



Power-to-X model overview

SuperP2G Stakeholder Meeting , 31st of March 2023

Lissy Langer
DTU Energy Economics & Modeling



This project has received funding in the framework of the joint programming initiative ERA-Net Smart Energy Systems' focus

initiative Integrated, Regional Energy Systems, with support from the European Union's Horizon 2020 research and innovation programme under grant agreement No 775970.

Introducing the PtX model zoo



DTU PtX
DTU Econ

Processes + Technologies

Value Chains

Europe → Global

Advanced electrolysis models

01 Electrolysis dynamic models

05 Electrolysis considering uncertainty

07 Electrolyzer model complexity

PtX system optimal operation

02 Robust optimization H₂ + MeOH

04 Demand response H₂ + NH₃

PtX system optimal investments

03 Electrolysis optimal investment

B Delegated Act on Renewable hydrogen H₂, MeOH, NH₃

C European Hydrogen Infrastructure

Markets and regulatory constraints

A Renewable fuel premiums H₂, MeOH, NH₃

06 Frequency regulation markets




Impact of renewable fuel premiums on PtX hub operation: The EnerHub2X model

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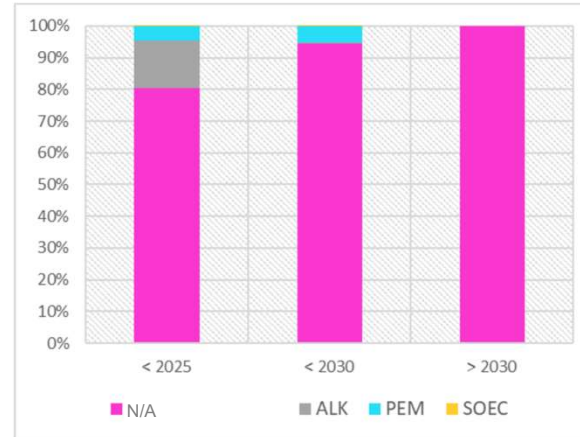
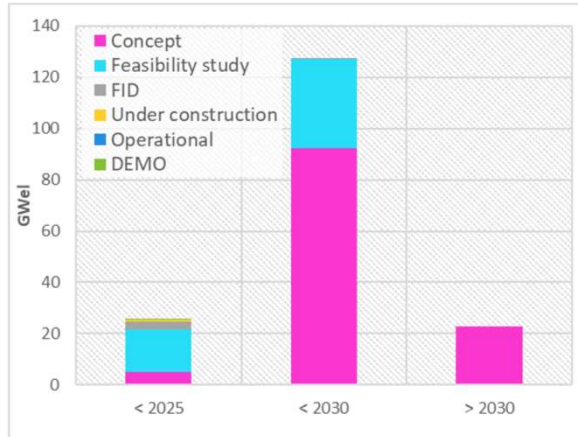


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Motivation: Power-to-X in Energy Hubs

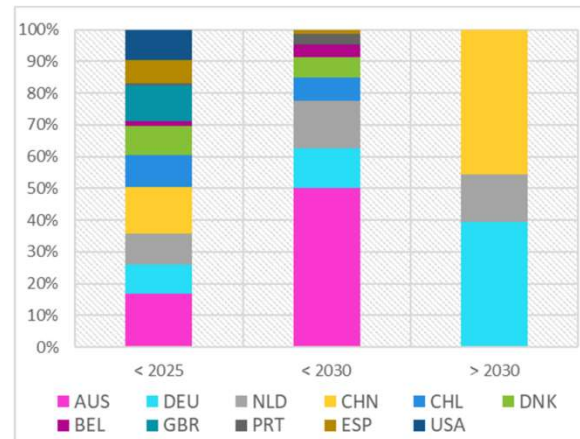
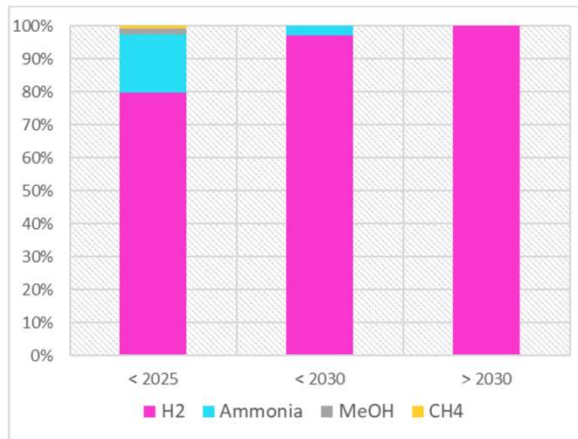


