This research has received funding from the German Federal Ministry for Economic Affairs and Climate Action under reference number 03EI1068A

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INVESTMENT DECISIONS IN THE ELECTRICITY SECTOR

An agent-based modelling approach

Leonard Willeke

Motivation

„German energy transition requires 884 Billion € of investments in the electricity system until 2045.“

Source: Agora Energiewende

Who?

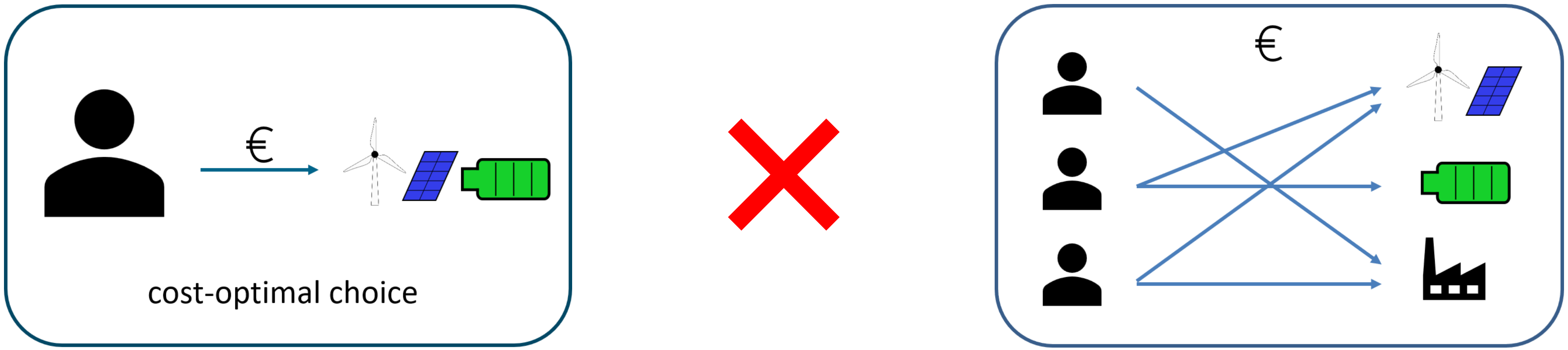
Why?

Where?

Agora Energiewende, Report „Analyse für ein klimaneutrales Deutschland“, https://www.agora-energiewende.de/fileadmin/Projekte/2023/2023-30_DE_KNDE_Update/A-EW_347_KNDE_Investitionsbedarfe_WEB.pdf (visited on 20.02.2025)

