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epexspot

Impacts of policy decisions and market design: An agent-based modelling approach using Alternating Direction Method of Multipliers (ADMM)

abm4energy 2025| 01.04.2025

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Dieses Projekt wird im Rahmen der Ausschreibung „Energie.Frei.Raum“ des Bundesministeriums für Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie (BMK) durchgeführt. Die Abwicklung erfolgt im Auftrag des BMK durch die Österreichische Forschungsförderungsgesellschaft (FFG).

Overview

Scope of this talk:

Creation of agents: **Open-source** integrated energy system modelling **framework** (IESopt)

Coupling of agents: Applying **ADMM (exchange)** and allowing agents to participate in various markets.

Coupling of time periods: Applying **ADMM (consensus**) for reaching a uniform investment decision for an agent type over all time periods

Results of a small case study for **three different policies** and **two market designs**.

- Perfect energy-only market
- Energy-only market with price caps
- Energy-only market with tax

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Modelling Framework

IESopt:

- Integrated Energy System Optimisation
- Energy flow model
- Fully implemented in Julia
- Abstract block structure
  - Combination of different core components
- Configuration of agents in YAML files

```
config:
  general:
    version:
      core: 2.6.1
  optimization:
    problem_type: Parmetric + QP
    snapshots:
      count: <T>
    solver:
      name: gurobi

  gasturbine:
    type: Unit
    inputs: {gas: gas_grid}
    outputs: {electricity: elec_grid}
    conversion: 1 gas -> 0.40 electricity
    capacity: 100 out:electricity
```

Strömer, S., Schwabeneder, D., & contributors. (2021-2024). IESopt: Integrated Energy System Optimization [Software].
AIT Austrian Institute of Technology GmbH. https://github.com/ait-energy/IESopt

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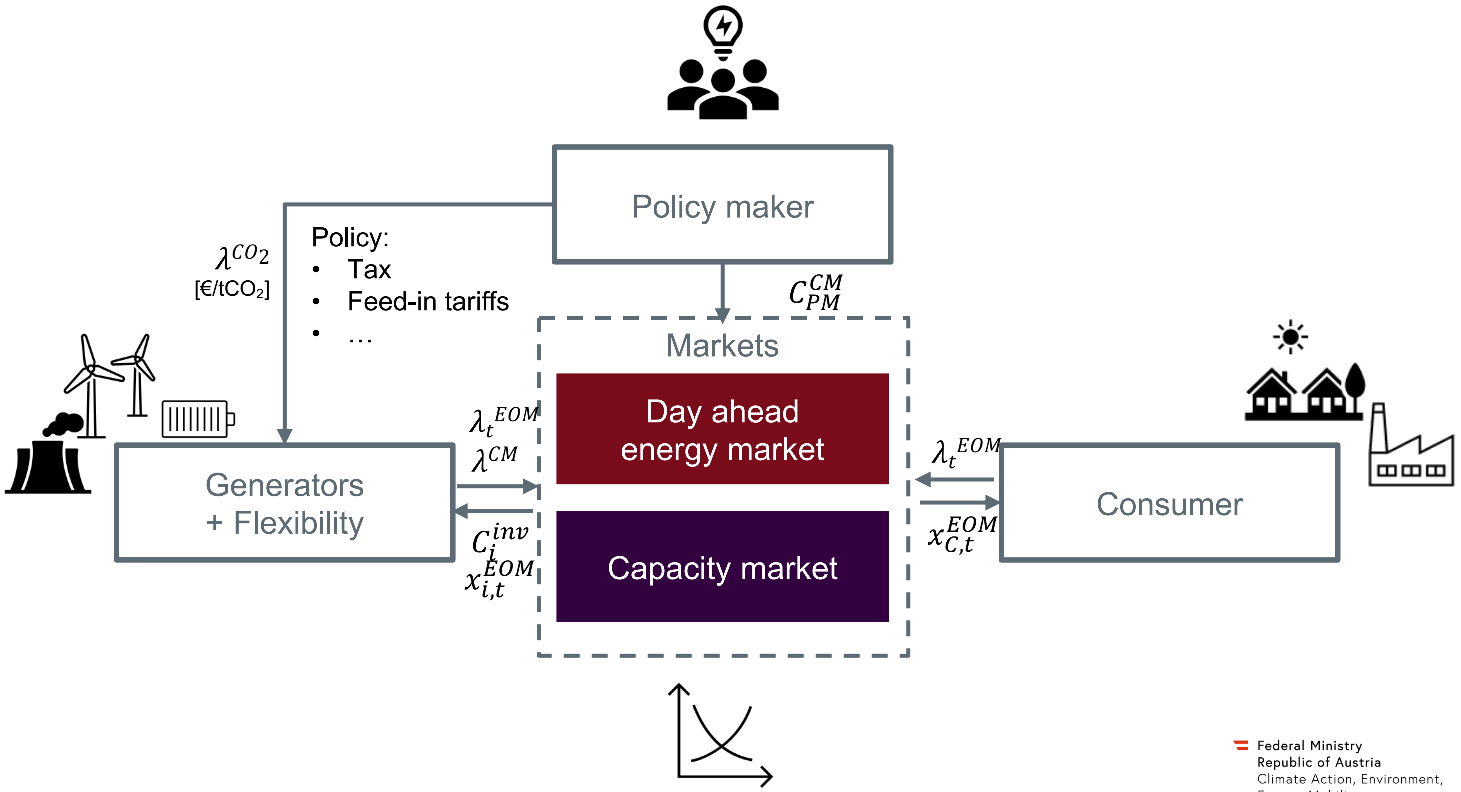
Coupling of agents