Lots of early-stage ambition



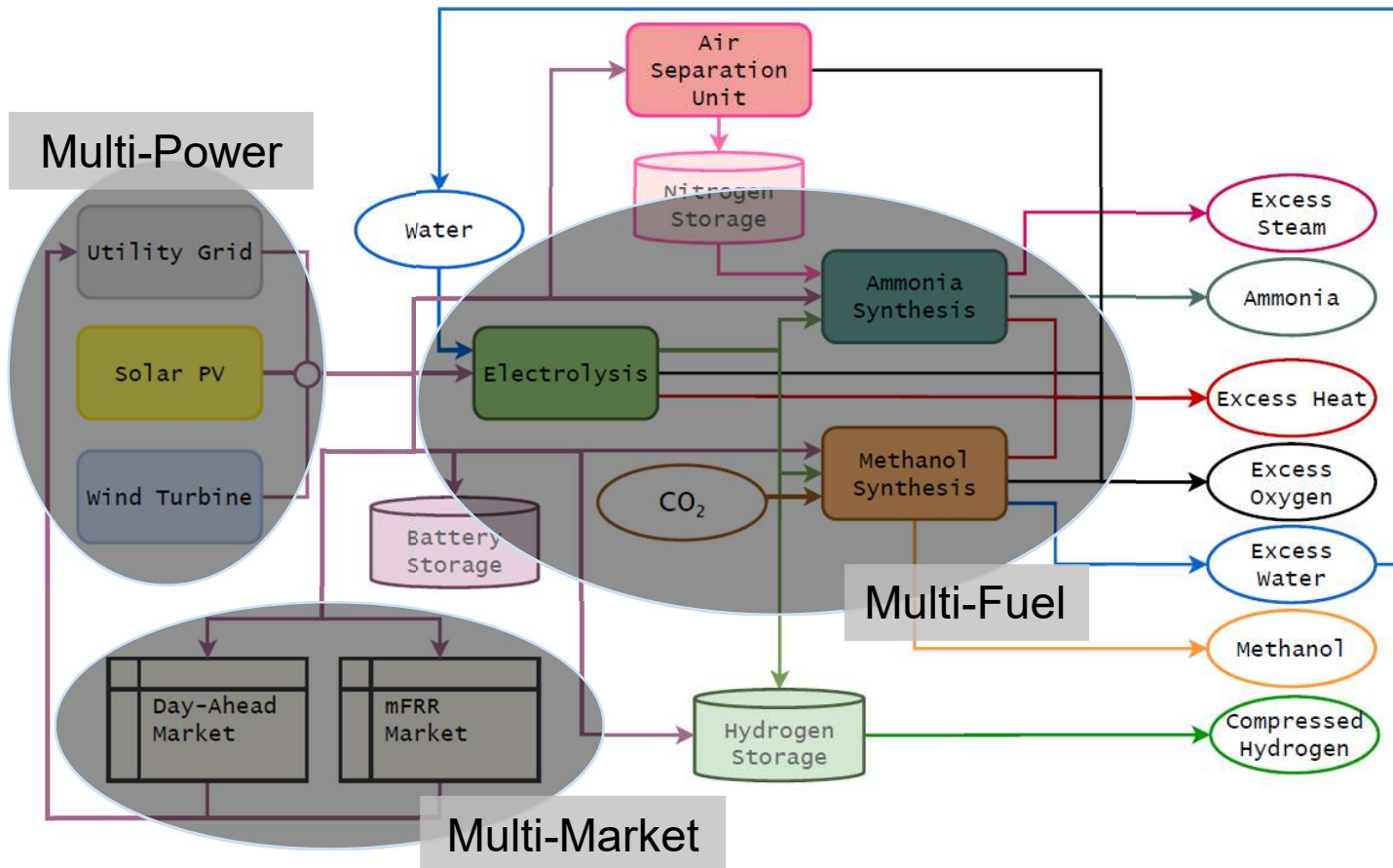
High technological uncertainty

High fuel uncertainty

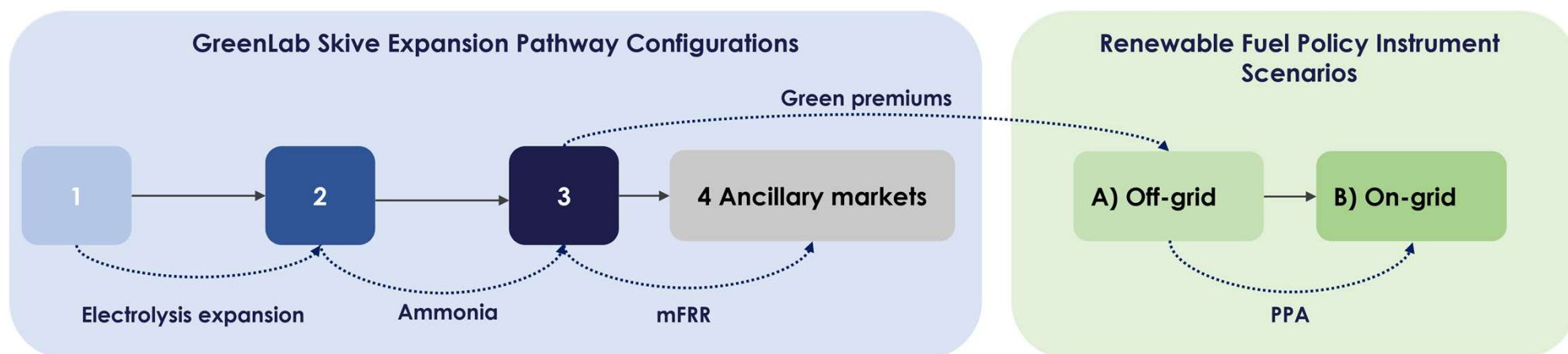


Some frontrunners

GreenLab Skive: Technology Flow Chart

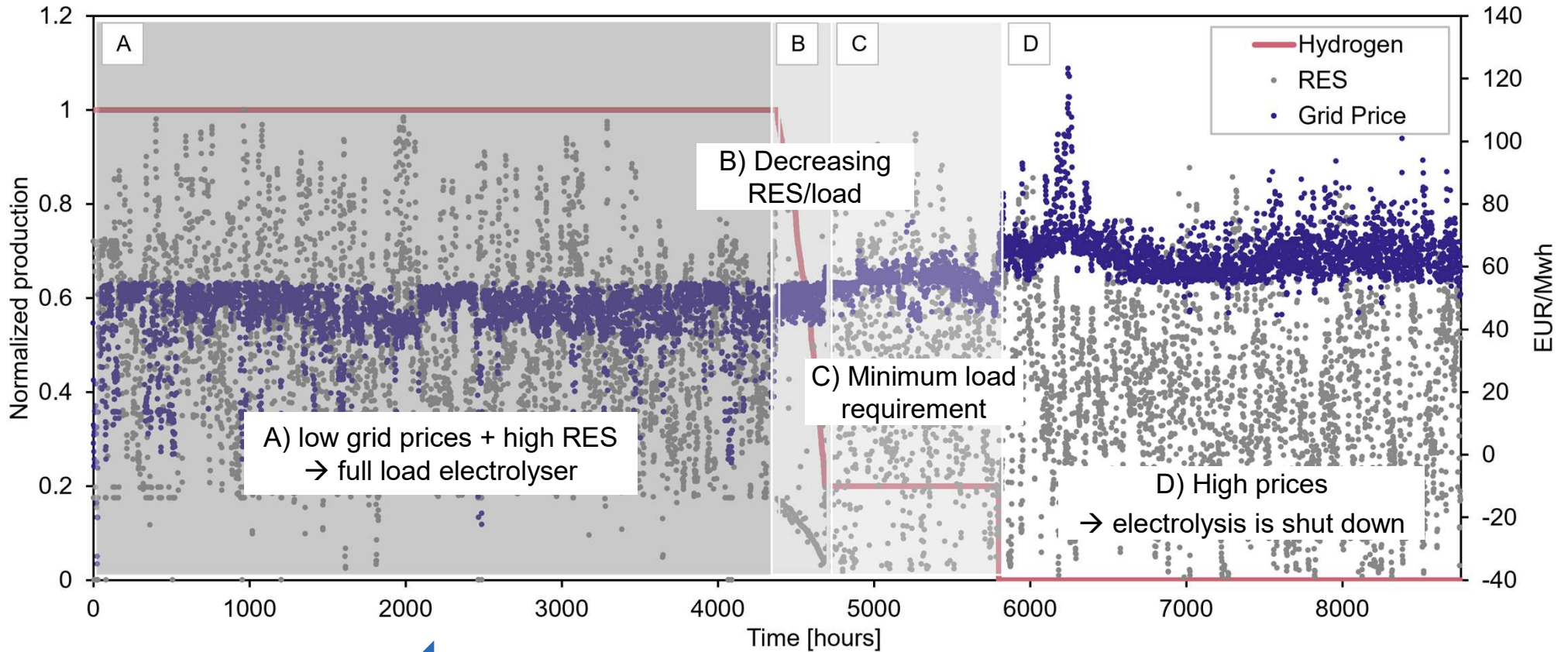


- Over one year with hourly time resolution
- Considering unit commitment
- Fixed fuel prices



Kountouris, I., Langer, L., Bramstoft, R., Münster, M. and Keles, D., 2023. Power-to-X in energy hubs: A Danish case study of renewable fuel production. *Energy Policy*, 175, p.113439.

