Electricity Demand modelling and projections in Europe combining the advantages of macro-economic and technology-oriented models by hard links

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Overview presentation

- Current EU-Wide context for Electricity Demand
- Overview of Modelling Approaches and FORECAST FC4 Platform
- Hybrid Modelling Approach and Challenges
- The case of Steel Modelling and TRANSFORM/MATEFF/IMPULSE Module
- Results for:
  - Steel Modelling
  - Energy and Electricity Demand Projections in EU
- Conclusion - Discussion
EU-Context: current Energy Efficiency objectives must fulfill long term requirements across different sectors

- The EU Energy Roadmap, published in 2011 by the EU Commission, serves as a basis for discussion for the future energy and climate policy in EU until 2050.
- All sectors must contribute to the Emissions Reduction Objective of -85% compared to the 1990 levels.
- The new Energy Efficiency Objectives in the framework of the Directive require actions from electricity consumers and producers
- The role of Energy Efficiency is until now insufficiently analysed
- Electricity is highly probable to be the most important energy carrier in 2050
- Energy Efficiency influences significantly in which way the electricity sector must be reorganized

EU Context: Electricity Demand will **continue to increase** in case, if not handled.

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**Table:**

<table>
<thead>
<tr>
<th>EU27</th>
<th>Total 2008</th>
<th>2003 vs. 2008</th>
<th>Relative change 2008-2050</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Primary Energy</strong></td>
<td>1800 Mtoe</td>
<td>±0.0%</td>
<td>REF -2.0%</td>
</tr>
<tr>
<td><strong>Final Energy</strong></td>
<td>1160 Mtoe</td>
<td>+0.3%</td>
<td>REF +5%</td>
</tr>
<tr>
<td><strong>Electricity Demand</strong></td>
<td>2860 TWh</td>
<td>+7.0%</td>
<td>REF +44%</td>
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</tbody>
</table>
Combining aspects from both Top-Down and technology-based bottom-up simulations for Electricity Demand and Energy Efficiency Potentials

**TOP-DOWN MODEL**
- economy as a whole
- aggregated effects

- Macroeconomic model

**HYBRID MODEL SYSTEM**
- Econometric models
- System-dynamic models
- General equilibrium models
- Input-output models

**TRANSFORM/MATEFF/IMPULSE**
- Technology-oriented model
- sector- and process level
- technological detail

**BOTTOM-UP MODEL**
- Optimisation models
- Multi-agent models
- Accounting models
- Simulation models

Source: Herbst et al. 2012a, 2012b
A technology-based bottom-up modelling platform for electricity and energy demand simulation and energy efficiency potentials

Definition Scenario
Assumptions GDP, energy carrier wholesale-prices, population, policy intensity

FORECAST Macro
Gross value added, physical production, employment

FORECAST Pricing
Sector specific retail prices, incl. tax legislation

FORECAST
Annual demand

Industry
Branch: Pulp & Paper
Process: Paper
Saving Option: Shoe press

Tertiary
Branch: Finance
Energy service
Saving option: LEDs

Residential
Sub-Modules: Appliances
Technology: Screens
Efficiency Class: LCD

Others
Agriculture
Rail transport
Electric mobility
Others

Results
Energy demand, efficiency & substitution potentials, related Investments, Indicators, GHG emissions

IREES
Institute for Resource Efficiency and Energy Strategies
eLOAD: Simulating hourly electricity demand from annual results for different sectors and electric appliances and processes

**FORECAST Macro**
Gross value added, physical production, employment, etc.

**FORECAST Pricing**
Sector specific retail prices

**FORECAST**
Annual demand results:
*Electricity & Fuel Demand, Potentials, Indicators, GHG Emissions*

**Consideration of structural change**
- Load curves, load profiles
- Temperature

**eLOAD**
*Hourly demand*

**DSM adjustment**
- DSM parameters
- Pricing: RTP, TOU, CPP

**Results**
*Hourly demand curve and profiles*
Transparent simulation of inter-sectoral and intra-industrial structural change and its influences on future energy and electricity demand

Objectives:

- Linkage of a macro-economic model with a bottom-up model by means of transparent transformation of value added into physical units of production (tons) of energy-intensive products
- Structural changes (foreign trade) and material efficiency & substitution considered

Challenges of the TRANSFORM-module:

- Decoupling of gross value added and physical production development (e.g. quality improvements, additional product-accompanying services)
- Insufficient or no knowledge about process-shifts
- Improvements in material efficiency by design or properties & recycling
- Changes due to material substitution & saturation effects
- Trade effects

Source: Herbst, A., Jochem, E. (2013a) following Jochem et al., 2007&2008; Schade et al., 2009; Fleiter et al. 2013, TEP Energy
STEEL PRODUCTION ROUTES AND SCRAPPAGE AVAILABILITY

Final basic product, distinguishing primary and recycle chains of production

- Traditional metal, energy-intensive, very much quality differentiated, highly traded, stagnating production in Europe since 1979
- Used in construction, vehicle industry, shipbuilding, investment goods and durable goods industries

Basic oxygen furnace route (BOF)

- Primary production
- Raw material: iron ore, coke, gas and raw iron and some steel scrap
- Primary energy consumption three times higher than for secondary production route

Electric arc furnace route (EAF)

- Secondary production
- Raw material: steel scrap

Apparent Steel Use (ASU)

