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Supported by:
Federal Ministry for Economic Affairs and Climate Action
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# INVESTMENT DECISIONS UNDER UNCERTAINTY

## An agent-based modelling approach

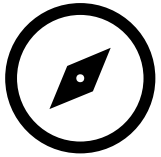
Leonard Willeke, Johannes Kochems, Christoph Schimeczek, Kristina Nienhaus

DLR

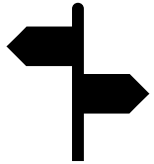
# Motivation

Investment decisions are based on uncertain assumptions about the future.

Who?

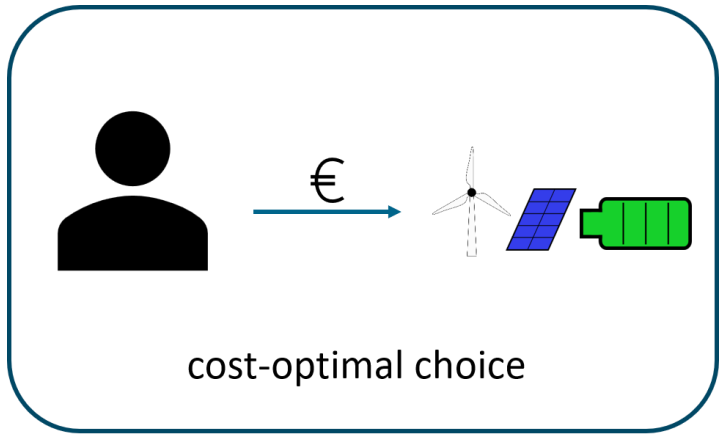


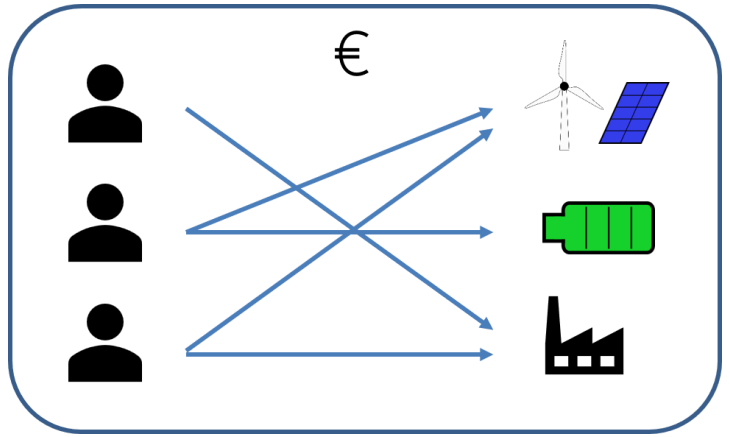
How?



Where?