Operational Results (S1)



A) low grid prices + high RES
→ full load electrolyser

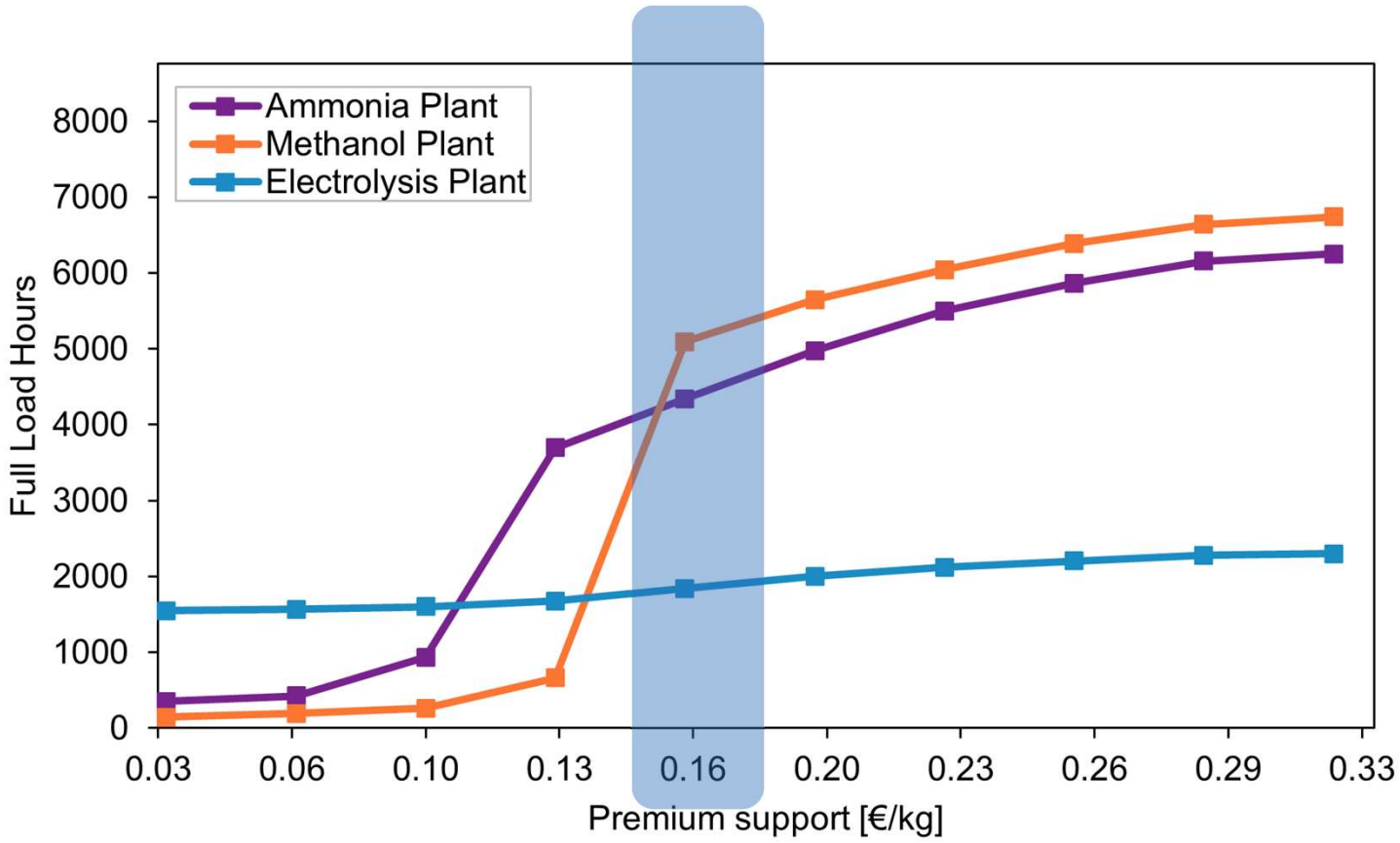
B) Decreasing
RES/load

C) Minimum load
requirement

D) High prices
→ electrolysis is shut down

← Renewable fuel premiums to increase full-load hours?