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Coupling of agents + time periods

- Objective function

$$\min_{x_{i,t},C_i^{inv}} = Capex \cdot C_i^{inv} + Opex_{fix} \cdot (C_i^{inv} + C_i^{nom}) + Opex_{var} \cdot \sum_{t=1}^{T} x_{i,t}$$

$$- \sum_{t=1}^{T} x_{i,t} \cdot \lambda_t^{EOM,k} + \rho/2 \cdot ||x_{i,t} - (x_{i,t}^k - \overline{X}_t^k)||_2^2$$

$$-\lambda^{CM,k} \cdot (C_i^{inv} \cdot F_{dr,i}^{CM}) + \frac{T}{8760} \cdot \rho/2 \cdot ||F_{dr,i}^{CM} \cdot C_i^{inv} - (F_{dr,i}^{CM} \cdot C_i^{inv,k} - \overline{C}^k)||_2^2$$

$$+\lambda^{cons,k} \cdot C_i^{inv} + \rho/2 \cdot ||C_i^{inv} - \overline{Z}_i^k||_2^2$$

Capacity market

Day ahead energy market

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Coupling of agents + time periods

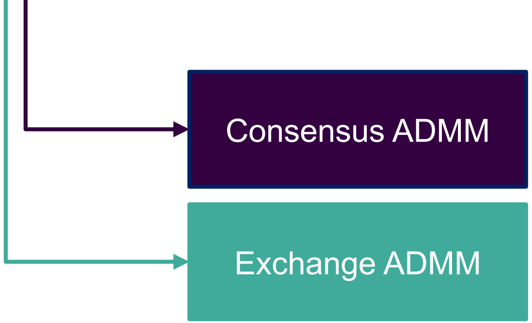
- Objective function

$$\min_{x_{i,t},C_i^{inv}} = Capex \cdot C_i^{inv} + Opex_{fix} \cdot (C_i^{inv} + C_i^{nom}) + Opex_{var} \cdot \sum_{t=1}^{T} x_{i,t}$$

$$-\sum_{t=1}^{T} x_{i,t} \cdot \lambda_t^{EOM,k} + \rho/2 \cdot ||x_{i,t} - (x_{i,t}^k - \overline{X}_t^k)||_2^2$$

$$-\lambda^{CM,k} \cdot (C_i^{inv} \cdot F_{dr,i}^{CM}) + \frac{T}{8760} \cdot \rho/2 \cdot ||F_{dr,i}^{CM} \cdot C_i^{inv} - (F_{dr,i}^{CM} \cdot C_i^{inv,k} - \overline{C}^k)||_2^2$$

$$+\lambda^{cons,k} \cdot C_i^{inv} + \rho/2 \cdot ||C_i^{inv} - \overline{Z}_i^k||_2^2$$



