



# **Are Energy Storage and Electrolysis competing each other?**

A Multistage Stochastic Dynamic Modelling of  
the German Case

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What you can go home with

An aerial photograph of a vast, forested landscape. A winding river flows through the center of the scene, surrounded by dense green trees. In the foreground, a large white wind turbine stands prominently. The background shows rolling hills and a clear sky, suggesting a rural or natural setting.

**01**

# Statement

The ongoing energy transition

# Decarbonizing Europe

Ambition: achieve carbon neutrality by 2050

- Energy efficiency
- Renewables
- Hydrogen

New challenges emerge, notably the growing need for **flexibility**



# Flexibility: why and how ?



## **Renewables are not dispatchable...**

It becomes challenging to match supply and demand



## **... And sector coupling will be strengthened**

Gas and power systems will become more linked



## **Hence, flexibility sources are numerous**

Electricity storage (PHS, Batteries), electrolysis, Hydrogen turbines, demand response...



« Using all the enablers of the flexibility portfolio of resources is the best way to lower the overall transition cost »

**—Alain Malot, energy expert**

An aerial photograph of a vast forest with a white wind turbine on the left side. The image is overlaid with a large yellow rectangular box containing bold, dark blue text. The text asks a question about the impact of PtG on other flexibility sources.

**Is the spread of  
PtG threatening  
other flexibility  
sources viability?**

An aerial photograph of a vast, forested landscape. A winding river flows through the center of the scene, surrounded by dense green trees. In the foreground, a large white wind turbine is visible, its three blades extending outwards. The background shows rolling hills and a hazy sky, suggesting a distant horizon. The overall scene is a mix of natural beauty and modern infrastructure.

