Development of methods and tools responding to the needs of energy transition: PSI perspective

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Renewable energy changes the electricity system

Main challenges in electricity modelling but very important to model the full energy system since (1) electricity is fundamental for the overall efficiency improvement; (2) necessary for optimal (with view to efficiency, cost, climate protection goals, etc.) allocation of electricity to specific demand sectors:

- Distinguishing between centralized and decentralized generation
- Representing electricity grid from high to low voltage
- Identifying storage options and new business models, e.g. prosumers
- Capturing the intra-annual variability of renewable generation and demand
- Assessing interactions between demand and supply

Source: http://ilsr.org/challenge-reconciling-centralized-v-decentralized-electricity-system/
Methods, Models and Databases

Swiss TIMES energy systems model

- Oil (conventional, unconventional)
- Natural Gas (conventional, unconventional)
- Coal ( lignite, anthracite, brown)
- Biomass (1st & 2nd generation, wood, waste)
- Renewables (Hydro, Wind, Solar, Geothermal)
- Uranium

Life Cycle Assessment

- Chain Boundary
- Electricity (at source)
- Power Plant
- Long-distance transport
- Reduction
- Exploration & Extraction

Ecoinvent Database

- > 12’000 processes
- Query tool
- Data consumer XY

Impact Pathway Approach

- Emissions, Dispersion, Physical & Chemical Reactions
- Impacts on human health, crop yields, buildings, land, ecosystems...

Bilevel Electricity Market Model

- 1st level (investment decision)
  - Optimization Player 1: Investment in supply technologies
  - Optimization Player 2: Investment in supply technologies
  - Optimization Player 3...
- 2nd level (spot market trading)
  - Quantity bidding (4*24hours)
  - Quantity bidding (4*24hours)
  - Market clearing of TSO under transmission constraints (price-taker)

ENSAD Database

- > 32’000 accidents
- 32’963 accidents data
- Importing to Ecoinvent
- Geo-database

Risk Assessment

- Geographic Information Systems (GIS)
- ENSAD
- PSA

- Other parameters:
  - socio-economic
  - ecological
  - geo-physical
  - etc.

Technology Database

- Technology Data
- Technology Information
- Technology Development
- Technology Testing
- Technology Deployment
- Technology Evaluation

Integration:
Multi-Criteria Decision Analysis

- User management
- MCDA data management
- Analysis of user preference profiles
New Technologies
## Sustainability Criteria

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<th>Criterion</th>
<th>Source: Hirschberg et al., 2007&amp;2008</th>
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Source: Hirschberg et al., 2007&2008
Energy systems models are the main tool for assessing long-term transformation strategies.

The STEM model represents the Swiss energy system from resource extraction to end-uses.

It is a bottom-up cost optimization model with long time horizon (2015 – 2100).

It has high hourly resolution and high technological detail (> 350 processes/technologies).

Significant development has been done in STEM to respond to the electricity sector’s challenges.
Centralized vs decentralized supply & grid levels

- Each grid level is differentiated in terms of transmission cost and losses
- Different types of power plants and storage options can be connected to each level
- A linearized approximation of the power plant unit commitment problem (dispatch) is formulated
- This structure allows for capturing the effect of incentives for decentralized generation and the benefits of own consumption and/or selling excess supply to upper grid levels (prosumers)

**REPRESENTATION OF CENTRALIZED/DECENTRALIZED GENERATION AND DIFFERENT GRID LEVELS IN THE STEM MODEL**

**ELECTRICITY GENERATION MIX IN 2050 REFERENCE SCENARIO**

- +50% increase in Solar PV when the prosumer concept is represented

**Grid levels 2, 4 & 6 are transformers**

Source: PSI/Kannan & Panos, 2017
The detailed transmission grid is mapped to an aggregated grid with 15 nodes and 319 lines. The mapping is based on a fix disaggregation of the reduced network injections to detailed network injections, by taking into account the grid transmission constraints. This structure allows for evaluating the impact of grid congestion on electricity supply and demand.

Marginal cost increases due to congestion occurs for about 2000 hours.

No grid means no representation of grid constraints. The different cases correspond to different locations of large gas power plants; grid expansion is limited to 2025 plans.

Climate policy cost +1.5 BCHF/yr if grid is not expanded.
Capturing the variability of renewables

- The variability of RES is based on the variance of mean RES production in each hour and for each typical day represented in the model over a 20-year bootstrapped sample.
- This allows to assess the storage requirements to balance the RES production.
- High shares of VRES require electricity storage peak capacity of ca. 30 – 50% of the installed capacity of wind and solar PV (together).
- About 13% of the excess summer VRES production is seasonally stored in P2G.
Features of PSI’s analytical framework for comprehensive energy systems modeling

• Strong technological basis
• Scope covers environmental, economic and social dimensions
• Variety of methods, models and databases
• Inter-disciplinary technology assessment coupled with system models
• Integrative approaches combining knowledge with stakeholder preferences
• Systematic approach to modeling and assessing prospective technological advancements
• Endogenous capacity expansion
• Systematic extension of system models within a modular framework
• Representation of whole energy system with detailed modeling of demand sectors (e.g. mobility)
• Coupling of bottom-up technology rich system models with grid
• Geographic coverage (CH, Europe, China and other regions, global)
• Temporal resolution and striving for increased spatial resolution
• Ongoing developments towards integrating behavior in system models
• Continuity and expandability
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Thank you for your attention!