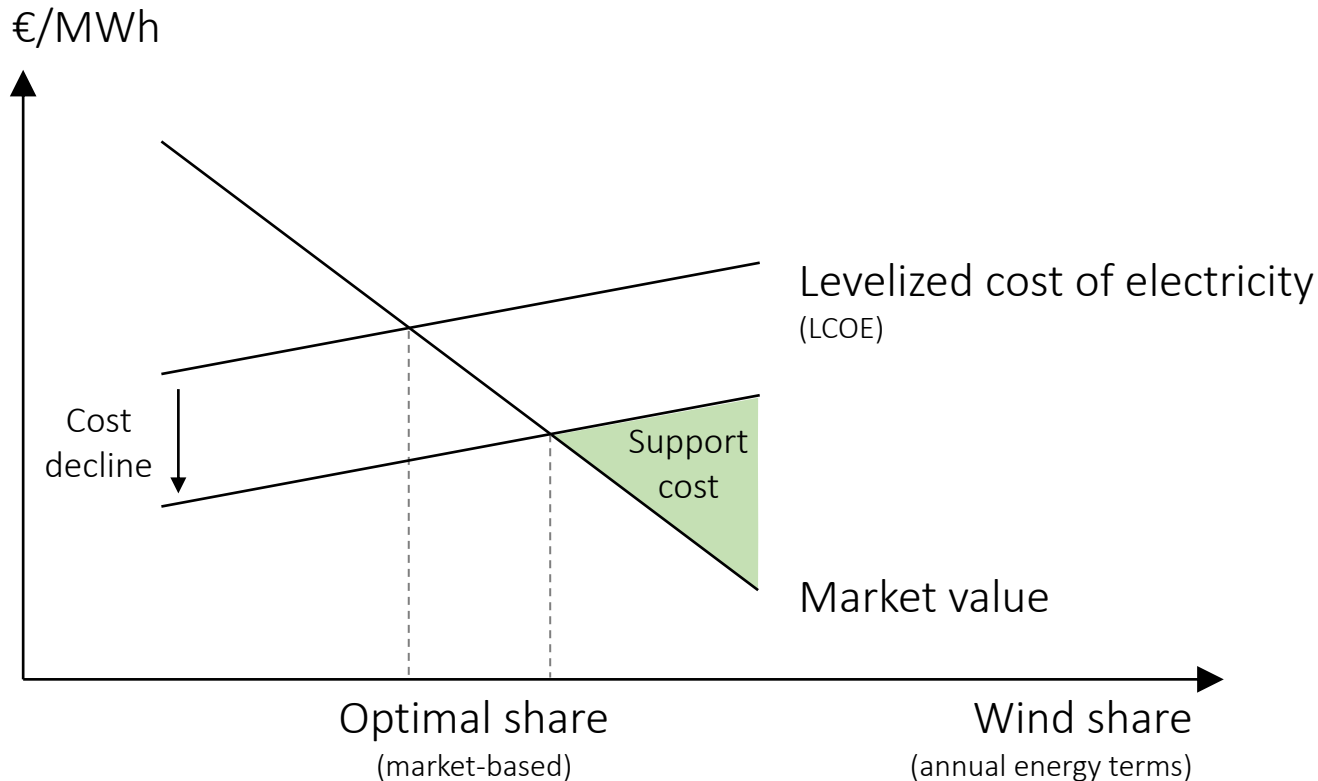# How flexible electricity demand stabilizes wind and solar market values: The case of hydrogen electrolyzers
(link to published working paper)

Oliver Ruhnau

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Market integration of variable renewable energy sources

€/MWh

Levelized cost of electricity
(LCOE)

Cost decline

Support cost

Market value

Optimal share
(market-based)
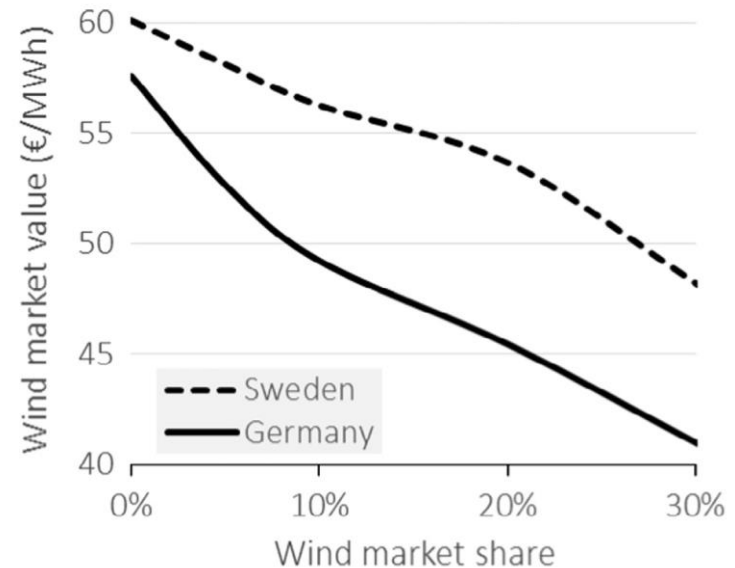
Wind share
(annual energy terms)

- Can renewables earn back their fixed costs on the free market?
- Will there be an ongoing need for renewable support schemes?