Renewable fuels premiums



- A 50% fuel premium for ammonia and methanol increases production substantially
- Capacity expansion needs to be harmonized between synthesizers and available RES
→ next paper




PtX hub investments under the Delegated Act: The EnerHub2X.spineopt model

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Delegated Act on Renewable Fuels of non-biological origin (RFNBOs)



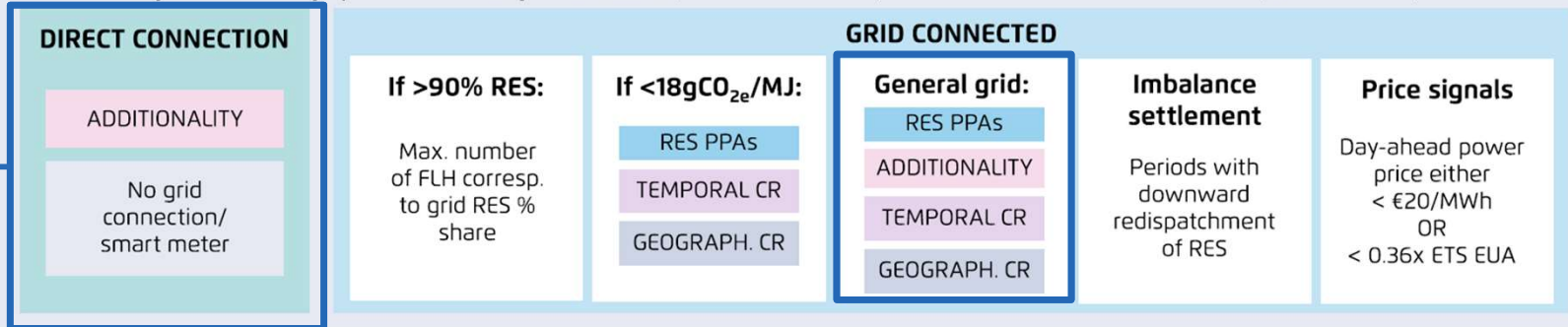
REGULATORY FRAMEWORK FOR THE PRODUCTION OF RFNBOs (REDII/REDIII)



RED Art. 25: min. 70% GHG emissions savings from use of RFNBOs

DA Art. 28: total emissions from RFNBOs/RCFs **min. -70%** vs fossil fuel comparator (**94gCO_{2e}/MJ**)

DA Art. 27: **input electricity** qualified as **fully renewable** (=zero emissions) for total emissions calculation (→DA Art. 28) if:



Local RES

RES PPAs

ADDITIONALITY:

- RES installations came into operation <36 months before RFNBO production; capacity additions considered part of original if added in <36 months.
- RES installations have **not received net support** (OPEX/CAPEX), excl. before repowering, repaid aid, R&D support

TRANSITION PHASE: additionality rules come into effect in 2028; installations coming into operation before 2028 remain exempt until 2038

