CO₂ prices and system costs - a multi-scenario analysis with an agent-based electricity market model

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Use of agent-based models in energy sciences

Agents:
- Attributes + Methods (+ Interfaces)
- Central: Behaviors / decision rules

Decision rules can be based on **any** model:
- Logic (if… , then…; else…)
- Machine learning algorithm
- System dynamics model
- Dispatch model
- …
AMIRIS architecture

Input
- RE generation
- Load curves
- Power plants
- Efficiencies
- Availability
- Fuel costs
- CO₂ prices resp. CO₂ cap

Output
- DA electricity price
- Power plant dispatch
- Storage dispatch
- Market values
- CO₂ emissions resp. CO₂ prices
- System costs
Advantages of AMIRIS

AMIRIS can incorporate:
• „Non-rational“ decision rules
• Policy rules
• Market distortions

AMIRIS allows us to:
• Study emerging effects on power markets
• Yield exactly the same results as optimization model
  if parametrized the same way

**Fast**: 10 s/per model year on a standard Laptop with 8 GB RAM
Multi-scenario analysis – exploring the possibility space of power markets

<table>
<thead>
<tr>
<th></th>
<th>Low</th>
<th>Mid</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO2 price [€/t]</td>
<td>5</td>
<td>50</td>
<td>100</td>
</tr>
<tr>
<td>Electricity demand [%/a to 2016]</td>
<td>-1.0</td>
<td>+0.5</td>
<td>+2.0</td>
</tr>
<tr>
<td>Fuel prices [% to 2016]</td>
<td>-50</td>
<td>+0</td>
<td>+100</td>
</tr>
<tr>
<td>VRE share [%]</td>
<td>40</td>
<td>50</td>
<td>60</td>
</tr>
<tr>
<td>Flexibility [GW]</td>
<td>6.2</td>
<td>12.4</td>
<td>18.6</td>
</tr>
<tr>
<td>Technological learning [%/a]</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Coal phase-out [%]</td>
<td>0</td>
<td>50</td>
<td>100</td>
</tr>
</tbody>
</table>

\[3^7 = 2187\] scenarios
Multi-scenario analysis – exploring the possibility space of power markets

- Calculate 2187 times
- Exemplary evaluation in 2 dimensions
Multi-scenario analysis – exploring the possibility space of power markets

CO₂ prices I

Klein, Deissenroth, Schimeczek (2019) - Mapping the challenge of renewable electricity market integration – Multi-scenario analysis with an agent-based electricity market model, IEWT Wien
Multi-scenario analysis – exploring the possibility space of power markets

CO₂ prices II

Klein, Deissenroth, Schimeczek (2019) - Mapping the challenge of renewable electricity market integration – Multi-scenario analysis with an agent-based electricity market model. IEWT Wien
Multi-scenario analysis – exploring the possibility space of power markets
Coal exit variations

Coal Decommissioning
- low
- mid
- high

Emissions in M€/y

VRE low  VRE mid  VRE high

Klein, Deissenroth, Schimeczek (2019) - Mapping the challenge of renewable electricity market integration –
Multi-scenario analysis with an agent-based electricity market model, IEWT Wien
Agent-based optimization – new way of optimizing power systems

System cost

Multi-dimensional parameter set
Agent-based optimization – new way of optimizing power systems

System cost

Multi-dimensional parameter set

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System cost

Band of „solutions“
accepted

Multi-dimensional parameter set

Marginal Costs
Conventional Power Plants

Reserve
Market

Energy
Exchanges
Storage
Operators
Money Flow
Virtual Power Flow
Regulatory Framework

Feed

Traders
Demand
Minute
Reserve
Market

Biomass and
Photovoltaic
Power Plant

Wind Plant

Hydro Plant

Operators...

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System cost maps – concise way of depicting power market trade-offs

Klein, Deissenroth, Schimeczek (2019) - Mapping the challenge of renewable electricity market integration, IEWT Wien
Discussion and outlook

Scenario exploration using an agent-based energy system model

⇒ Fast model execution allows many scenario evaluations

Analyses reveal multi-dimensional dependencies

$\text{CO}_2$ price turns out to be robust against other parameter configurations regarding reduction of $\text{CO}_2$ emissions

Further research planned on parameter complexity and path dependence of energy systems

- Maps can show power system trade-offs at one glance
- Size and stability of system cost minima
Thank you for your attention!

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