Modelling of storage processes in TIMES-PanEU

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Copenhagen, 18.11.2014
# Structure

1. Introduction
2. The TIMES-PanEU energy system model
3. Modelling of storage processes in TIMES-PanEU
4. Exemplary results
5. Conclusion and outlook
Structure

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3 Modelling of storage processes in TIMES-PanEU
4 Exemplary results
5 Conclusion and outlook
Motivation and objective

Motivation:

- Political included expansion of electricity generation from renewable energies in Germany
- In consequence increasingly fluctuating feeding of electricity from wind- and photovoltaic systems
  - Thus there will be occur to an increasing degree negative and fluctuating residual loads in the future
  - Storage of excess electricity or curtailment
  - Versatile possibilities for using excess electricity

Objective:

- Determination of optimal configuration of storage- and Power-to-X-technologies (for Germany) under minimization of total system costs
- Analysis of interactions between energy supply and energy demand with use of Power-to-X
# Structure

<table>
<thead>
<tr>
<th>1</th>
<th>Introduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>The TIMES-PanEU energy system model</td>
</tr>
<tr>
<td>3</td>
<td>Modelling of storage processes in TIMES-PanEU</td>
</tr>
<tr>
<td>4</td>
<td>Exemplary results</td>
</tr>
<tr>
<td>5</td>
<td>Conclusion and outlook</td>
</tr>
</tbody>
</table>
The TIMES-PanEU energy system model

- Linear optimization model
- 30 regions (EU-28 + Norway, Switzerland)
- Time horizon: 2010 – 2050
- Mapping of the whole energy system:
  i. Energy supply (electricity, heat, gas)
  ii. Energy demand, divided into sectors:
     1. Residential sector
     2. Commercial sector
     3. Agriculture
     4. Industry
     5. Transport
General structure of TIMES-PanEU

Cost and emissions balance

Energy flows

Prices

Emissions

Demand services

GDP
Process energy
Heating area
Population
Light
Communication
Power
Person kilometers
Freight kilometers

Domestic sources
Energy prices, Resource availability

Coal processing

Refineries

Power plants, Storage and Transportation

CHP plants and district heat networks

Gas network

Industry

Commercial and tertiary sector

Households

Transportation

Final energy

Primary energy

Capacities

Costs

Imports

Energy prices, Resource availability

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Demand services

Costs

Prices

Emissions

Energy flows

Demand services
Temporal resolution

Germany
- 224 time segments (One week per season, three-hourly)
- Continuous temporal resolution for mapping storage processes

Rest of Europe
- 12 time segments
- Discontinuous temporal resolution

➡ Coupling of timeslice trees for modelling trade processes with parameter IRE_TSCVT
➡ Integral optimization
Exemplary demand services

- Residential
  - Space Heat
    - Single Rural
    - Single Urban
    - Multi
  - Space Cool
    - Single Rural
    - Single Urban
    - Multi
  - Water Heat
    - Single Rural
    - Single Urban
    - Multi
  - Other
    - Lighting
    - Cooking
    - Refrigeration
    - Cloth Washing
    - Cloth Drying
    - Dish Washing
    - Other Electric
    - Other Energy
  - RCA

- Commercial
  - Space Heat
    - Small
  - Space Cool
    - Large
  - Water Heat
    - Large
  - Other
    - Lighting
    - Cooking
    - Refrigeration
    - Public Lighting
    - Other Electric
    - Other Energy

- Agriculture
  - Other
    - Lighting
    - Cooking
    - Refrigeration
    - Public Lighting
    - Other Electric
    - Other Energy
Residential Other

Power

GW

Other
Lighting
Cooking
Dish Washing
Cloth Drying
Cloth Washing
Refrigeration
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Modelling of storage processes in TIMES-PanEU