**03**

# Methodology

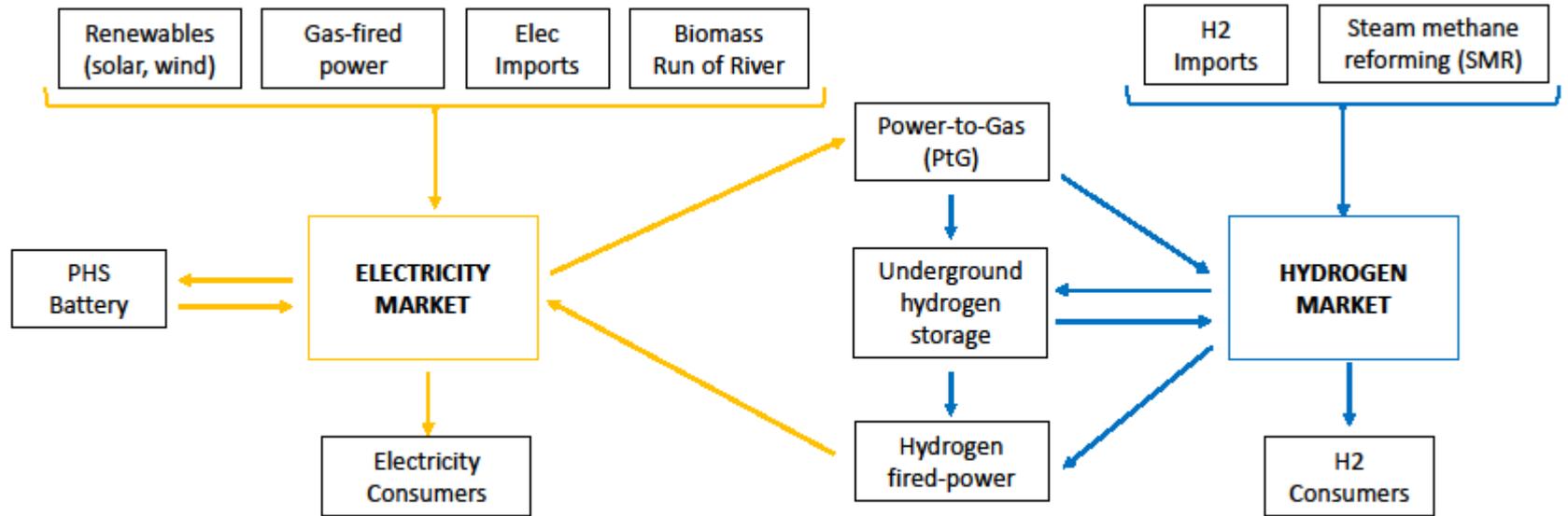
The SDDP framework



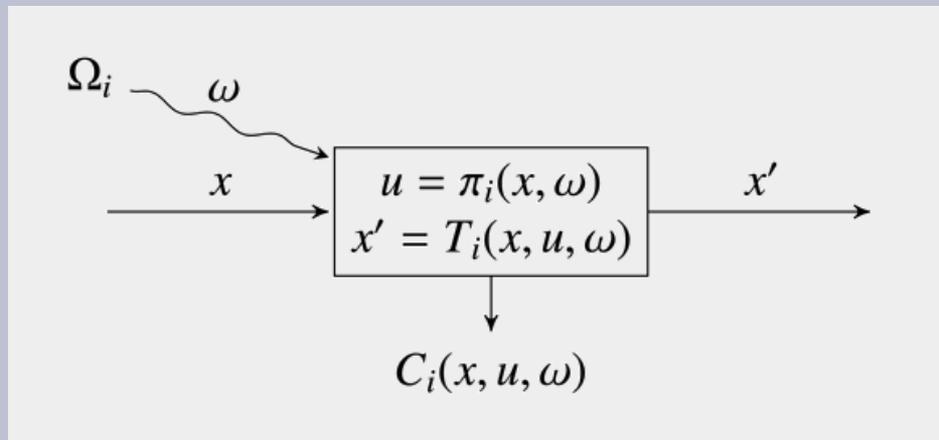
# Modelling the German power and H2 markets with **uncertainty**

Using a Multi-Stage Stochastic  
Dynamic Programming model to  
account for the variability of  
Renewables and avoiding to  
overestimate flexibility potential

# Model Overview: Germany in 2035



# How to use a stock optimally?



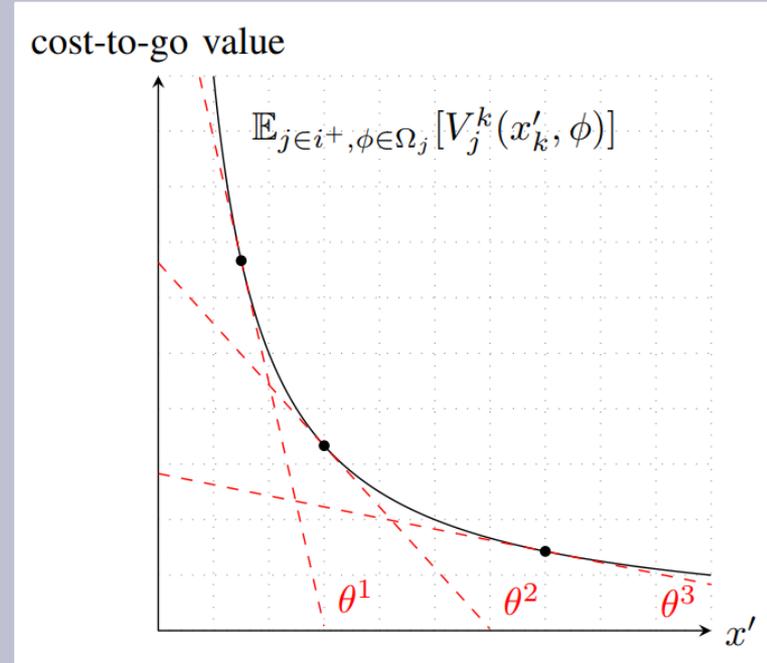
$$\text{minimize}_{\pi} \quad \mathbb{E}_{i \in \mathbb{R}^+, \omega \in \Omega_i} (V_i^\pi(x_0, \omega))$$

$$V_i^\pi(x, \omega) = \min_{x, x', u} C_i(x, u, \omega) + \mathbb{E}_{j \in i^+, \phi \in \Omega_j} (V_j(x', \phi))$$

$$\text{subject to} \quad \begin{aligned} x' &= T_i(x, u, \omega), \\ u &= \pi_i(x, \omega) \in U_i(x, \omega) \end{aligned}$$