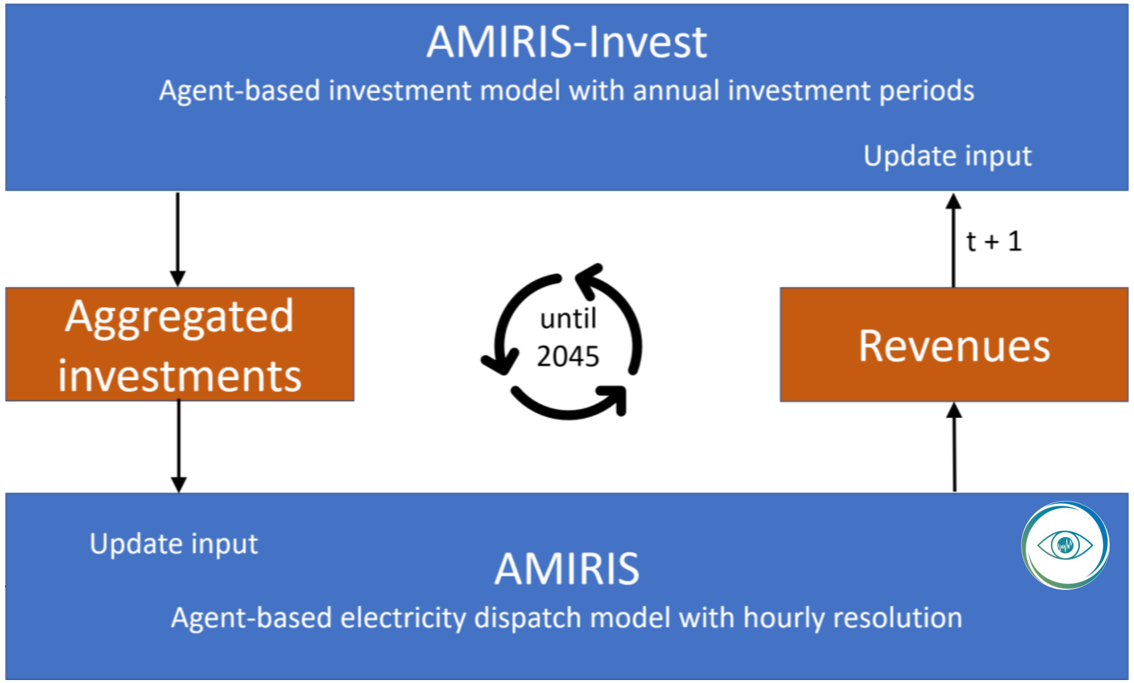
Problem

Optimization models assume system-optimal investments



→ Investment decisions of heterogenous actors are not fully captured

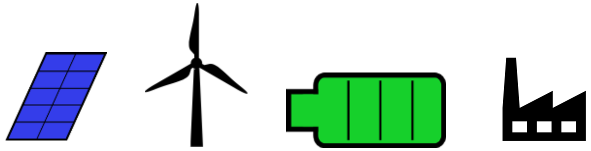
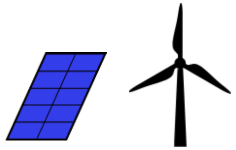
Idea
Use agent-based modelling



→ Evaluate transition pathways with a consistent agent-based modelling approach

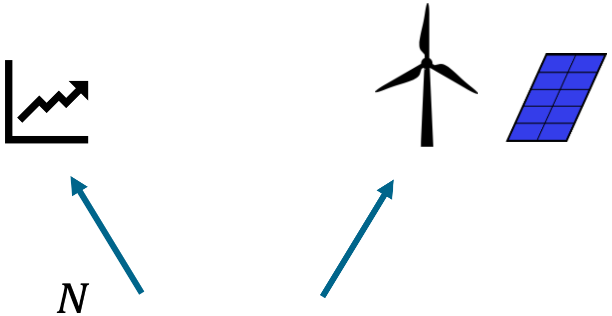
Modelling

How to characterize heterogenous actors?

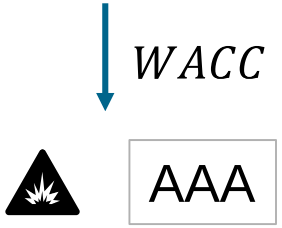
	Big energy provider	Small developer
Technology choice		
Risk perception		
Electricity price prognosis		
Financing conditions	AAA	BBB

→ Different conditions and assumptions

Modelling
How to model investment decisions?



$$NPV = -I_0 + \sum_{t=0}^{N} \frac{R_t - C_t}{(1+i)^t}$$



→ Use expected profit (NPV) as key metric

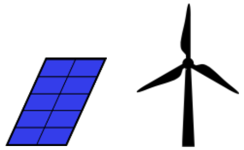
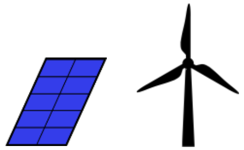
NPV: Net Present Value
$WACC$: Weighted Average Cost of Capital
R_t: Revenue of year t
C_t: Costs of year t
i: Interest rate
I_0: Initial investment

Verification
Do different investors make different decisions?