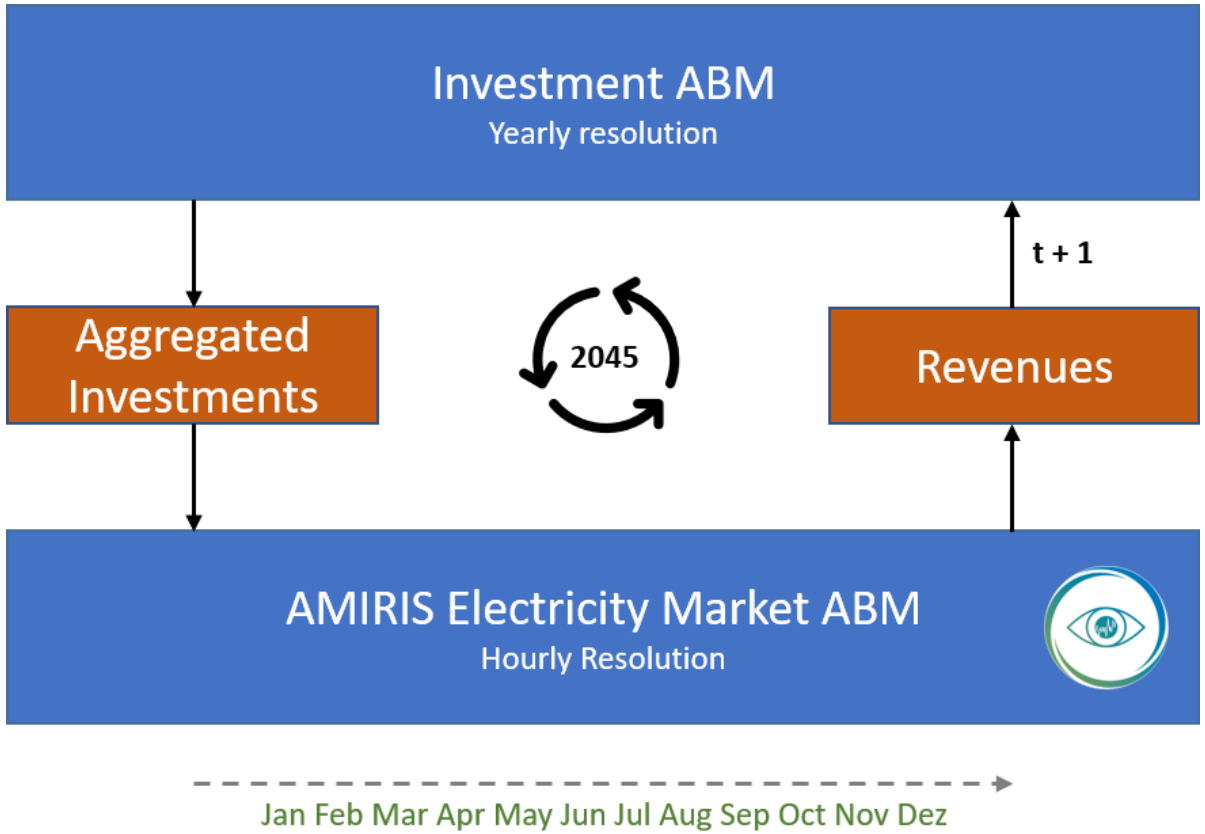
# Problem
## Optimization models assume system-optimal investments



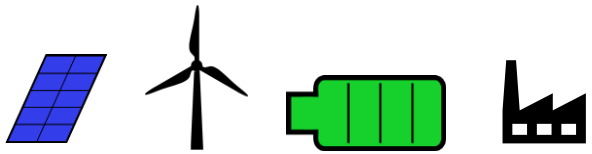
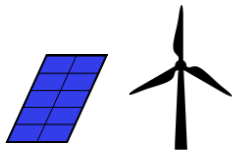

→ Investment decisions of heterogenous actors under uncertainty are not fully captured

# Idea
## Use agent-based modelling (ABM)




→ 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 $t$
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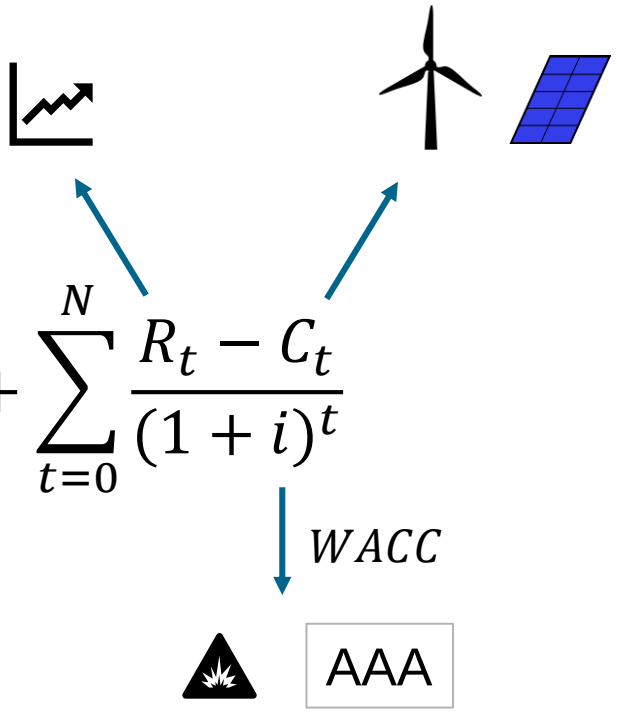