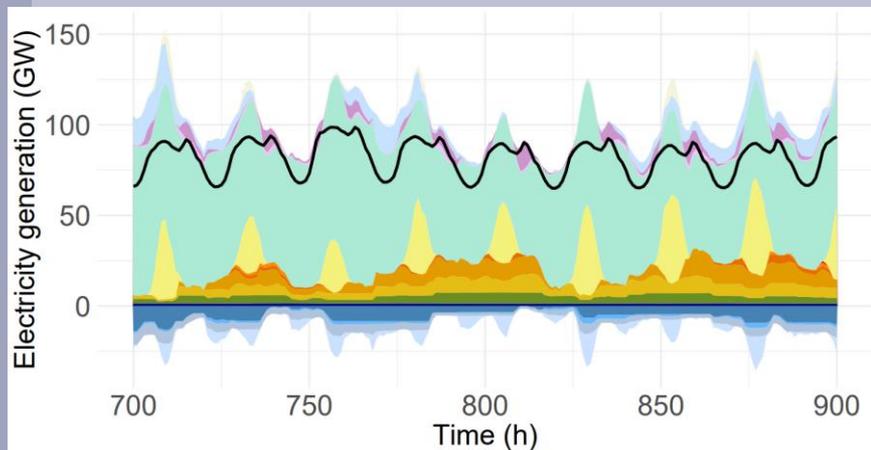
# How to use a stock optimally?

- Approximation of the cost-to-go term with Benders cuts
- Back & Forth iterations for building the convex envelope of the function
- Once training ends, we get a « policy » to be run over hundreds of simulations