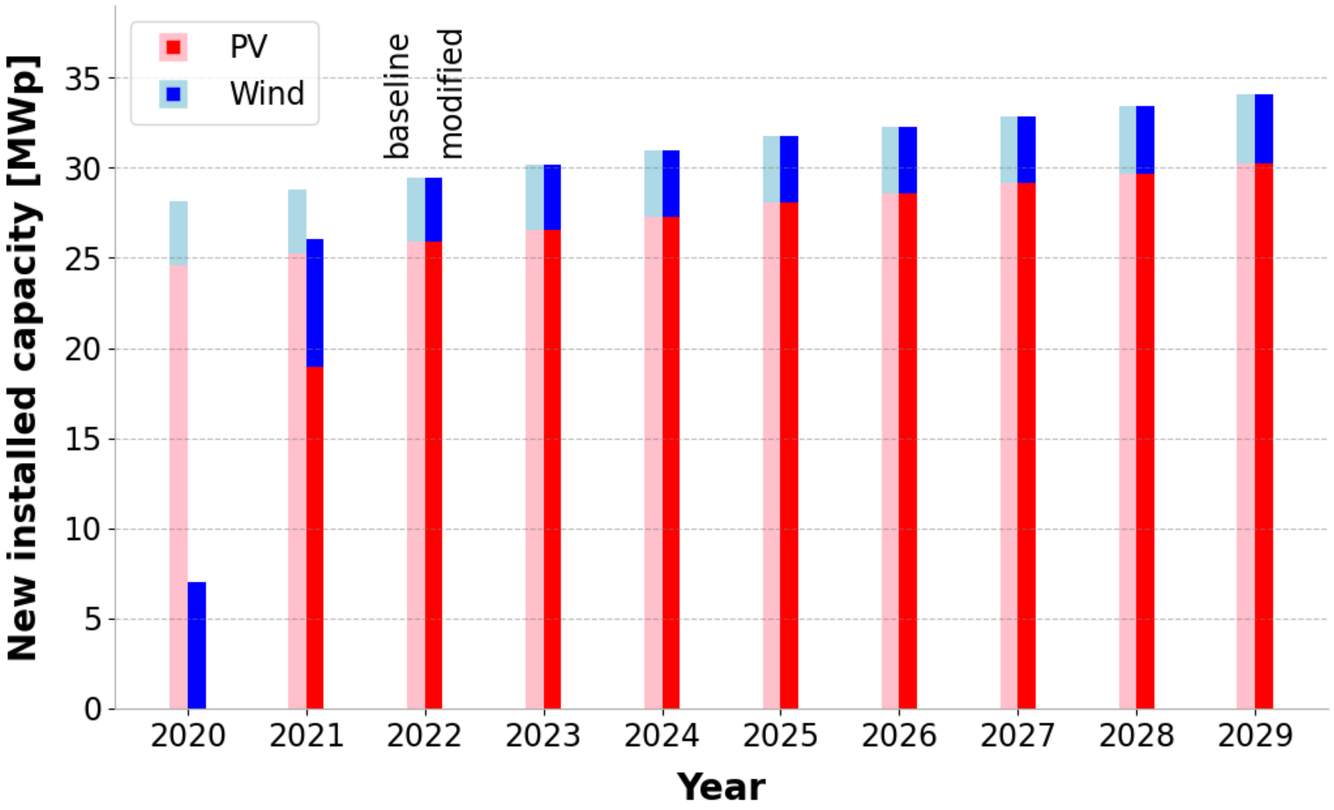
Setup

- Simulate two investors
- Set parameters differently
- Assess impact on investment decision

Case 1: Modify risk perception

	Baseline	Modified
Technology choice		
Risk perception		
Electricity price prognosis		
Financing conditions	AAA	AAA

Case 1: Modify risk perception

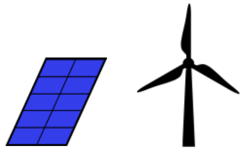
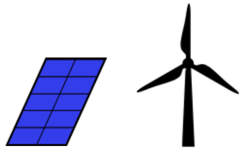


→ Higher risk leads to lower NPV
→ Less investment
→ Falling technology costs outperform this trend