Existing literature on mitigating the value decline
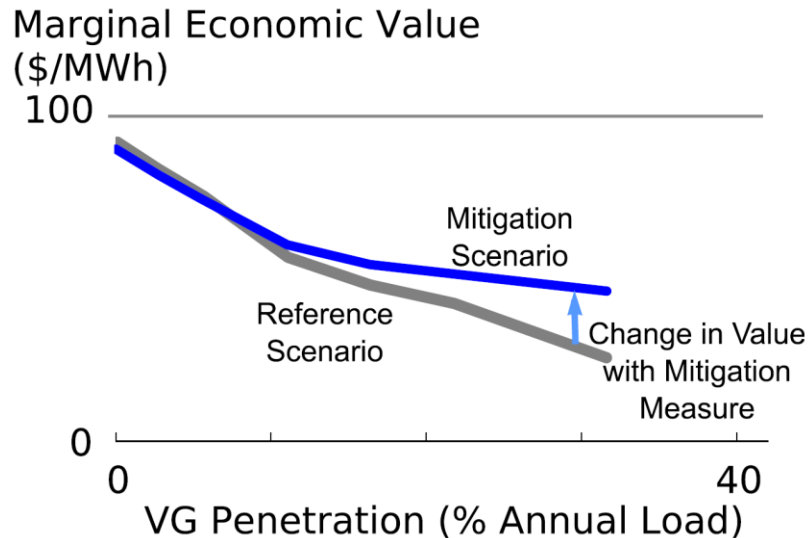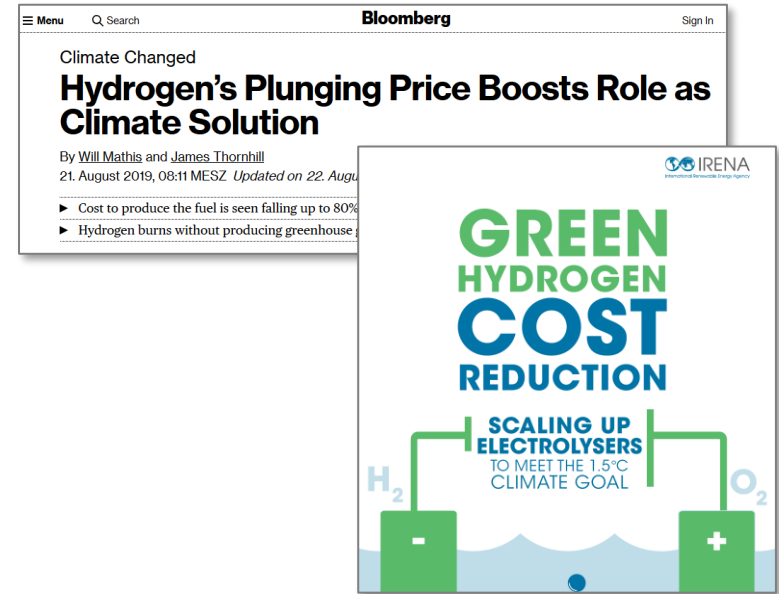

Mills and Wiser (2015)

Hirth (2016)

- Known options to slow down declining market values: storage, transmission, "low wind speed" turbines, …

- Nothing has yet been found that can permanently stop the decline

Green hydrogen

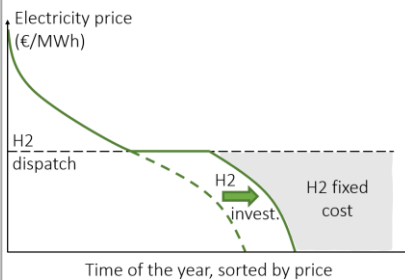## Political attention

Costs may also decline

- So far: competitiveness of green hydrogen as a function of renewables
- This study: competitiveness of renewables as a function of green hydrogen

Agenda

Research question:
How can flexible hydrogen electrolyzers stabilize renewable market values?
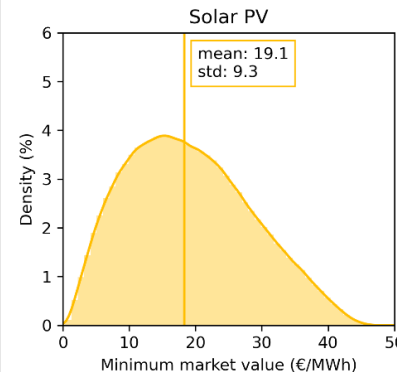