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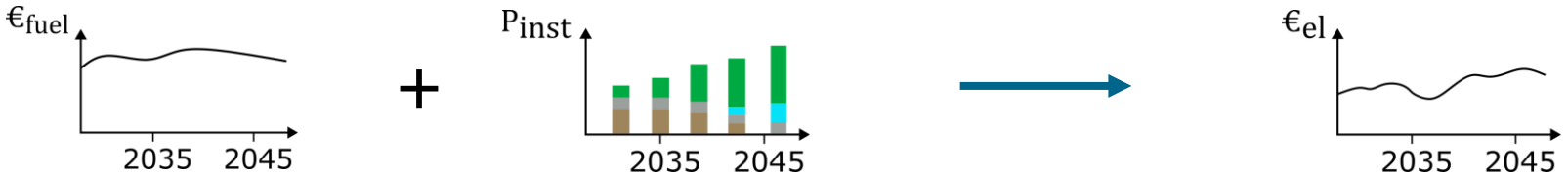
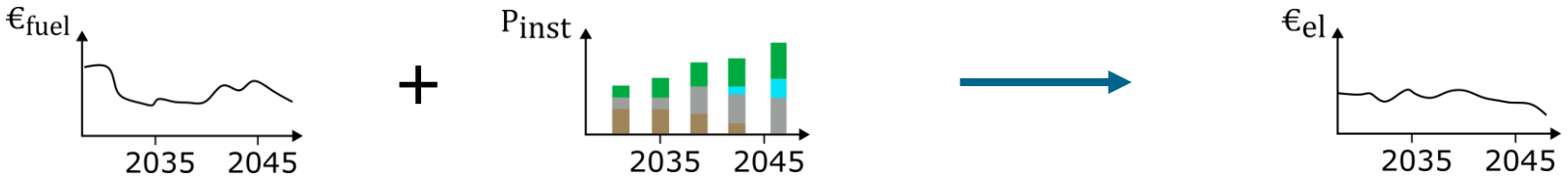
# Modelling
## How to model uncertainty?