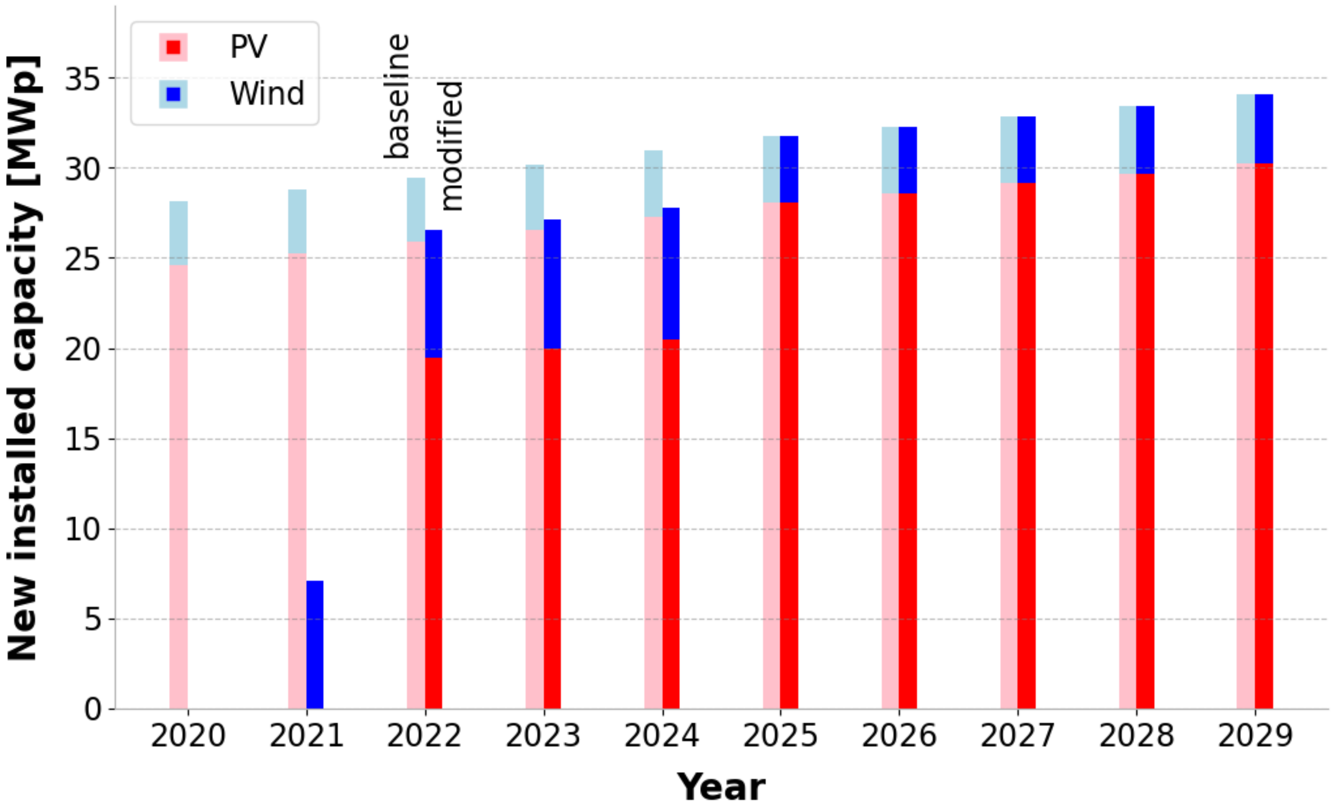
→ Risk perception has an influence on the investment decision

	Baseline	Modified
Risk perception	⚠	⚠ ⚠ ⚠

Case 2: Modify price prognosis

	Baseline	Modified
Technology choice		
Risk perception		
Electricity price prognosis		
Financing conditions	AAA	AAA

Case 2: Modify price prognosis



→ Electricity price affects NPV
→ Less investment in PV
→ More investment in Wind
→ Falling technology costs outperform this trend

→ Electricity price prognosis has an influence on investment decision

	Baseline	Modified
Price prognosis		

Outlook

- Include shut-down of unprofitable plants
- Update electricity price prognosis with external model
- Add back-up plants and storage systems to technology choices

→ Evaluate policy design

- Open-source code publication planned

Summary

- Showed modelling approach of investment decisions in the electricity sector
- Coupled ABMs for investment decision and market dispatch
- Proof of concept for key model mechanisms

→ Consistent agent-based modelling enables new analyses on transformation pathways

gitlab.com/amiris

OpenMod Forum

Friday 10:00 a.m.

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Appendix: Model formulation

Net Present Value

$$R_t = p_{el,prog}(t) * P_{gen}(t)$$

$$C_t = \left(c_{bor} - C_{payback}(t)\right) * i_{bor}$$

$$NPV = -I_0 + \sum_{t=0}^{N} \frac{R_t - C_t}{(1+i)^t}$$

$$WACC = i_{eq} * \frac{c_{eq}}{c_{tot}} + i_{bor} * (1-s) * \frac{c_{bor}}{c_{tot}}$$