Theoretical framework

Analytical formula
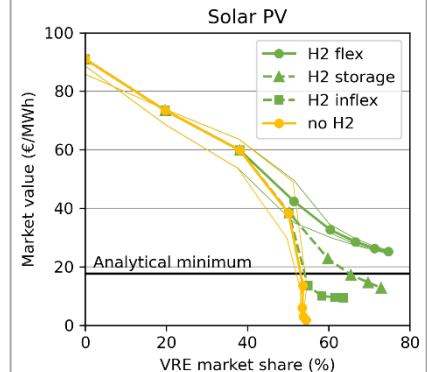
In the long-term equilibrium:
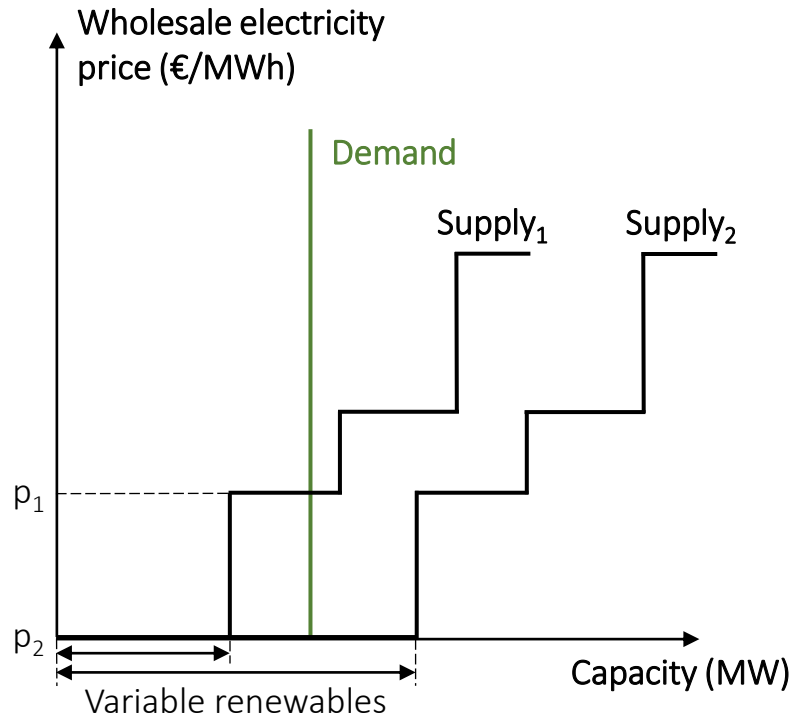
$$value_{RE,min} = f(H2)$$

Monte Carlo analysis

Solar PV

mean: 19.1
std: 9.3

Electricity market model

Solar PV
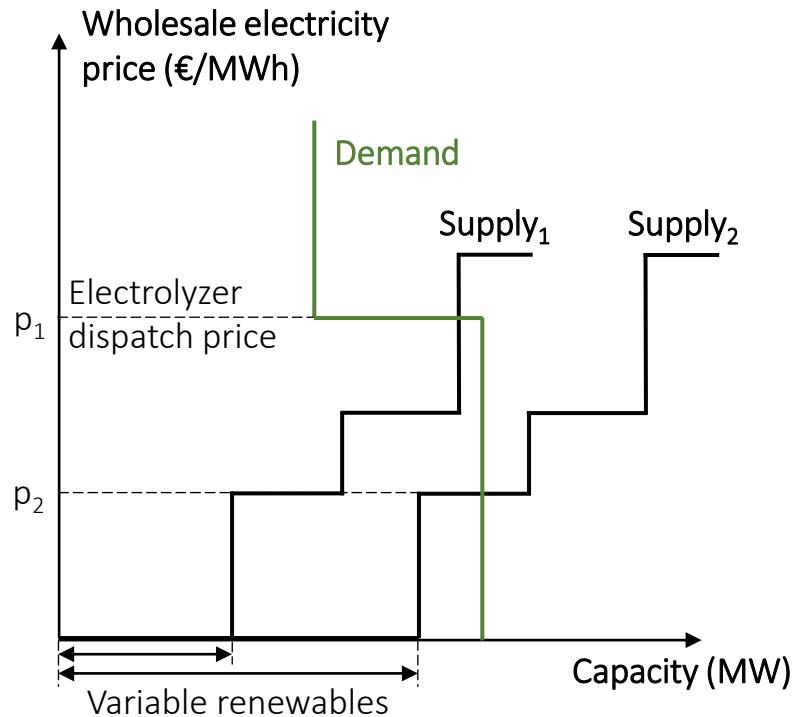
H2 flex
H2 storage
H2 inflex
no H2

Analytical minimum

Policy implications and conclusions

Merit order model with renewables

- Power prices equal the variable costs of the marginal generator – except for scarcity prices.

