Actors’ behaviour analysis in a decentralised energy system:
Overview of TIMES-Actors-Model and the German supply sector

Ali Tash

Source: Getty
Agenda

• Project “Decentral”
  • Motivation
  • TIMES-Actors-Model (TAM)
  • Model coupling

• Supply sector
  • Introduction
  • Methodology
  • Scenario construction
  • Preliminary results
  • Discussion
Project “Decentral”

Motivation

• The German energy system is increasingly becoming diverse and decentralised through the variable spatial distribution of energy resources and the variety of actors and technologies.

➢ Ensuring that the ambitious goals of the Energy Transition are met cost-efficiently has become exceedingly complex.

• What is the optimal structure of the overall German energy system constructed from a mixture of centralised and decentralised technologies, considering the existing diversity of actors and their decision-making behaviour?

• Development of a methodological approach for improving the current average/aggregated representation of the actors in energy system optimization models (e.g. TIMES) in order to capture heterogeneous actors’ diverse rational behaviour.

• Provide an insight into the heterogeneous energy system for targeting the right actors to achieve the energy transition goals at least costs.
Project “Decentral”

Motivation

- **(Rational) Actor behaviour** refers to the way actors in an energy system respond to different frameworks, while they are being subjected to their boundary conditions and at the same time satisfying their preferences and maximising/minimising their surplus/costs.
• (Rational) Actor behaviour refers to the way actors in an energy system respond to different frameworks, while they are being subjected to their boundary conditions and at the same time satisfying their preferences and maximising/minimising their surplus/costs.

Research Objectives:

1. Capture the heterogeneous actors’ behavior in an optimal energy system which achieves the targets of the “Energy Transition”.

2. Assessment of the policy instruments, which shape the current actors’ behavior towards this optimal behavior at least system costs.
Project “Decentral”
TIMES Actors Model (TAM)

Energy suppliers
Minimization of costs (Profit maximization)

- Investors
- Grid
- Potential

Transport services
Minimization of costs (Profit maximization)

- Energy carrier
- Technology

Industry
Minimization of costs (Profit maximization)

- Type of industry
- Techno-economic potential
- Sensitivity to changes
- Transportation

Households
Budget constraints (Utility maximization)

- Building type / ownership etc.
- Techno-economic potential
- Socio-economic factors
- Transportation

Other demand sectors
Minimization of costs (Profit maximization)
Project “Decentral”

Model coupling

\[
\begin{align*}
|Price_i - Price_{i-1}| & \leq Err_{price} \\
|demand_i - demand_{i-1}| & \leq Err_{demand}
\end{align*}
\]
Agenda

- **Project “Decentral”**
  - Motivation
  - TIMES-Actors-Model (TAM)
  - Model coupling

- **Supply sector**
  - Introduction
  - Methodology
  - Scenario construction
  - Preliminary results
  - Discussion
Supply sector

Introduction

The volume of capital needed for a widespread transition towards a renewable energy system **will/might require** increasing participation of institutional investors and citizens.


* It is absolutely essential to study the diverse actors‘ behaviour in the supply sector as well.*
Supply sector
Methodology; Actors’ characteristics
Example: Actor’s investment decision-making

• How does an investor decide?
Supply sector
Methodology; Actors’ characteristics
Example: Actor’s investment decision-making

• How does an investor decide?
Supply sector
Methodology; Actors’ characteristics
Example: Actor’s investment decision-making

• How does an investor decide?

- Other preferences e.g. environment
- Risk/Return of past Investments

Cost of Capital

Internal Rate of Return

Alternative investments/Hurdle Premiums

Investment₀ - \sum_{t=1}^{N} \frac{(Project Cash Flow)_t}{(1 + IRR)^t} = 0

• Cost of Capital
  - High → OPEX (e.g. Conventionals)
  - Low → CAPEX (e.g. Renewables)

Modelling the cost of capital by actor’s specific discount rates
Supply sector
Methodology; Actors’ environment
Example: Energy potentials & Grid

✓ The German supply sector is divided into 4 regions.

- How to deal with spatial imbalance in renewable generation? Curtailment, storage, investment in more expensive renewables within the region or grid development for power exchange.

✓ Grid costs (new investment, operation) are implemented in the model for an accurate comparison between the solutions.
Supply sector
Scenario construction

- There are an overall six scenarios.
Supply sector
Scenario construction

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
<th>Renewable share (%)</th>
<th>Carbon taxes (2015US$/t\text{CO}_2)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>2020    2030  2040  2050  2060</td>
<td>2020    2030  2040  2050  2060</td>
</tr>
<tr>
<td>RES</td>
<td>Achieving renewable quota</td>
<td>≥35      ≥65   ≥75   ≥85   ≥95</td>
<td>0       0     0     0     0</td>
</tr>
<tr>
<td>CO2</td>
<td>Imposing 2°C carbon taxes</td>
<td>-        -     -     -     -</td>
<td>20      100   140   180   240</td>
</tr>
<tr>
<td>RES_CO2</td>
<td>Renewable quota + 2°C carbon taxes</td>
<td>≥35      ≥65   ≥75   ≥85   ≥95</td>
<td>20      100   140   180   240</td>
</tr>
</tbody>
</table>