**PRC_ACTUNT**: Activity of a process

**PRC_CAPUNT**: Capacity of a process

**PRC_CAPACT**: Ratio from activity and capacity

Storage power and storage capacity are endogenous results of modeling.
Modelling of storage processes in TIMES

Two different types of storage processes in TIMES:

- Inter-Period Storage: Storage between periods (Store in and store out with constant power over the whole period)
- Timeslice Storage: Storage between time segments within a period (in accordance with the definition of the storage level)
- Generalized timeslice storage: Combination of timeslice storages with different timeslice levels, STS or STK
Timeslice Storage

General simplified equations ($\forall r, v, t, p, c, ts$):

1. Time overall equation EQ_STGTSS:
   \[ VAR\_ACT(r, v, t, p, ts) = VAR\_ACT(r, v, t, p, ts - 1) + VAR\_SIN(r, v, t, p, c, ts - 1) - VAR\_SOUT(r, v, t, p, c, ts - 1) \]

2. Whole storage capacity is available in every timeslice EQL_CAPACT:
   \[ VAR\_ACT(r, v, t, p, ts) \cdot \frac{1}{RS\_STGPRD(r, ts)} \leq \left( \sum_{v=Baseyear}^{t} VAR\_NCAP(r, v, p) + NCAP\_PASTI(r, v, p) \right) \cdot PRC\_CAPACT(r, p) \]

$r$: Region
$v$: Year of commissioning
$t$: Current period
$p$: Process
$c$: Commodity
$ts$: timeslices of storage level
$VAR\_ACT$: Storage content at the beginning of $ts$
$VAR\_NCAP$: New installed capacity
$NCAP\_PASTI$: Stock
$PRC\_CAPACT = 1$

<table>
<thead>
<tr>
<th>Storage Level</th>
<th>Season/Annual</th>
<th>Weekly</th>
<th>Daynite</th>
</tr>
</thead>
<tbody>
<tr>
<td>$RS_STGPRD(r, ts)$</td>
<td>1</td>
<td>$\frac{8760}{24 \cdot 7} \cdot G_YRFR(r, x)$</td>
<td>$365 \cdot G_YRFR(r, x)$</td>
</tr>
</tbody>
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(x is directly upstream, defined node of weekly)
(x is directly upstream, defined node of daynite)
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<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Introduction</td>
<td></td>
</tr>
<tr>
<td>2</td>
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<td></td>
</tr>
<tr>
<td>3</td>
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<td></td>
</tr>
<tr>
<td>4</td>
<td>Exemplary results</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Conclusion and outlook</td>
<td></td>
</tr>
</tbody>
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Operation of electricity storage in the year 2050 without Curtailment (only Germany)

- Store in times of low or negative residual load (electricity price low)
- Store out in times of high residual load (electricity price high)
Operation of electricity storage in the year 2050 with Curtailment (only Germany)

- Lower storage capacity than in scenario without curtailment
- Lower total system costs in scenario with curtailment
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</tr>
<tr>
<td>5</td>
<td>Conclusion and outlook</td>
</tr>
</tbody>
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Conclusion and outlook

Conclusion:
- Need of more electricity storage with increasingly power input of fluctuating renewable energies
- Objective value difference ca. 35 Billions Euro
  ➔ Possibility of curtailment leads to a lower electricity storage capacity and lower total system costs

Outlook:
- Analysis of Power-to-Heat, Power-to-Gas and other electricity storages (compressed air, battery)
- Reserve power
- Different scenarios
- Sensitivity analysis
Thank you!

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Backup
Modeling of storage processes in TIMES-PanEU

### Energy storage
- **Electricity storage**
  - Pumped storage
  - Compressed air storage
  - Battery storage

- **Heat storage**
  - Hot water storage

- **Gas storage**
  - Hydrogen storage
  - Natural gas storage
  - Natural gas grid

### Transformation processes
- **Power-to-Heat**
- **Heater**
- **Power-to-Gas**
  - Elektrolysis
  - Fuel cell
  - Methanation