- When available, variable renewables depress market prices – possibly to zero.

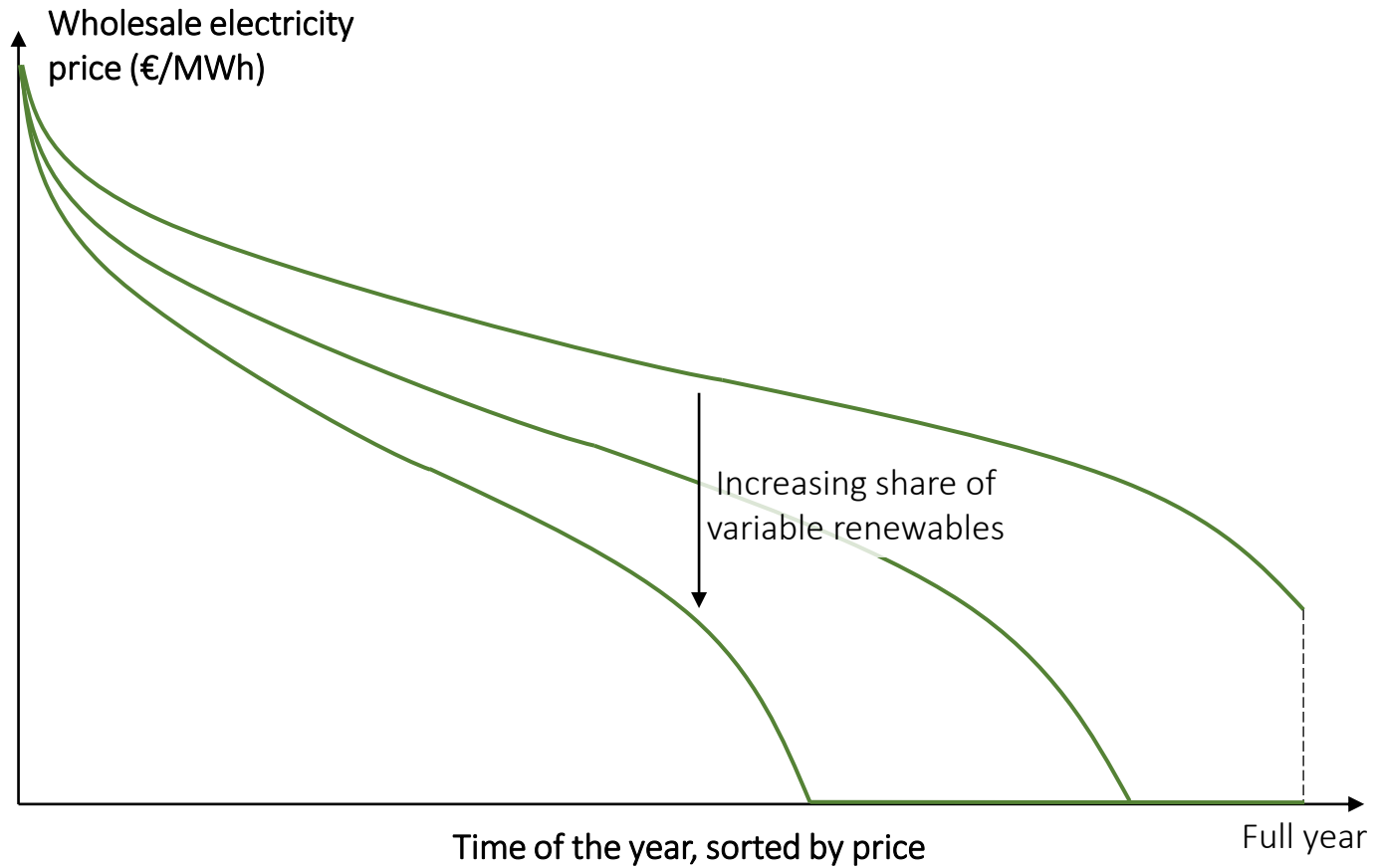# Merit order model with renewables *and electrolyzers*

