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TECHNO-ECONOMIC ASSESSMENT OF WASTE HEAT RECOVERY FOR GREEN HYDROGEN PRODUCTION: A SIMULATION STUDY

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AGENDA

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- Motivation
- System Description
- Electrolyser Model
- Results
  - Seasonal Simulation Results
  - KPIs with focus on enhancement of efficiency
  - Economic Evaluation
- Conclusion

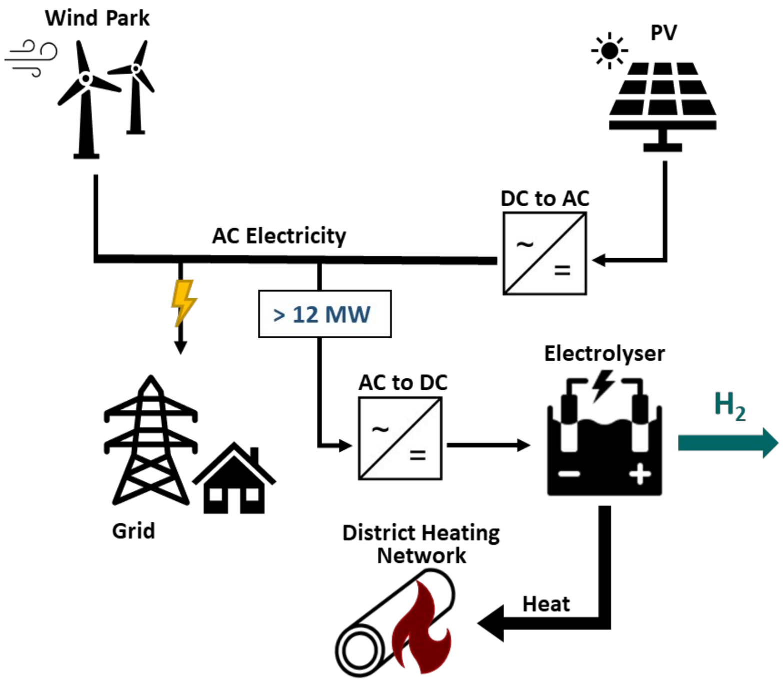
MOTIVATION

- *Hydrogen* as **future energy carrier** to balance intermittent nature of renewables
- Green Hydrogen connected to **substantial energy loss**
  - Alkaline Electrolysis Efficiency 60 – 80 %
  - Energy is lost as **heat**

> ○ What is the potential of **Waste Heat Recovery** in the Alkaline Electrolysis Process to **enhance efficiency** and **decrease *Levelized Cost of Hydrogen***?
>
> ○ Is it feasible to **supply recycled heat** to district heating systems?

SYSTEM DESCRIPTION

- RENEWABLES:
  - **Wind** Park (16.5 MW)
  - Variable **PV** capacity with DC/AC Converter
- **Grid** Supply Limit of **12 MW**
- ALKALINE ELECTROLYSER
  - AC/DC Converter
  - Heat Exchanger
  - <u>Powered by surplus electricity!</u>



ELECTROLYSER MODEL

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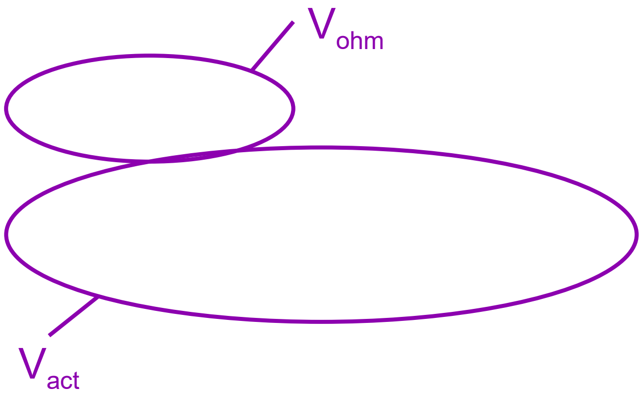
Thermodynamic Model → **Electrochemical Model** → **Thermal Model**