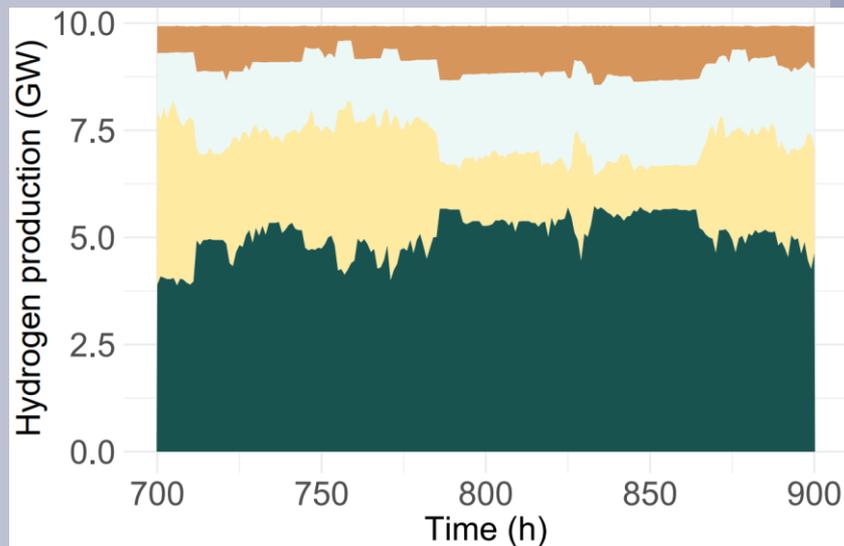


# Visual outputs

## Power dispatch



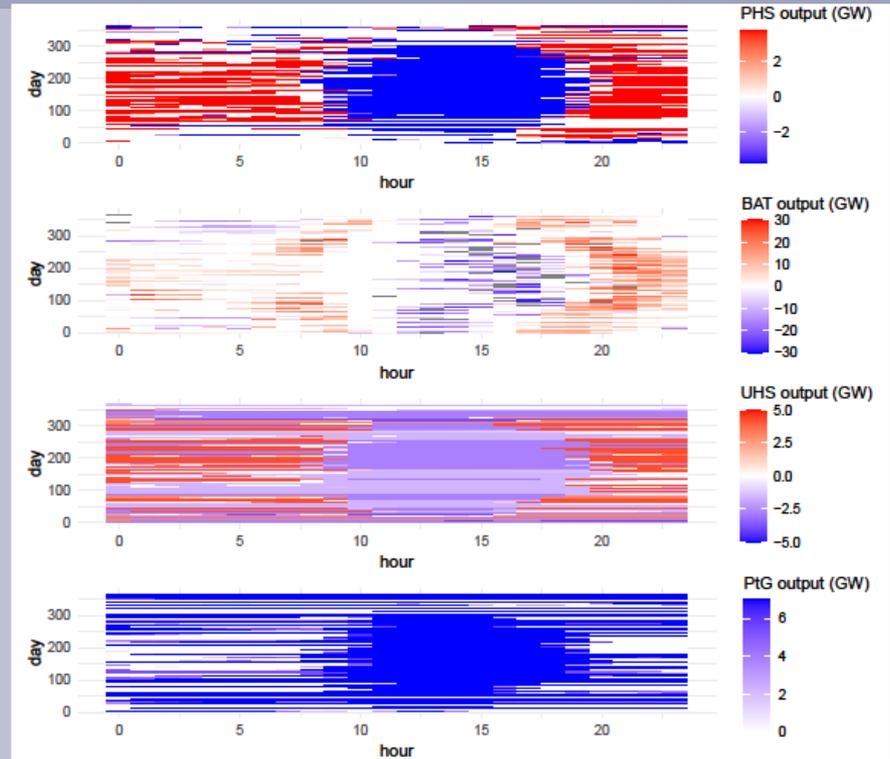
## H2 dispatch



# Technologies patterns of use

## Findings

- Daily cycles are shared by all technologies in summer times
- Batteries offer more power (peaker behaviour)
- Flexibility assets are mapped on renewables production patterns





**What impact of an increased PtG capacity?**

**35%**

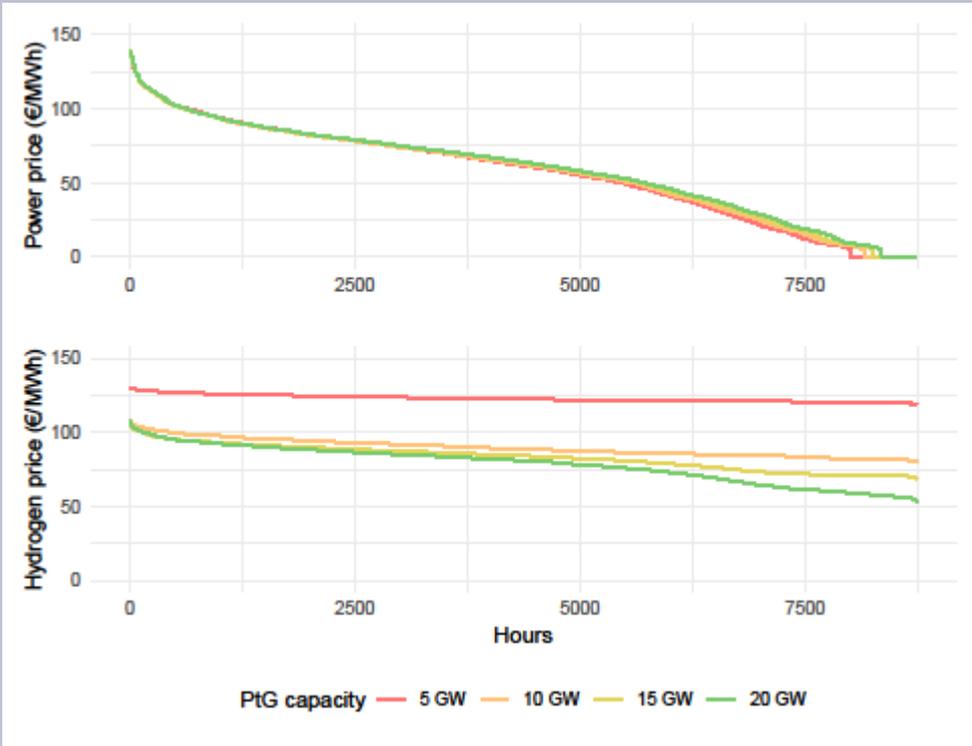
**Reduction in energy curtailment when  
the electrolysis capacity goes from 5  
to 20 GW. (From 100 TWh to 65 TWh)**