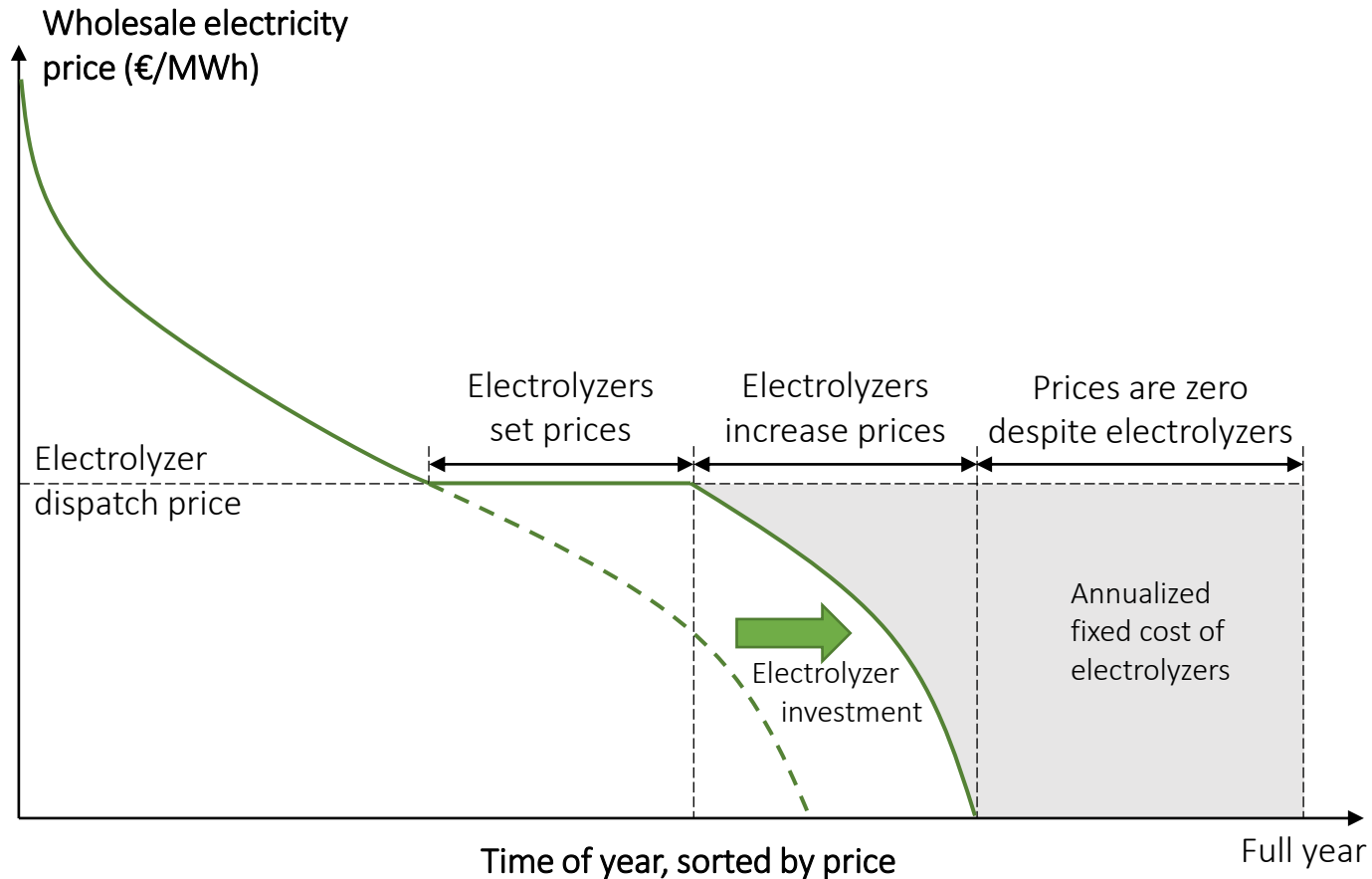$$P_{dispatch} = (P_{H2} - C_{OPEX,var}) \cdot \eta - C_{sup}$$

- Dispatch if electricity price is below product revenues (for hydrogen) minus variable cost per MWh_{el}.

- Electrolyzers can increase or even set the electricity price.

Wholesale electricity price (€/MWh)

Demand

$Supply_1$ $Supply_2$

Electrolyzer dispatch price

p_1

p_2

Capacity (MW)

Variable renewables

Simplification: constant hydrogen price

$P_{dispatch}$	Dispatch price (€/MWh_{el})
P_{H2}	Hydrogen price (€/kg_{H2})
$C_{OPEX,var}$	Variable operational cost (€/kg_{H2})
η	Electrolyzer efficiency (kg_{H2}/€/MWh_{el})
C_{sup}	Demand supplement on wholesale electricity prices (€/MWh_{el})

Price duration curve with renewables

Wholesale electricity price (€/MWh)

Increasing share of variable renewables

Time of the year, sorted by price

Full year

Price duration curve with renewables *and electrolyzers*

Wholesale electricity price (€/MWh)

Electrolyzers set prices

Electrolyzers increase prices

Prices are zero despite electrolyzers

Electrolyzer dispatch price

Electrolyzer investment

Annualized fixed cost of electrolyzers

Time of year, sorted by price

Full year

Electrolyzers will be installed until the annual margin equals annual fixed cost.