(Bundesnetzagentur, Monitoringbericht, 2017) & (Coalition agreement, 2018) & (ETP, 2017)

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Specific discount rate (Cost of capital)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Utilities</td>
</tr>
<tr>
<td>NOACT</td>
<td>7.5%</td>
</tr>
<tr>
<td>DRACT</td>
<td>9%</td>
</tr>
</tbody>
</table>

(Steinbach et al., 2015)
## Supply sector

### Scenario construction

<table>
<thead>
<tr>
<th>Actor</th>
<th>Region</th>
<th>Technology</th>
<th>Maximum yearly new capacity allowance (GW) in DRACT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Citizens</strong></td>
<td>NORTH EAST</td>
<td>Wind Offshore Potential</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>SOUTH WEST</td>
<td>Wind Onshore Potential</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>PV Plant-size Potential</td>
<td>5.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PV Rooftop Potential</td>
<td></td>
</tr>
<tr>
<td><strong>Institutional Investors</strong></td>
<td>NORTH EAST</td>
<td>Wind Offshore Potential</td>
<td>3.0</td>
</tr>
<tr>
<td></td>
<td>SOUTH WEST</td>
<td>Wind Onshore Potential</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>PV Plant-size Potential</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>PV Rooftop Potential</td>
<td>0</td>
</tr>
<tr>
<td><strong>Utilities</strong></td>
<td>NORTH EAST</td>
<td>Wind Offshore Potential</td>
<td>No limits</td>
</tr>
<tr>
<td></td>
<td>SOUTH WEST</td>
<td>Wind Onshore Potential</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>PV Plant-size Potential</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>PV Rooftop Potential</td>
<td>0</td>
</tr>
</tbody>
</table>

Supply sector
Preliminary results & discussion

Gross electricity generation by different energy carriers

- Base-Year
- RES_DRACT
- RES_NOACT
- CO2_DRACT
- CO2_NOACT
- RES_CO2_DRACT
- RES_CO2_NOACT

Energy carriers:
- Hard Coal
- Hard Coal_CCS
- Lignite
- Lignite_CCS
- Nuclear
- Oil
- Gas
- Gas_CCS
- Biomass
- Biomass_CCS
- Non-Ren Waste
- Ren Waste
- Hydro
- Wind_On
- Wind_Off
- Solar
- Geothermal
- Hydrogen
Supply sector

Preliminary results

Gross electricity generation by renewables

- Biomass
- Biomass_CCS
- Ren Waste
- Geothermal
- Hydro
- Wind_On
- Wind_Off
- Solar
Supply sector

Preliminary results & discussion

Yearly CO2 emissions
Supply sector
Preliminary results & discussion

Regional share of renewables in gross electricity consumption

- WEST
- SOUTH
- EAST
- NORTH

Share [%]
0% 100% 120% 140% 160%

2013 2020 2030 2040 2050 2060

IER University of Stuttgart
Supply sector

Preliminary results & discussion
Supply sector
Preliminary results & discussion

Regional share of actors in the existing renewable capacity of the year 2050

Utilities
Institutional investors
Citizens
Supply sector

Preliminary results & discussion

• CO2 taxes are effective for reducing emissions from incumbent actors.

• The so-called challengers should be targeted by renewable generation incentives.

• The north of Germany should play a key role by exporting renewable electricity to other regions especially through investments in more expensive technologies such as wind offshore by actors with lower cost of capital.

• The more participation of the actors with lower cost of capital, the quicker and the cheaper the energy system becomes decarbonised.

➢ This can be done by securing the financial landscape of renewable energy investments.
References


Fais, Birgit; Blesl, Markus; Fahl, Ulrich; Voß, Alfred (2014): Comparing different support schemes for renewable electricity in the scope of an energy systems analysis. In Applied Energy 131 (Supplement C), pp. 479–489. DOI: 10.1016/j.apenergy.2014.06.046.


Schmid, Eva; Pechan, Anna; Mehnert, Marlene; Eisenack, Klaus (2017): Imagine all these futures. On heterogeneous preferences and mental models in the German energy transition. In Energy Research & Social Science 27, pp. 45–56. DOI: 10.1016/j.erss.2017.02.012.

Loulou, Richard; Remme, Uwe; Kanudia, Amit; Lehtila, Antti; Goldstein, Gary (2016): Documentation for the TIMES Model Part I. In Energy technology systems analysis programme (ETSAP).


Bundesnetzagentur, Bundeskartellamt (2017): Monitoringbericht, Monitoringbericht gemäß § 63 Abs. 3 i 35.

Thank you!

Ali Tash

e-mail ali.tash@ier.uni-stuttgart.de
phone +49 (0) 711 685-87500
fax +49 (0) 711 685-87873

Universität Stuttgart
Institute of Energy Economics and Rational Energy Use (IER)
Department of Energy Economics and Social Analysis (ESA)
Heßbrühlstraße 49a, 70565 Stuttgart