$$i_{eq} = i_{rf} + (i_m - i_{rf}) * \beta$$

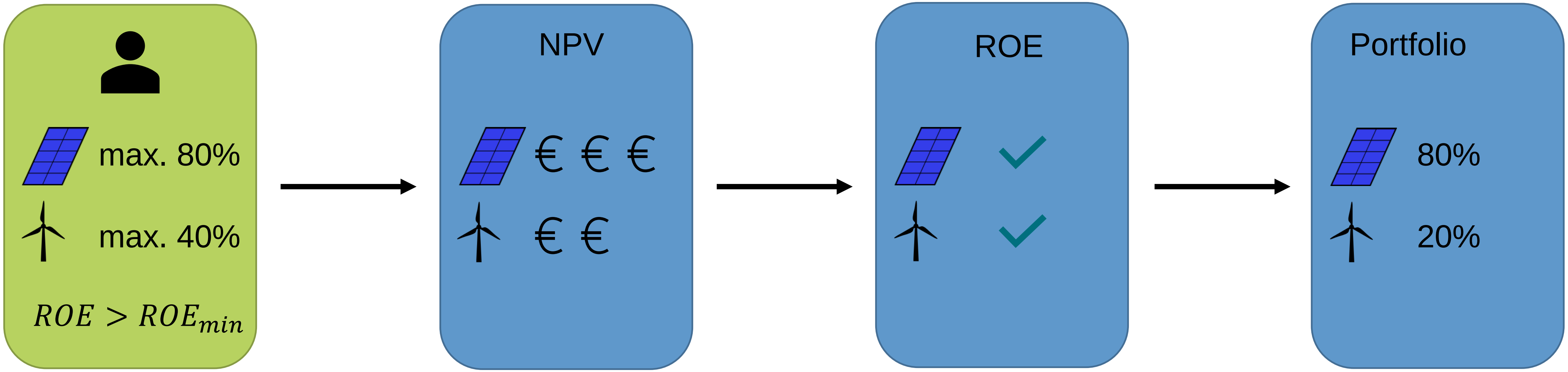
NPV: Net Present Value
$WACC$: Weighted Average Cost of Capital
R_t: Revenue of year t
C_t: Costs of year t
i: Interest rate
I_0: Initial investment