The argument

Flexible electrolyzers balance the value decline of variable renewables:
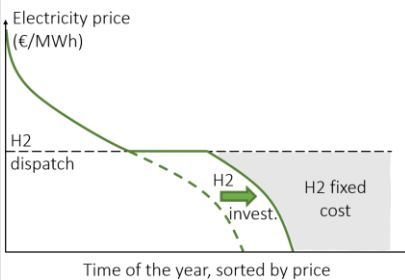
trigger investment

| Variable renewables | → *depress* → | Market prices / market value | | Flexible electrolyzers |

stabilize

Agenda
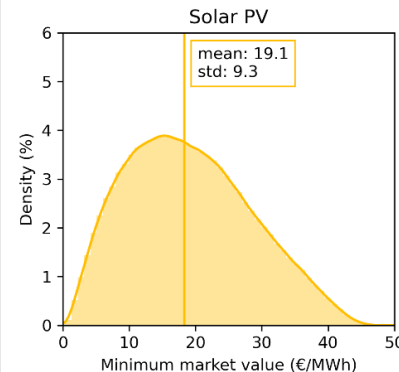
Research question:
How can flexible hydrogen electrolyzers stabilize renewable market values?

Method

Electricity market model EMMA

- Long-term equilibrium: green-field investment + dispatch
- Exogenous wind and solar investment
- New: endogenous electrolyzer investment + dispatch

Fixing the uncertain parameters from before

- Center estimates of the hydrogen parameters (2 €/t$_{H2}$, 450 €/kW$_{el}$)
- Renewable profiles for Germany + 4 neighbors in 2050 (weather year 2010)

Three scenarios

- *H2 flex*: constant hydrogen price (as before) → perfectly flexible electrolyzers
- *H2 storage*: constant hydrogen supply → flexibility comes at the cost of H$_2$ storage
- *H2 inflex*: constant hydrogen supply, no storage → perfectly inflexible electrolyzers

# Results: hydrogen electrolyzers stabilize market values
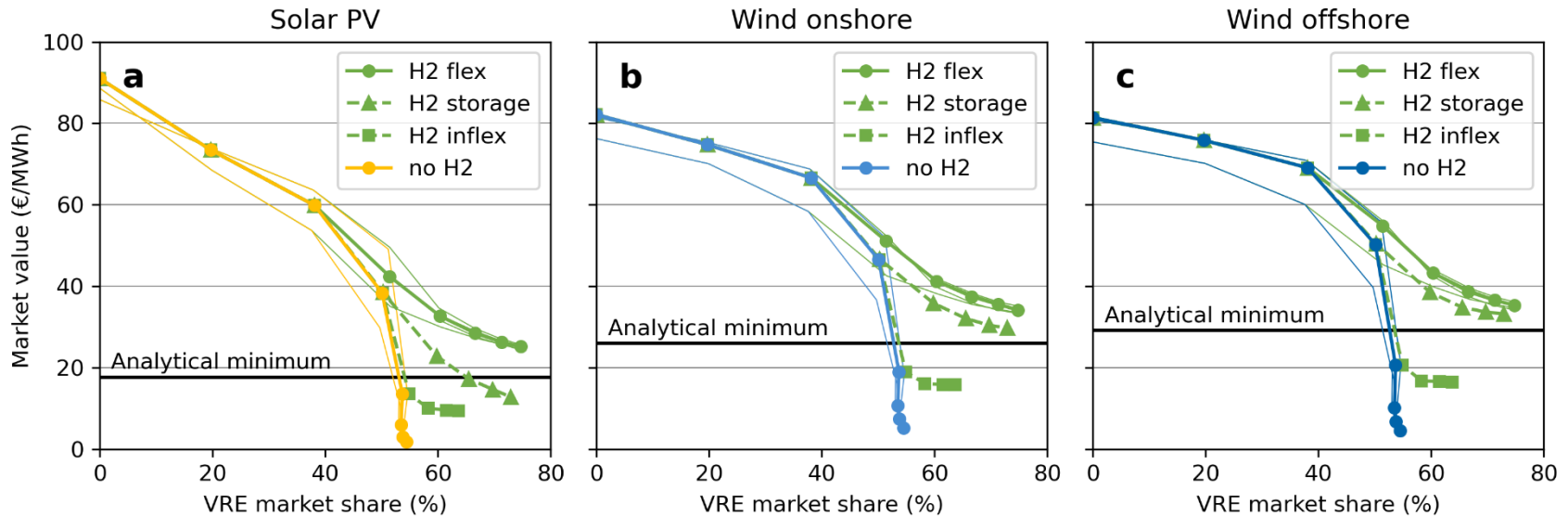
- *no H2:* market values fall close to zero
- *H2 flex:* market values converge well above the analytical minimum
- *H2 storage:* market values decrease further but they still seem to converge
- *H2 inflex:* significantly lower market values