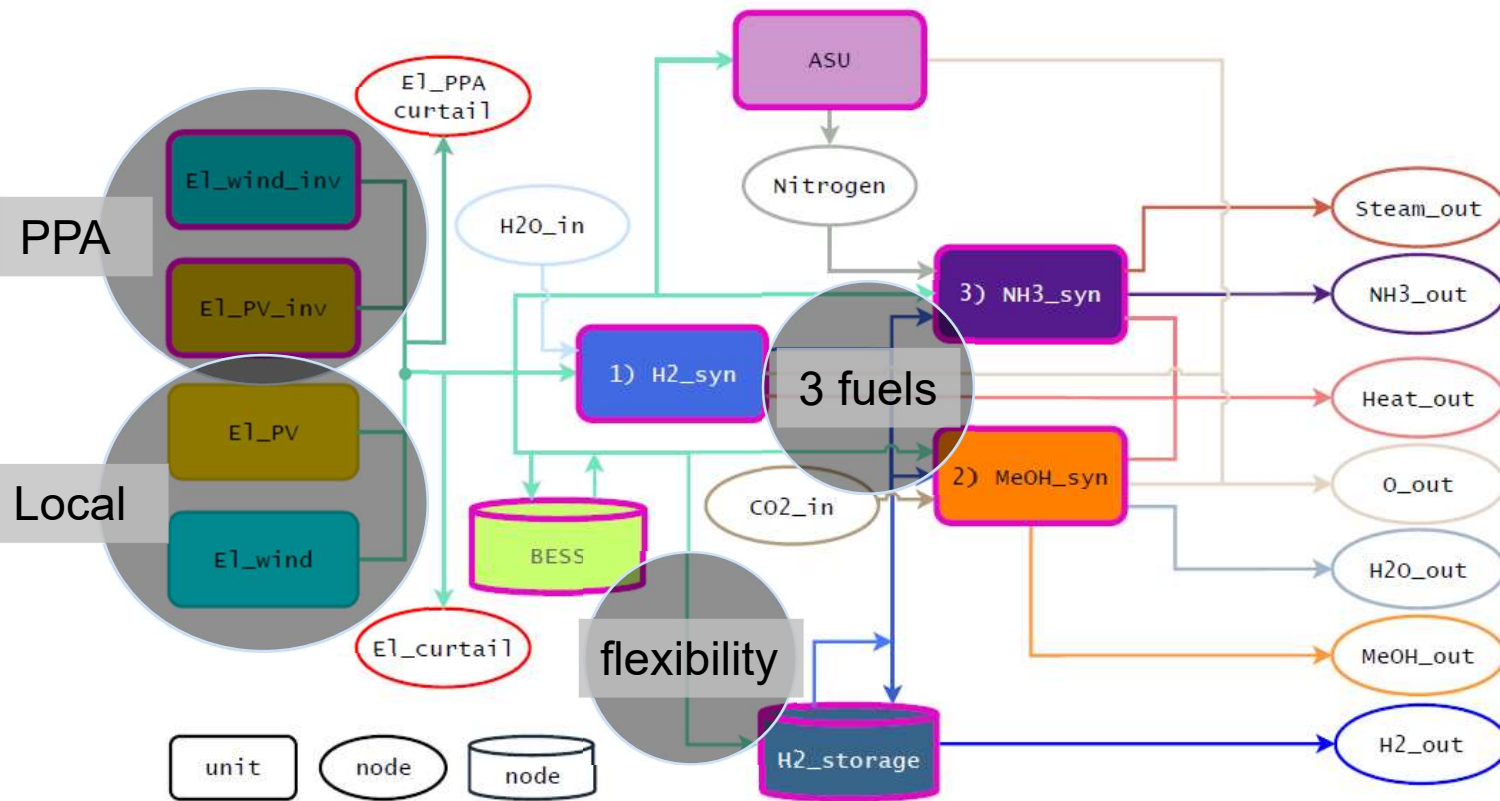
TEMPORAL CORRELATION: monthly matching between RES and RFNBO production until 2030; hourly correlation from 2030

GEOGRAPHICAL CORRELATION: RES installations for RFNBO production are located in the same bidding zone / an interconnected offshore bidding zone / interconnected bidding zone with lower or equal power prices

DA Art. 27: Methodology for production of RFNBOs / "Additionality DA"
 DA Art. 28: GHG emissions savings and accounting methodology for RFNBOs and RCFs

RFNBO: Renewable Fuel of Non-biological Origin; RCF: Recycled Carbon Fuel
 RES: Renewable energy source; FLH: Full load hours
 ETS EUA: ETS Emission allowance

GreenLab Skive: Technology Flow Chart



- Over one year with hourly time resolution
- Considering unit commitment
- Fixed fuel prices
- **Capacity investments**