- Steel production minus exports of finished steel and foreign trade of steel products
- per capita ASU declining since 1979 (except Italy)
Steel Material Flow Analysis – Highly Complex and Data Demanding Simulation and Modelling

Steel production (crude steel to semi- and finished products)

Oxygen
Electricity
Natural gas
Iron ore, sinter
Coke

Converter
BOF
EAF

Steel scrap
Prompt scrap
Post-use scrap
Home scrap

Steel good manufacture (asu)

Exports of finished steel
Imports of steel goods
Export of steel goods
Imports of finished steel

Scrap export
Scrap import

Results reflect **stagnation in total steel production**, slight increases in post-use **recycling rates** further increase the share of electric steel (the basis of this projection is high economic growth in Europe)

- **Electric steel production** follows rather different pathways:
  - stagnation/decrease in Italy after 2025; France little increases; United Kingdom continues historic trends; Total steel use (TSU) dominates German results (stagnation in oxygen steel and increase in electric steel)
  - In less favourable economic growth scenarios, Europe has to face surplus production capacity particularly in oxygen steel production

Source: Herbst et al. (2014)
A STABILIZATION OF THE ELECTRICITY DEMAND IN EUROPE TO THE PRESENT LEVELS IS POSSIBLE

Assumptions

- Baseline from EU official source PRIMES
- Almost 70 TWh correspond to heat pumps in households and services sectors (12% all European Households)
- 60 TWh correspond to ca. 23 Mio. E-Cars (8% of Pass. Car Stock)
- On the contrary: the electrification of 66% of the complete passenger car stock would require an additional of 260 TWh

Gross electricity demand and efficiency potentials

Source: Fraunhofer ISI on behalf of Federal Environmental Ministry, 2012
INDUSTRIAL ENERGY AND ELECTRICITY DEMAND CAN BE REDUCED BY 52% IN 2050

- Baseline from EU official source PRIMES grows 17% compared to 2008.
- Final energy demand reduction potential of 52% compared to baseline.
- 75% efficiency increase from cross-cutting technologies.
- Cost savings in 2050 amount to 102 billion Euros (€2005).

Source: Fraunhofer ISI on behalf of Federal Environmental Ministry, 2012
Conclusions

- The design of a bridge between macro-economic and technology-oriented energy demand models combines the advantages of both model types. However,
  - the econometric analysis is cumbersome and data-intensive,
  - future structural and technology changes may vary the coefficients of those equations
  - energy-intensive basic products: effects of material efficiency & substitution, and recycling, changes in foreign trade have to be looked at from a material flow perspective
- Future electricity demand should be clearly separated in effects of electricity efficiency, structural changes, and additional electricity demand due to new electricity applications.
- Future electricity demand of Europe is likely to stagnate in the next decades. Electricity efficiency and structural change to less energy-intensive branches may fully compensate effects of additional electricity applications and growth effects.
- Load shaping and shifting by DMS will be one of several strategies to make the transition to renewables in the coming decades a success story, as electricity use has to follow the electricity supply in the long term, opposite to present supply patterns.
Thank you for your attention!

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Research Areas
• Modelling Electricity and Energy Demand and simulation of the diffusion of Energy Technologies in Industry, Services and Transport sectors
• Barriers for Energy Efficiency Technologies in Industry and Services and development of Strategies, Policy Instruments and promoting factors
• Techno-Economic Potential Analysis and Cost-Benefit for industrial Co-Generation and Renewable Energies
• Modelling of Energy and Material Efficiency in energy intensive industries based on scenario assumption and frameworks
• Energy Policy, Economics and Climate Policy

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References


Examples of energy projections and policy advice of FORECAST/eLOAD

**European Commission**
- Energy saving potentials in all sectors until 2030 ([http://www.eepotential.eu](http://www.eepotential.eu))
- Long-term climate mitigation scenarios for the EU ([www.adamproject.eu](http://www.adamproject.eu))
- European Institute of Technology: “Case studies of the EU energy system in 2050” ([www.esa2.eu](http://www.esa2.eu))

**National governmental institutions**
- Long-term climate policy scenarios for Germany ([http://www.umweltbundesamt.de/uba-info-medien/4412.html](http://www.umweltbundesamt.de/uba-info-medien/4412.html))
- Saving potentials and costs in German energy-intensive industry ([http://publica.fraunhofer.de/dokumente/N-214110.html](http://publica.fraunhofer.de/dokumente/N-214110.html))
- Support of integrated heating and cooling strategy

**European energy utilities**
- Long-term EU electricity demand scenarios in European countries
- Load curves and DSM potentials in European countries
- CHP potentials and structure of heat demand (temperature levels) in Switzerland
- Long-term electricity demand and load curves of the German household sector
- Scenarios for industry demand for EU ETS CO2 certificates (EUAs)
Forecast development:
Common work of the involved four research institutes

- **Fraunhofer Institute for Systems- and Innovation Research (ISI), Karlsruhe**
  - Responsibilities: Coordination, programming, industry sector, household sector, load curves

- **IREES (Institut für Ressourceneffizienz und Energiestrategien), Karlsruhe**
  - Responsibilities: TRANSFORM/MATEFF and support tertiary and industry sectors, agriculture

- **TEP Energy, Zurich**
  - Responsibilities: tertiary sector, programming, load curves
Example: loadcurve in Germany 2010 (left) and 2035 (right)