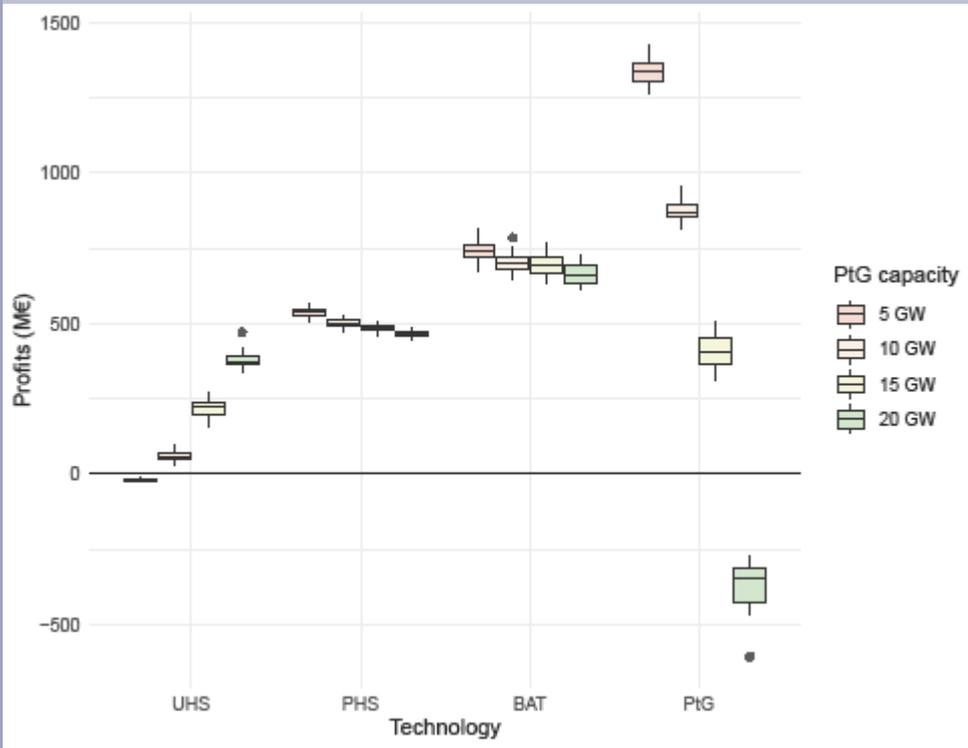
# Dynamics on prices

## Findings

- Power prices are not very sensitive to PtG capacity
- Tremendous impact on Hydrogen prices (35% reduction)



# Winners & Losers



## Findings

- UHS is the only technology to benefit from PtG development
- Low impact on PHS and Batteries profits
- Tremendous impact on Electrolysers profits, negative values obtained between 15 and 20 GW installed

An aerial photograph of a vast, forested landscape. A winding river flows through the center of the scene, surrounded by dense green trees. In the foreground, a large white wind turbine stands prominently. The background shows rolling hills and a clear sky, suggesting a rural or natural setting.

**05**

# **Analysis**

Main insights

# Insights

**01**

## **Power-to-Gas is helpful**

It is a key tool for decarbonizing hydrogen production and reduces renewables curtailment.

**02**

## **PtG fosters the rise of a full H2 infrastructure**

Underground Hydrogen Storage are increasingly profitable with PtG development.

**03**

## **Your are your own worst enemy**

Electrolysers lose utilization rate and lower hydrogen prices, sawing off the branch they are sitting on. PHS and batteries are not endangered by it.

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**06**

# **Conclusion**

What to remember

# Study objectives



## Modelling

SDDP is applied to model the interaction between two energy systems, with uncertainty



## Economics

The spread of PtG is found to greatly benefit the H2 system. Storage assets are not threatened.



## Politics

PtG may help lowering the CO2 emissions of Germany, as well as enhancing its energy security by reducing imports

# Thanks!

**Do you have any questions?**

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