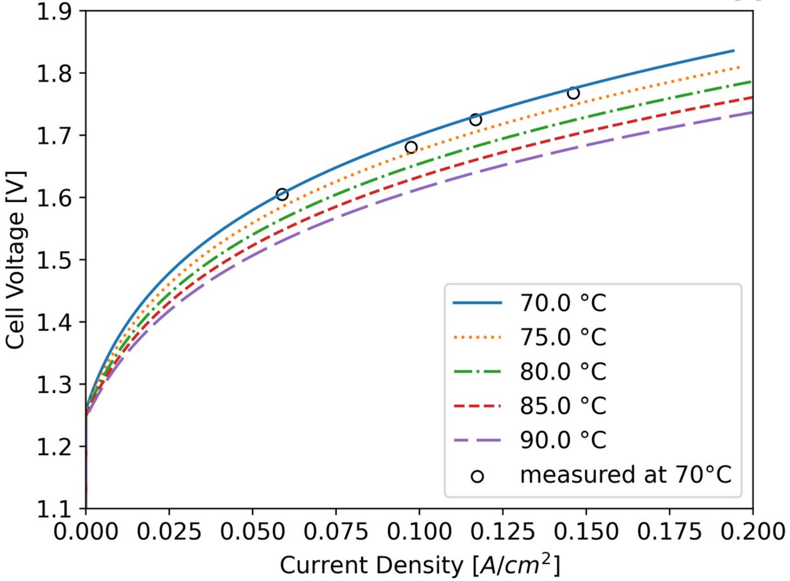
- **Thermodynamic Model**: Theoretical minimum voltage for water splitting process = **reversible Voltage**
- **Electrochemical Model**: Model for Cell Voltage, Efficiency and Hydrogen Flow Rate
- **Thermal Model**: Heat and Temperature Calculations

ELECTROCHEMICAL MODEL

- **Cell voltage** is higher than reversible voltage due to losses:

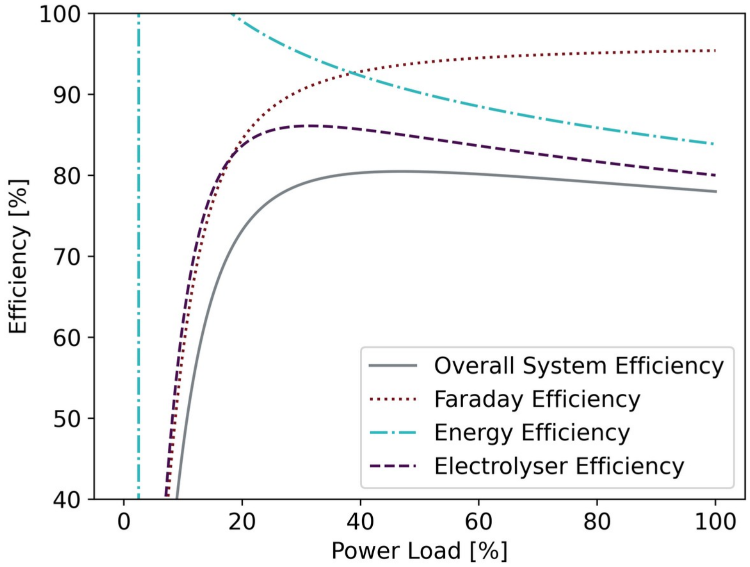


Source for measurements: [3]



ELECTROCHEMICAL MODEL

- **Faraday Efficiency**
  - parasitic current losses
  - Empirical expression
- **Energy Efficiency**
  - electrical losses
  - Ratio of thermoneutral and cell voltage
- **Hydrogen Flow Rate** using Faraday‘s law:



THERMAL MODEL

- **Lumped thermal capacitance model:**
- Heat is extracted via **cooling** – dependent on:
  - *heat transfer coefficient* of the heat exchanger
  - *cooling flow rate* – varied to influence the output temperature of the provided heat
- Temperature Calculation:
- Parameters: thermal resistance and capacity of the electrolyser stack

ELECTROLYSER MODEL

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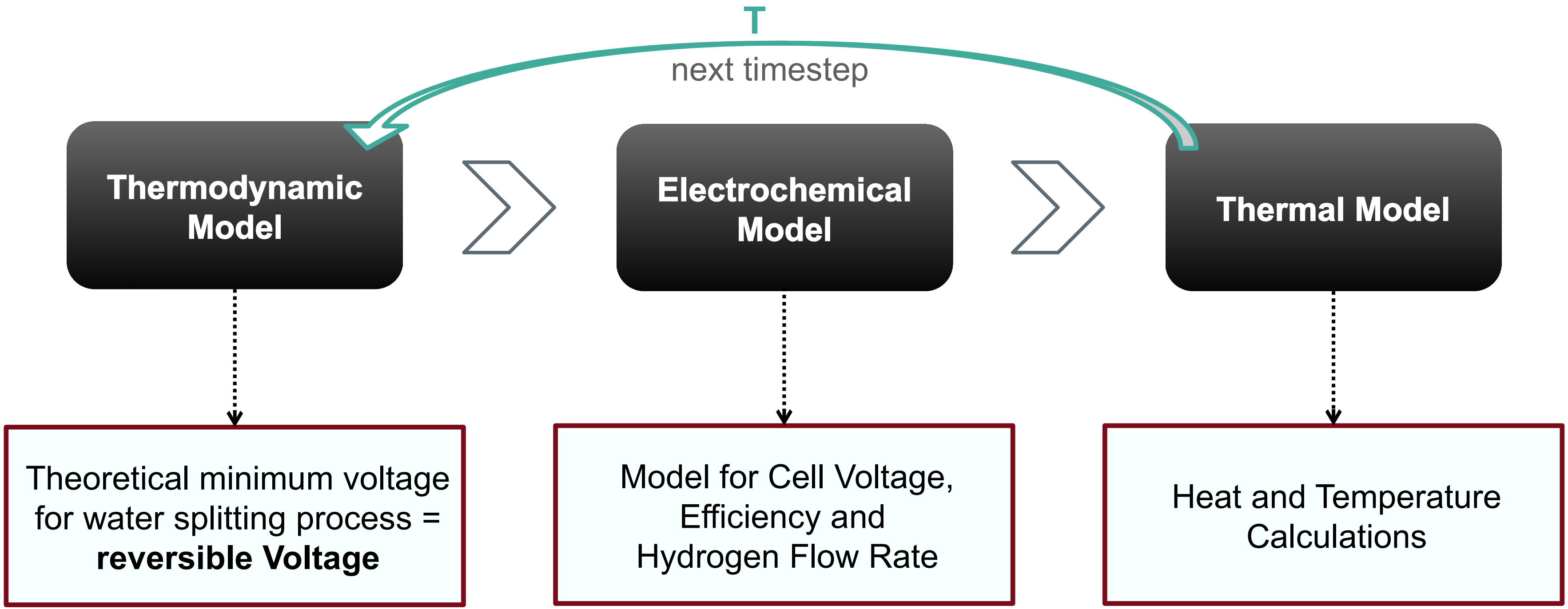