Scenarios



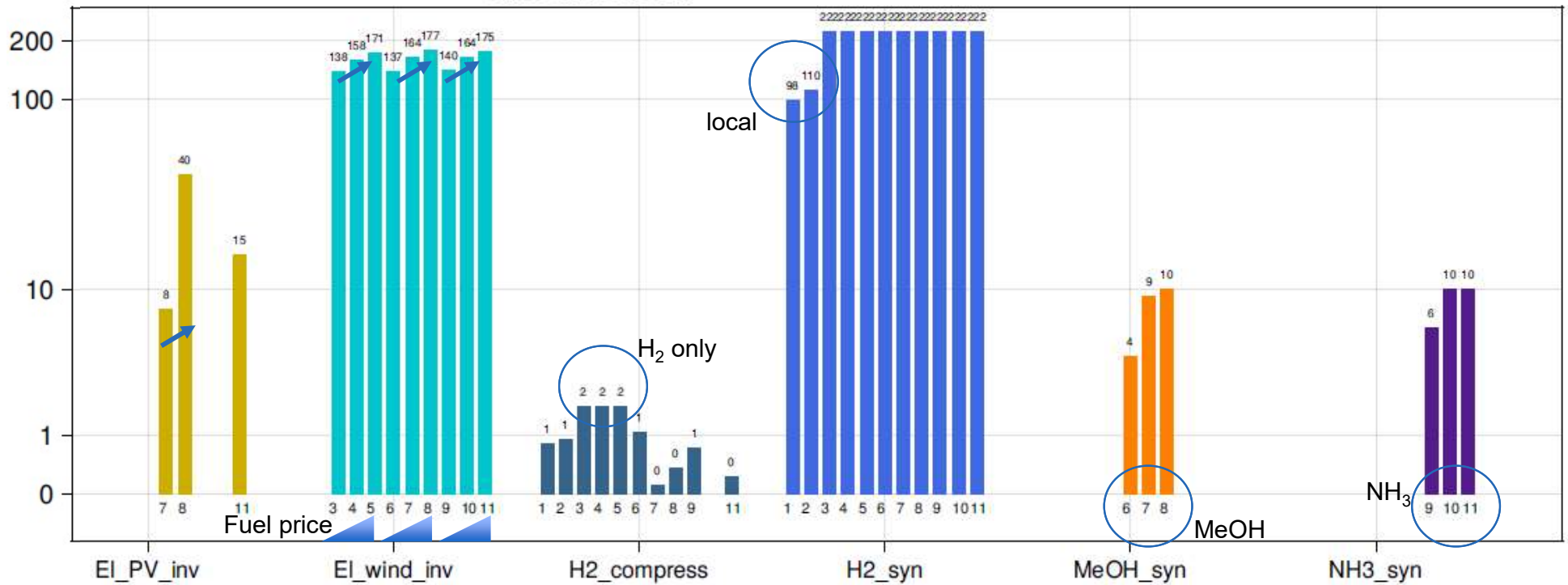
No	Fuels		RES		Fuel price
0	H ₂		Local		1x
1	H ₂		Local		1.5x
2	H ₂		Local		2x
3	H ₂		Local	PPA	1x
4	H ₂		Local	PPA	1.5x
5	H ₂		Local	PPA	2x
6	H ₂	MeOH	Local	PPA	1x
7	H ₂	MeOH	Local	PPA	1.5x
8	H ₂	MeOH	Local	PPA	2x
9	H ₂	NH ₃	Local	PPA	1x
10	H ₂	NH ₃	Local	PPA	1.5x
11	H ₂	NH ₃	Local	PPA	2x

- P2X price projections made for 2030 by the Danish Energy Agency:
 - H₂ €2.16 per kg
 - MeOH €0.65 per kg
 - NH₃ €0.46 per kg

Langer, L., Kountouris, I., Bramstoft, R., Münster, M. and Keles, D., 2023. Renewable fuel regulation: Implications for e-fuel production infrastructure in energy hubs. *Under review in European Energy Market Conference 2023.*