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

→ Expected profit depends on many uncertain parameters

# Modelling
## Investors face uncertainty by making assumptions



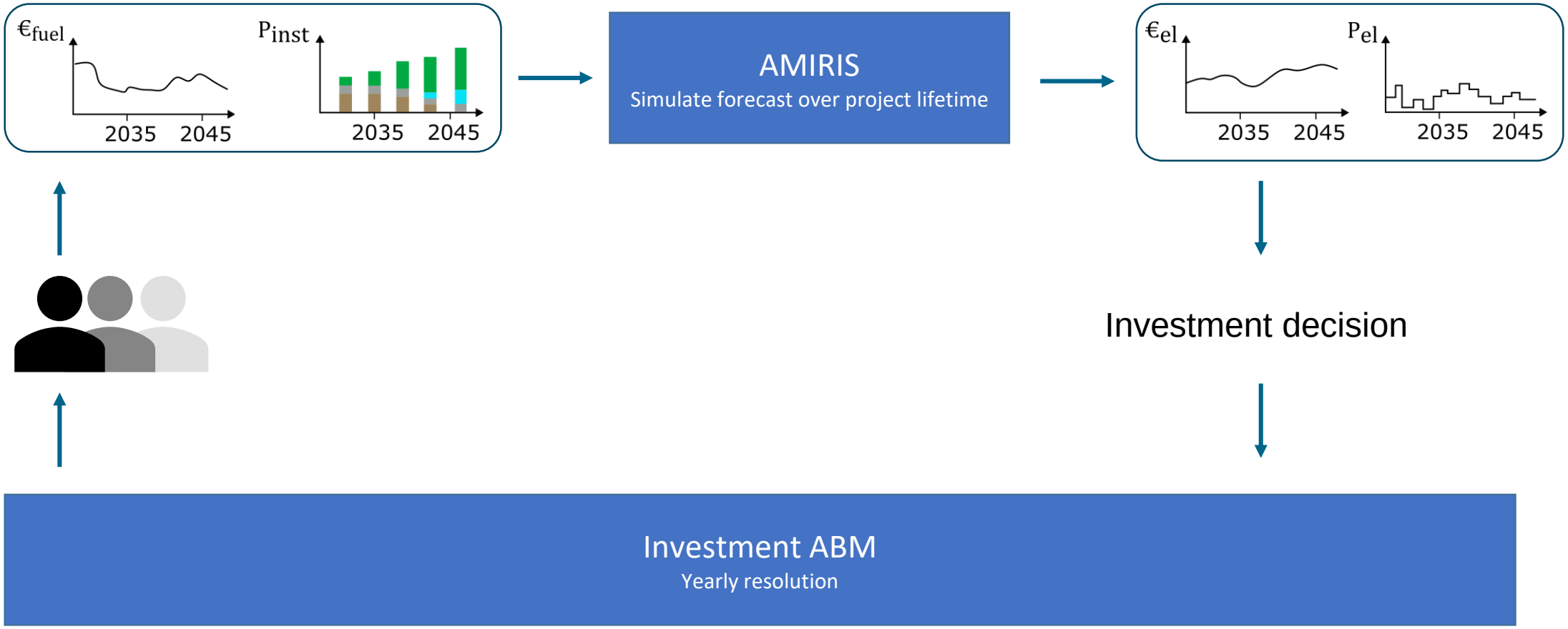




→ Actors get personalized forecasts based on their assumptions



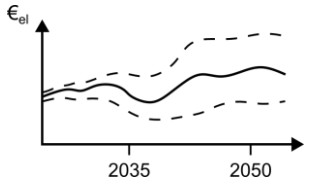
Map icon by freepik

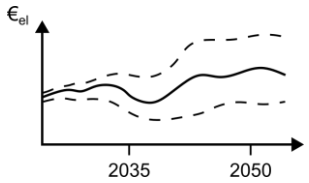
# Modelling
## How to integrate agent-specific forecasts?




→ Compute endogenous price and dispatch forecasts for each agent

# Modelling
## And if the assumptions were wrong?




| | Year 1 | Year 2 | Year 3 | Year 4 |
|---|---|---|---|---|
| | ✓ | ✓ | ✓ | ✓ |
| | €€€€ | €€€ | €€€€ | €€€€ |
| | ✓ | ✓ | ✓ | ✗ |
| | €€ | € | € | |

→ Evaluate profitability annually and shut plant down if necessary

# Verification
## Does it work?

Use stylized test cases

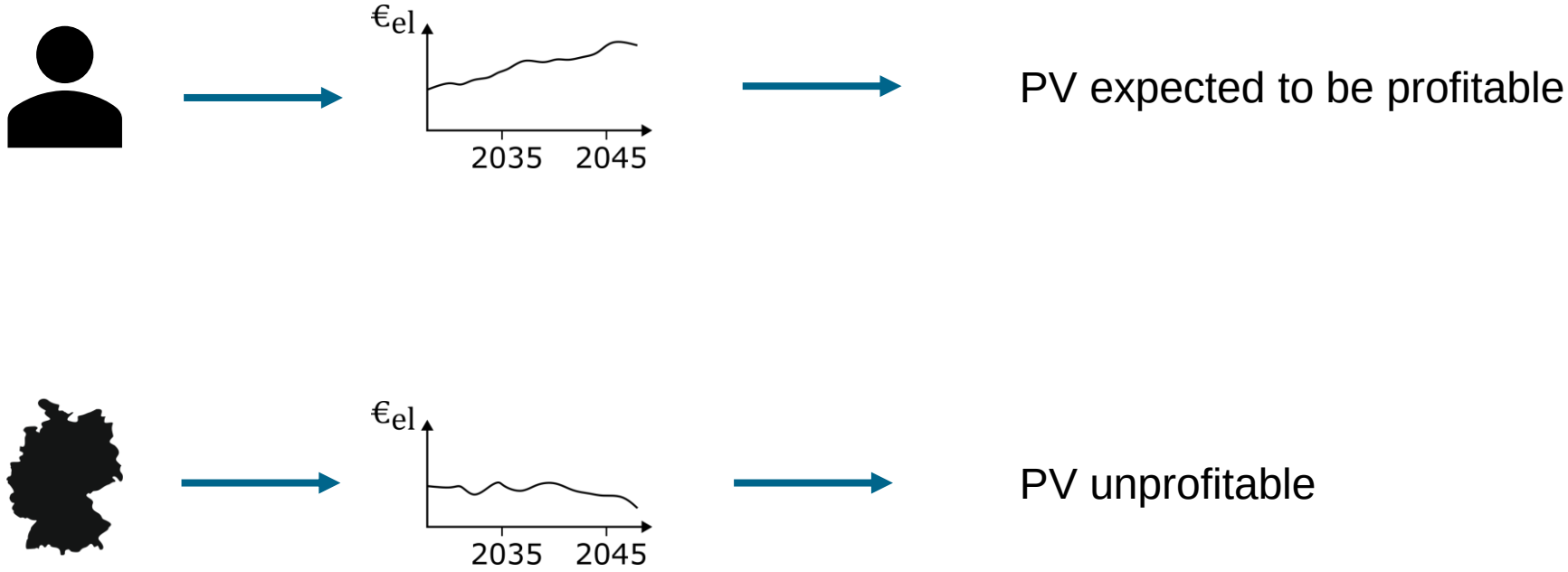
- Investors have a fixed budget for every year
- Investors can invest all or nothing
- PV as example technology

