2050 defines possible demand pathways
  • Business as Usual (WWB)
  • Political Measures (POM)
  • New Energy Policy (NEP)

• **Uncertainty regarding future supply options** – A combination of gas based generation, renewables and electricity imports are mentioned in SES 2050.
Swiss Energy Strategy 2050 – Demand projections

Demands from BFE, 2012

- BFE: Weiter Wie Bisher
- BFE: Politische Massnahmen
- BFE: Neue Energiepolitik

*"Swiss Electricity Supply Options: Techno-economic Analysis”– Ramachandran Kannan, ENE-NES Colloquium 2013
Future of Electricity sector – Tradeoffs

Developments in Europe
- Integration of intermittent Renewables
- Nuclear phase-out?
- CO₂ emission targets
- Gas imports

Supply Security

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

Electricity
Supply Options
- Gas
- Renewables
- Import

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

Climate change
- CO₂ emission targets
- Expansion of Gas plants
• CROSs border Swiss TIMES Electricity Model
• Extension of the STEM-E model to include the four neighbouring countries
• Time horizon: 2010 – 2070
• 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
TIMES – The Integrated MARKAL / EFOM System

- Technology rich, Perfect foresight, cost optimization framework
- Used to explore a range of parametric sensitivities under a “what-if” framework via exploratory scenario analysis.
- Integrated modelling of the entire energy system
- Prospective analysis on a long term horizon (20-50-100 yrs)
- Allows for representation of high level of temporal detail – load curves
- Enhanced Storage algorithm – modelling of pumped storage systems
- Optimal technology choice – based on costs, environmental criteria and other constraints.

MARKAL – MARKet ALlocation
EFOM – Energy Flow Optimization Model
Motivation – European nuclear phase-out
• **Low carbon pathway for electricity** – EU Roadmap 2050

• **“Nuclear Renaissance”** – Switzerland and France to continue with its nuclear program. Italy to have 25% of net generation from nuclear by 2030. Germany to extend life times of existing plans\(^3\).

• **Fukushima Accident** – Socio-political consequences

• **Nuclear phase-out**
  • Germany by 2022
  • Switzerland by 2034
  • Italy to continue with its nuclear moratorium
  • France to reduce share from 75% to 50% by 2025 (?)

European Nuclear phase-out - Background

- **Alternative supply options** – Germany substituting nuclear power with coal based generation → 43% (2010) to 52%(2013)

- **Green house gas (GHG) reductions** – Complete de-carbonization of power sector by 2050

  *Alternative low carbon sources of electricity*

- Technical, Economical and Social challenges and uncertainties
2 basic scenarios and 3 CCS scenario variants selected for Analysis

• **Reference Scenario (REF)** – Nuclear policies of 5 countries implemented. No CO$_2$ emission targets. Nuclear phase-out in CH by 2034, DE by 2022. French nuclear fleet can be replaced.

• **CO2 reduction scenario (CO2-Base)** – REF scenario with 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, 95% by 2050.
CCS Scenario variants

• **High CCS scenario (CO2-CCS-H)** – Upper variant of CCS potentials.

• **Low CCS scenario (CO2-CCS-L)** – Lower variant of CCS potentials.

• **No CCS scenario (CO2-NoCCS)** – No investment in CCS technology. Free trade allowed in this scenario.
Key assumptions

Input Assumptions

• **Electricity Demand** – EU Trends to 2050 (Reference scenario), BAU demands for CH (SES 2050)

• **Trade with “fringe regions”** – Historical limits applied

• **CO2 price** – European ETS prices implemented (SES 2050, Bfe)

• **Fuel Prices** – International fuel prices from WEO 2010.

Methodological Assumptions

• **Copper Plate regions** – No transmission and distribution infrastructure within each country. Interconnectors between regions, with no trade loss.

• **Endogenous trade limits** – Based on historical trends. Net importers cannot become net exporters and vice versa. Not applied to NoCCS.
Results
Electricity generation mix – 5 countries aggregated

- 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

2010, 2050, 2050, 2050, 2050, 2050
Country wise Results

Electricity generation mix - Switzerland

- 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
Country wise Results

Electricity generation mix - France

- 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
Country wise Results

Electricity generation mix - Germany

- 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
Electricity generation mix - Italy
Country wise Results

Electricity generation mix - Austria

- 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
Load Curve – Summer Weekday 2050 (CO2-CCS-L)

FR: SUM-WK (2050)

DE: SUM-WK (2050)

IT: SUM-WK (2050)

AT: SUM-WK (2050)

CH: SUM-WK (2050)

FR - Import

DE - Import

IT - Import

AT - Import

CH - Import

FR - Export

DE - Export

IT - Export

AT - Export

CH - Export
Conclusions

- Model of the electricity system of Switzerland and its neighbouring countries over a long term horizon combined with dispatch aspect achieved.

- Effects of surrounding country developments on the Swiss electricity system have been demonstrated.

- Possibilities for alternative low carbon electricity generation pathways for the five countries has been explored.

- Sensitivity of various CCS potentials analysed

- Decarbonisation of the power sector is plausible, but significant investments necessary in both renewable technologies as well as CCS.
Limitations & Uncertainties

- CROSSTEM is not a pure dispatch model.

- Modelling of representative days – Overall simplifications

- T&D infrastructure not explicitly modelled.

- CO2 transport not modelled

- Trade with fringe regions

- Model assumes perfect information, perfect foresight, well functioning markets and economically rational decisions – Optimal solution for 5 countries together, not for each country
Thank you for your attention !!!
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