Agenda

Research question:
How can flexible hydrogen electrolyzers stabilize renewable market values?
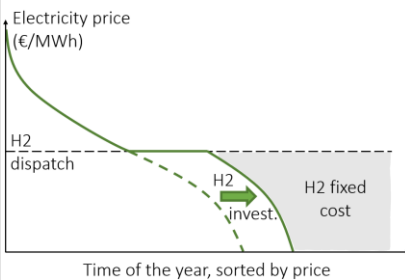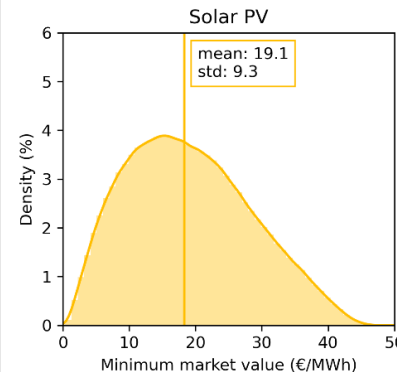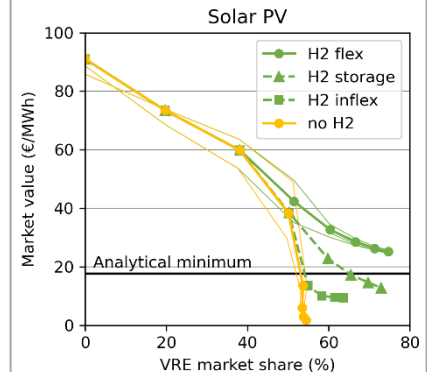
Theoretical framework	Analytical formula	Monte Carlo analysis	Electricity market model

In the long-term equilibrium:

$$value_{RE,min} = f(H2)$$

Policy implications and conclusions

Conclusions on market-based renewables

€/MWh

Levelized cost of electricity
(LCOE)

Cost
decline

Market value

Optimal share
(market-based)

Wind share
(annual energy terms)
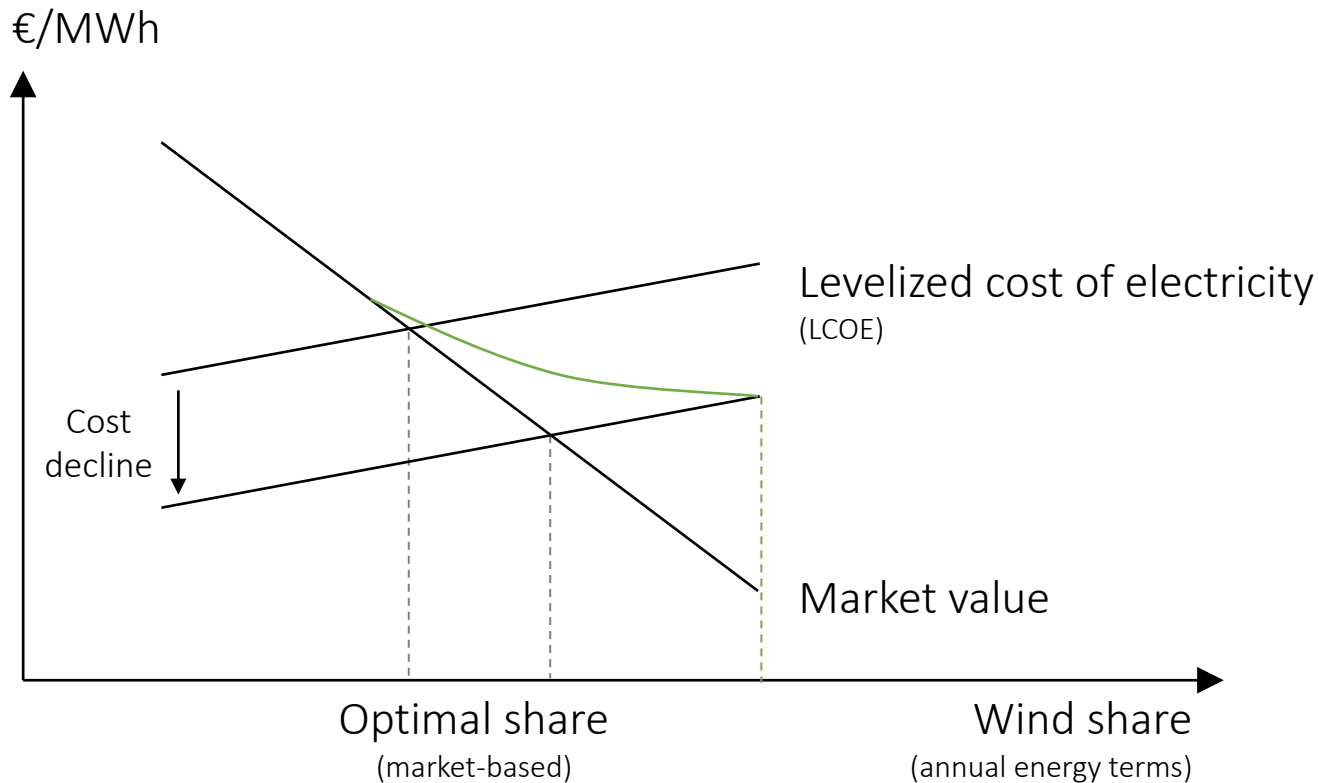
- Stabilizing market values mean higher optimal shares of wind and solar