Goal

✓ Test model mechanisms

✗ Make conclusions about the transition pathway

# Verification
## Shutdown decision

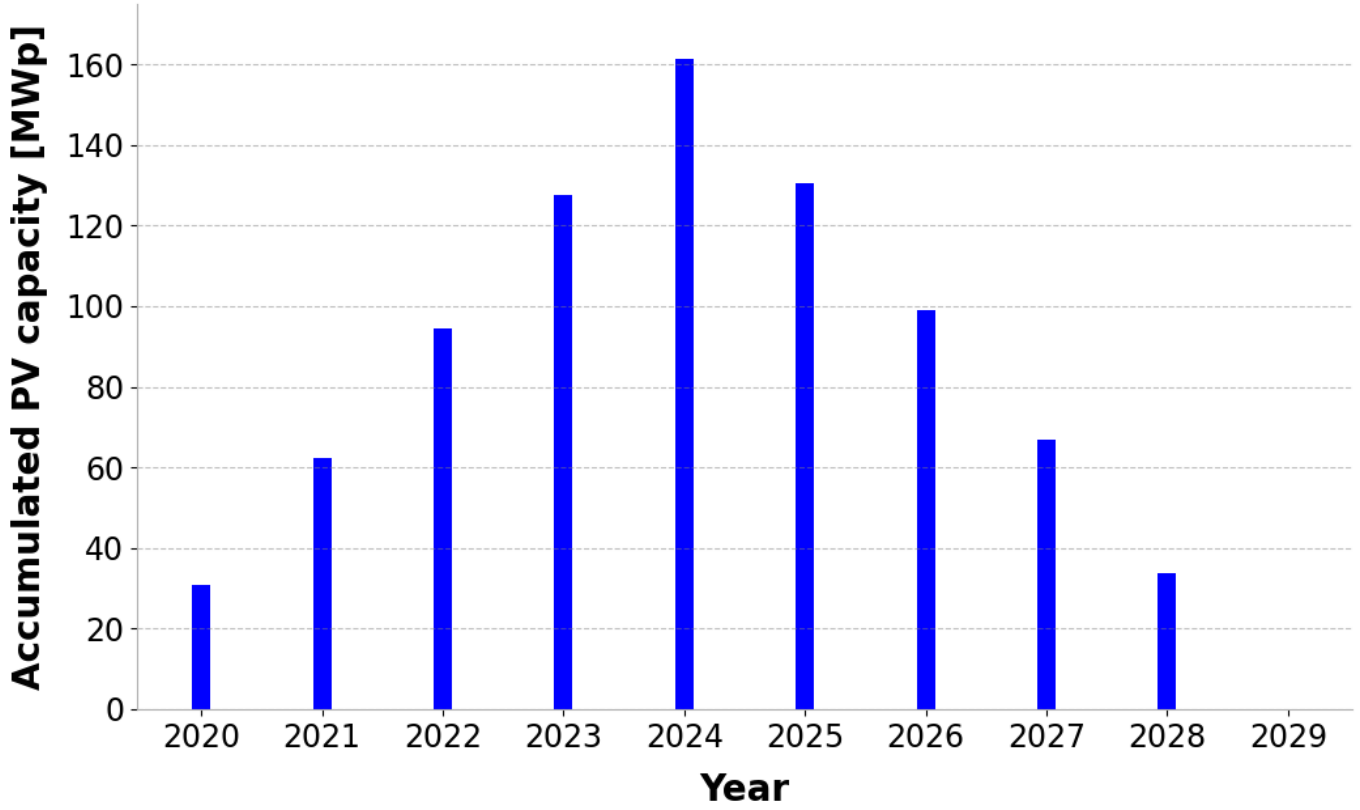



→ Assumptions on future development don’t match simulated reality



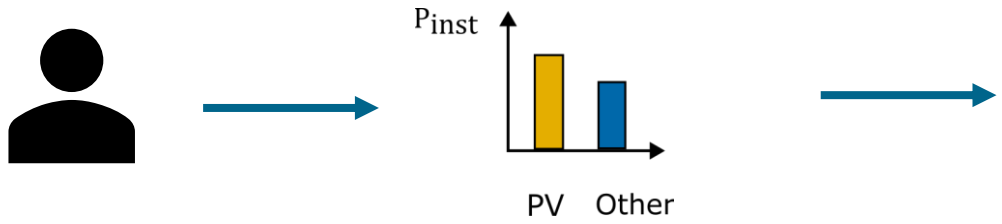
Map icon by freepik

# Verification
## Shutdown decision

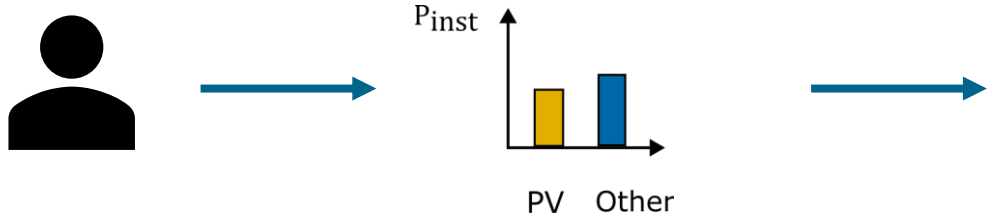



→ Overly optimistic forecast leads to stranded assets

# Verification
## Agent-specific endogenous forecasts



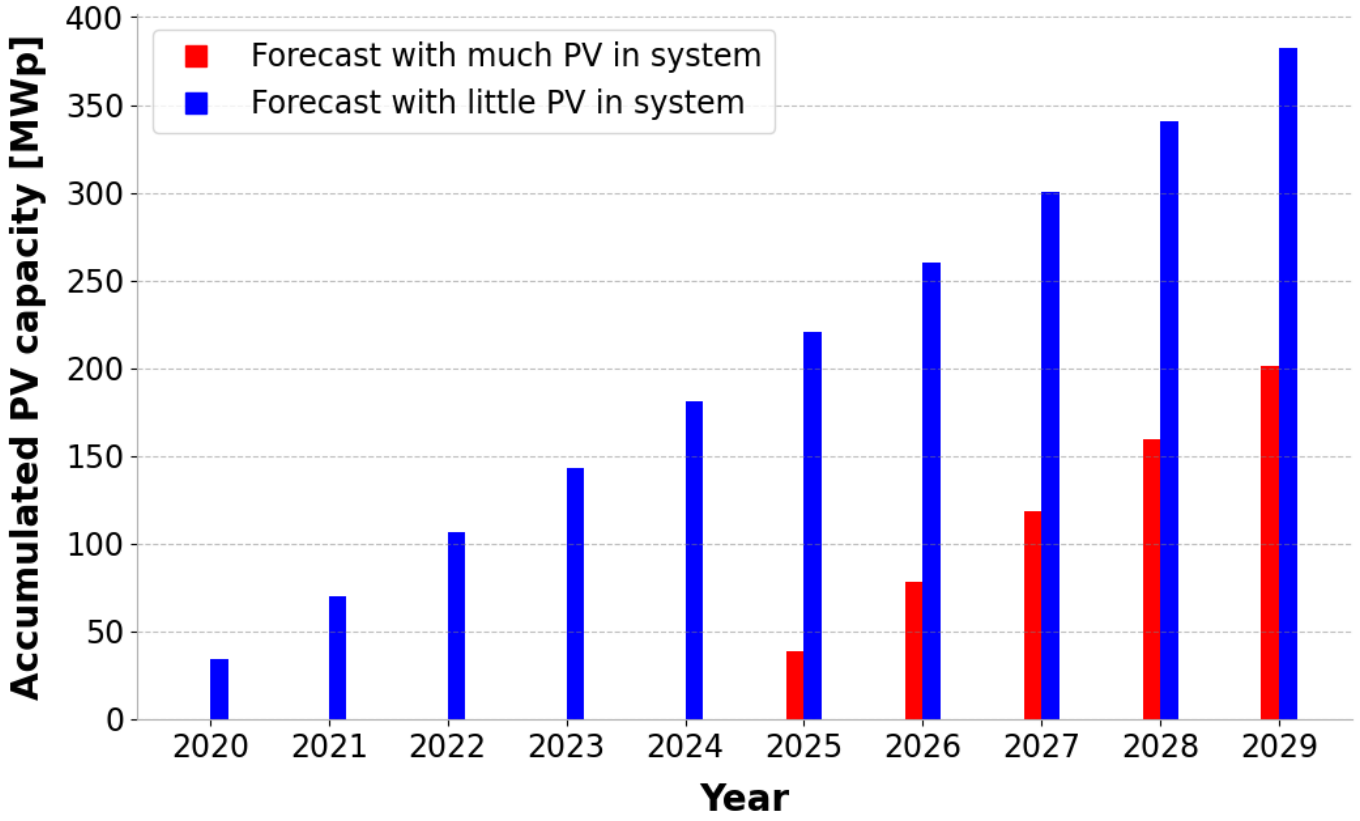

Low PV profitability due to cannibalisation




High PV profitability

→ Different assumptions on future technology mix affect profitability estimation

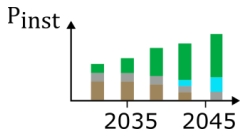
# Verification
## Agent-specific endogenous forecasts




→ Different assumptions lead to different investment behaviour