- Update steps exchange (agent coupling)

$$\overline{X}_t^k = \frac{1}{N} \sum_{i \in N} x_{i,t}$$

$$\overline{C}^k = \frac{1}{N} \left(\sum_{i \in N} F_{dr,i}^{CM} \cdot C_i^{CM} - C_{PM}^{CM} \right)$$

$$\lambda^{EOM,k+1} = \lambda^{EOM,k} - \rho \cdot \overline{X}_t^k$$

$$\lambda^{CM,k+1} = \lambda^{CM,k} - \rho \cdot \overline{C}^k$$

- Update steps consensus (time coupling)

$$\overline{Z}_i^k = \sum_{j=1}^{n} \frac{C_{i,j}^{inv,k}}{n}$$

$$\lambda_{i,j}^{cons,k+1} = \lambda_j^{cons,k} + \rho \cdot (C_{i,j}^{inv,k} - \overline{Z}_i^k) \quad j = 1, \ldots, n$$

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Example Results

Resulting System and Market Parameters

Policy scenarios		Price (avg.)	Price (max.)	EENS
Perfect EOM	• $\bar{\lambda} = Inf$ • No tax • No capacity market	83 €/MWh	1399 €/MWh	0 GWh/a
Price caps	• $\bar{\lambda} = 100\ €/MWh$ • No tax • No capacity market	72 €/MWh	100 €/MWh	20.4 GWh/a
Tax “Energy crisis contribution”	• $\bar{\lambda} = Inf$ • Tax: > 90 €/MWh, 95 % • No capacity market	84 €/MWh	1652 €/MWh	0 GWh/a

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Example Results

Resulting System and Market Parameters with a capacity market

Policy scenarios		Price (avg.)	Price (max.)	EENS
Perfect EOM + capacity market	• $\bar{\lambda} = Inf$ • No tax • CM: 20 GW	71 €/MWh	97 €/MWh	0 GWh/a
Price caps + capacity market	• $\bar{\lambda} = 100\ €/MWh$ • No tax • CM: 20 GW	71 €/MWh	97 €/MWh	0 GWh/a
Tax "Energy crisis contribution" + capacity market	• $\bar{\lambda} = Inf$ • Tax: > 90 €/MWh, 95 % • CM: 20 GW	71 €/MWh	99 €/MWh	0 GWh/a

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TakeAways

Weakness of the proposed modelling approach:

- Proper scaling of the cost and penalty terms needed → **Oscillation**
- Careful choosing of modelling **scale** needed (kW ↔ MW ↔ GW)

Strengths of the proposed modelling approach:

- **Reduced** computational **time** (solving of models in parallel)
- Optimization over **extended time periods** possible (solving of time periods in parallel)
- **Rule-based** implementation of **policies** and regulatory frameworks possible
- Data privacy

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> Thank you!

Project: TeKaVe

Technologieneutrale Kapazitätsmechanismen für eine Versorgungssichere Energiezukunft

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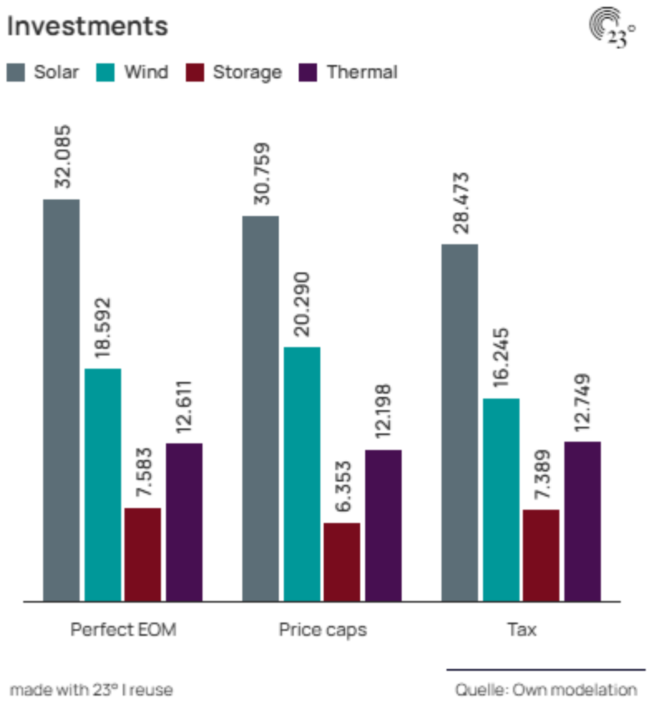
INVESTMENTS



- Tax leads to reduced PV + wind installations
- Subsequently also to reduced potentials for storages
- More thermal capacity needs to be installed to cover demand
- Higher price peaks

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