Investment decisions

Units invested in



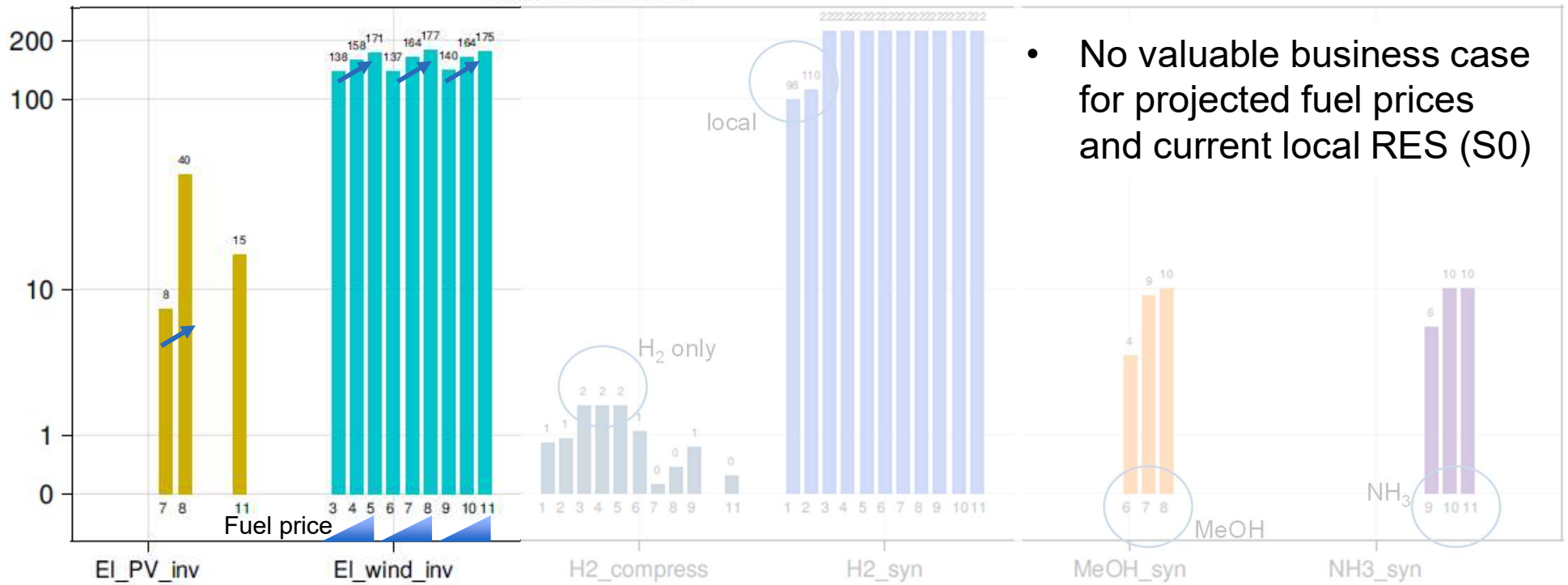
Massive additional PPA needed

H₂ seems no regret with PPA

At higher prices full capacity

Investment decisions

Units invested in



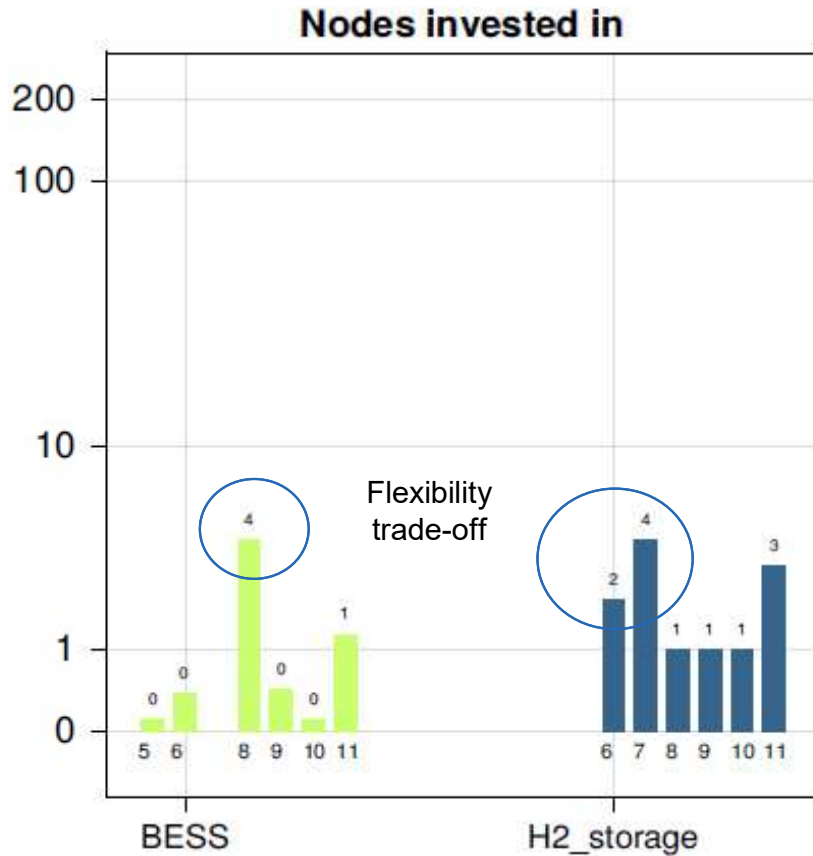
- No valuable business case for projected fuel prices and current local RES (S0)

Massive additional PPA needed

H₂ seems no regret with PPA

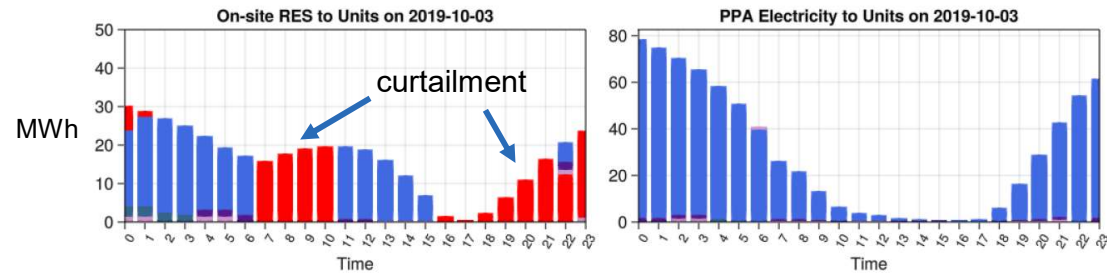
Full capacity at higher prices

Flexibility requirements



- Trade-off between batteries, H₂ storage, and overcapacity
- Higher flexibility requirements for MeOH than NH₃

- PPAs become essential
- Sharing of risks and rewards with local RES owners will drive model behavior



Operation Results, Electrolysis expansion