# Outlook

- Add more dispatchable technologies
- Simulate the transition pathway of the German electricity sector
- Publish model open-source




→ Evaluate policy design

# Summary

- Showed agent-based modelling approach of investment decisions in the electricity sector
- Endogenous, agent-specific forecasts allow heterogenous assumptions
- Proof of concept for key model mechanisms

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

gitlab.com/amiris

OpenMod Forum

Every Friday

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# Appendix: Model formulation

## Net Present Value

$$R_t = p_{el,prog}(t) * P_{gen}(t) \qquad C_t = \left(c_{bor} - C_{payback}(t)\right) * i_{bor}$$

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

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

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

$NPV$: Net Present Value
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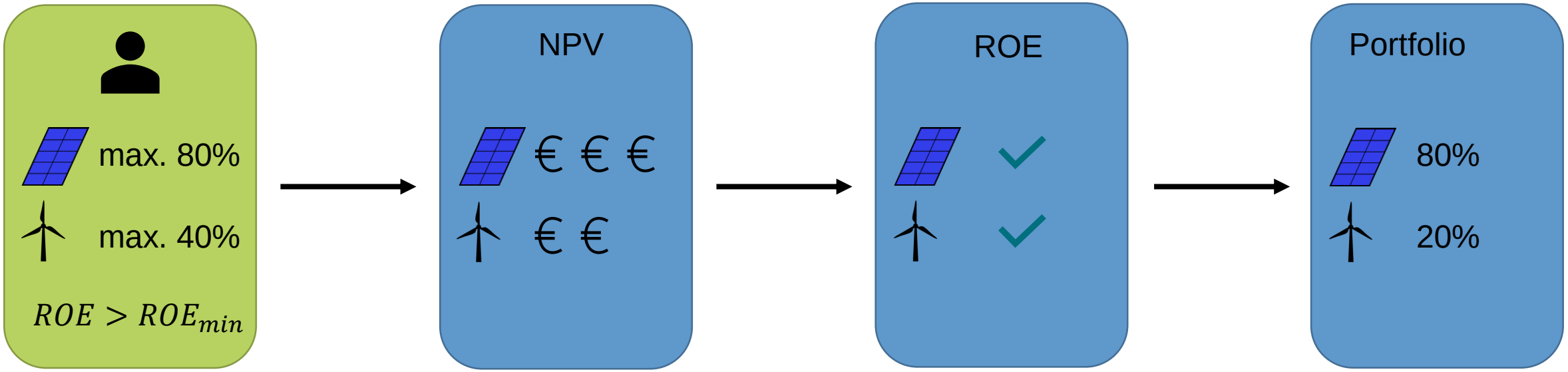
## Return on Equity

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

$$ROE > ROE_{min}$$

# Appendix: Workflow




→ Generic decision workflow applicable for different actor types and technologies

# Imprint

| | |
|---|---|
| **Topic** | Investment decisions under uncertainty<br>An agent-based modelling approach |
| **Date** | 2025-08 |
| **Author** | Leonard Willeke |
| **Institute** | Institute of Networked Energy Systems |
| **Credits** | DLR (CC BY-NC-ND 3.0)<br>except stated otherwise |

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