Return on Equity

$$ROE = \frac{NPV}{N} * \frac{1}{c_{eq}}$$

$$ROE > ROE_{min}$$

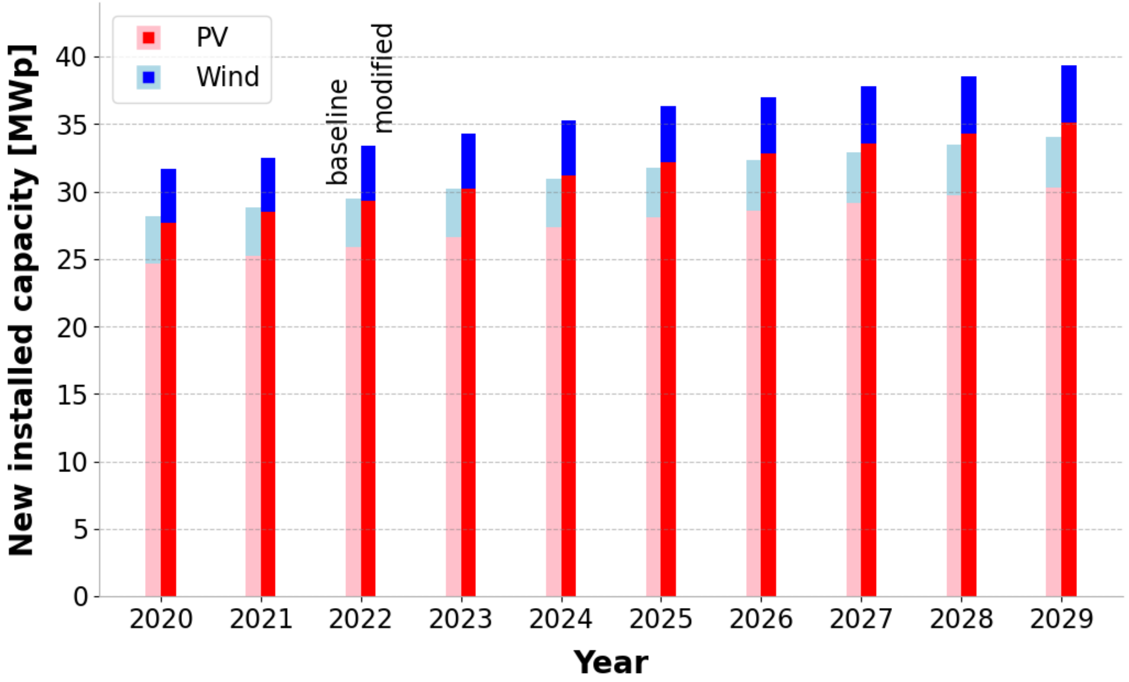
Appendix: Workflow



→ Generic decision workflow applicable for different actor types

Appendix: Influence of capacity premium

Modification: Increase the capacity premium



Apendix: Influence of investment decisions

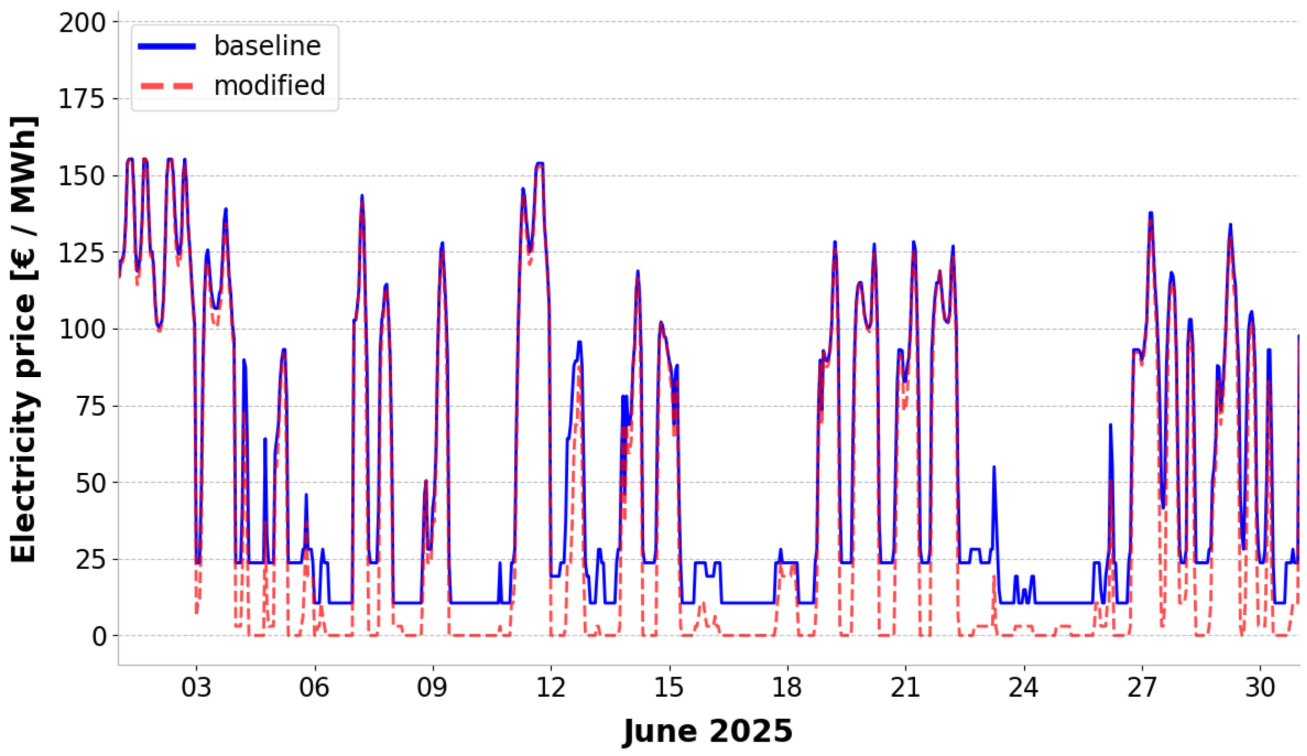
Goal: Verify influence of investments on electricity market

Setup

- Investor builds a lot of capacity
- Compare results to baseline scenario without investments
- Assess impact on market dynamics

Appendix: Influence of investment decisions

Modification: Add annual renewable capacity of $\Delta P_{ann} = 2\% * P_{baseline}$



→ Lower electricity price with more volatility

Imprint

Topic	Investment decisions in the electricity sector
	An agent-based modelling approach
Date	2025-02
Author	Leonard Willeke
Institute	Institute of Networked Energy Systems
Credits	DLR (CC BY-NC-ND 3.0) except stated otherwise

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Bundesministerium für Bildung und Forschung

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