- These may be reached in competitive markets without direct policy support

- Regulation may still play a role (e.g., supplement on wholesale prices)

Conclusions on flexible electricity demand

Flexible electricity demand is crucial when analyzing variable renewables

Hydrogen electrolysis…

- …may also be feasible on a market basis, triggered by renewables

- …is an ideal type of flexible electricity demand with distinct characteristics

Other flexible electricity demand…

- …may be analyzed using and adjusting the presented framework

- …will compete with hydrogen electrolyzers for using renewable electricity and jointly contribute to stabilizing the market value of renewables
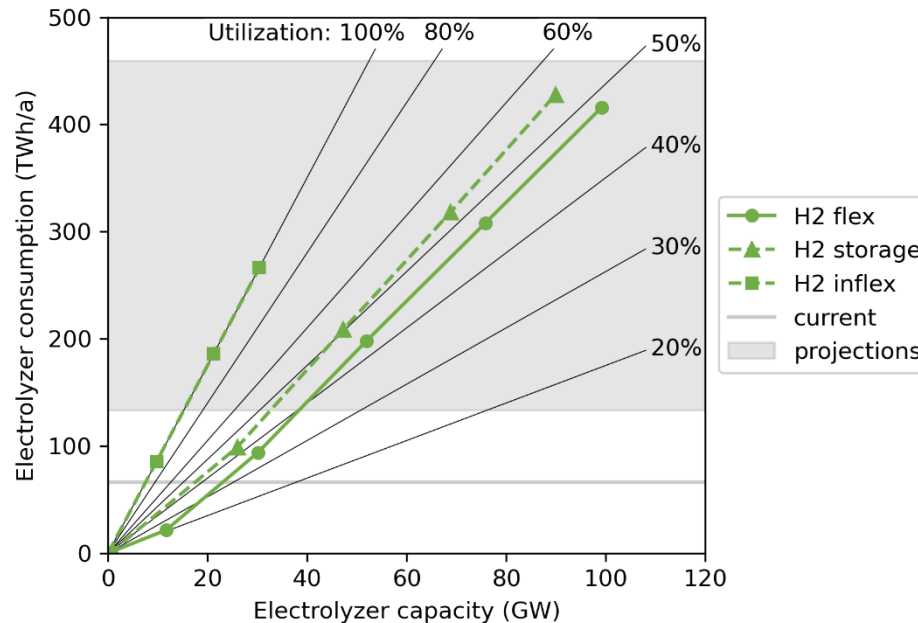
Thank you!

Feel free to reach out via
ruhnau@hertie-school.org

Link to published working paper
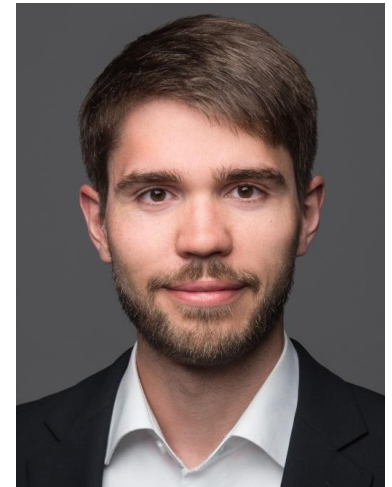
Back-up: details on electrolyzers

- For perspective: today's German hydrogen consumption is 55 TWh; by 2050, the hydrogen demand is estimated to increase to 110-380 TWh (BMWi 2020)

- Flexible operation means low utilization (40-55%) but higher overall hydrogen production