SYSTEM DESCRIPTION - *RECAP*

- RENEWABLES:
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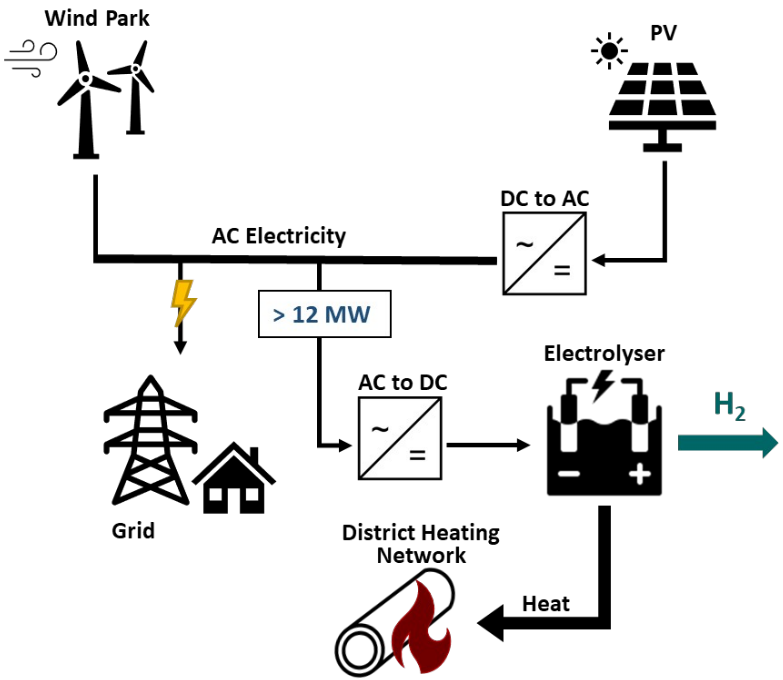

SEASONAL SIMULATION RESULTS

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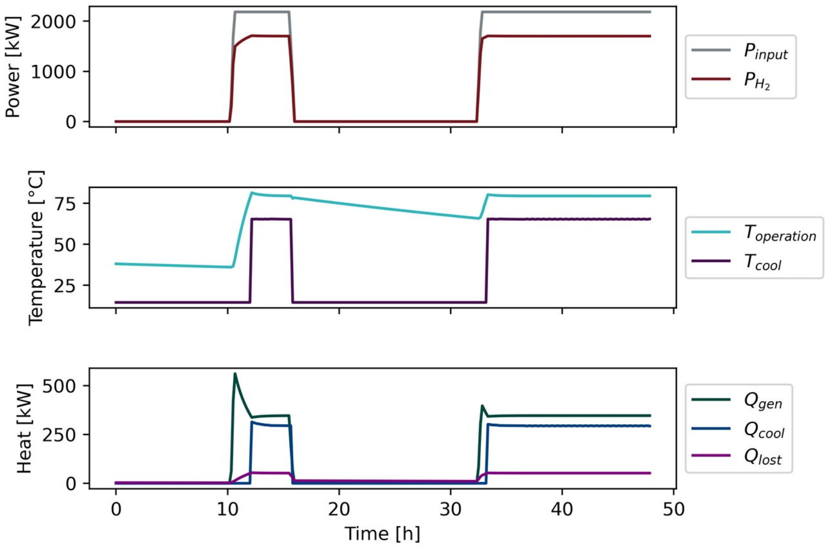
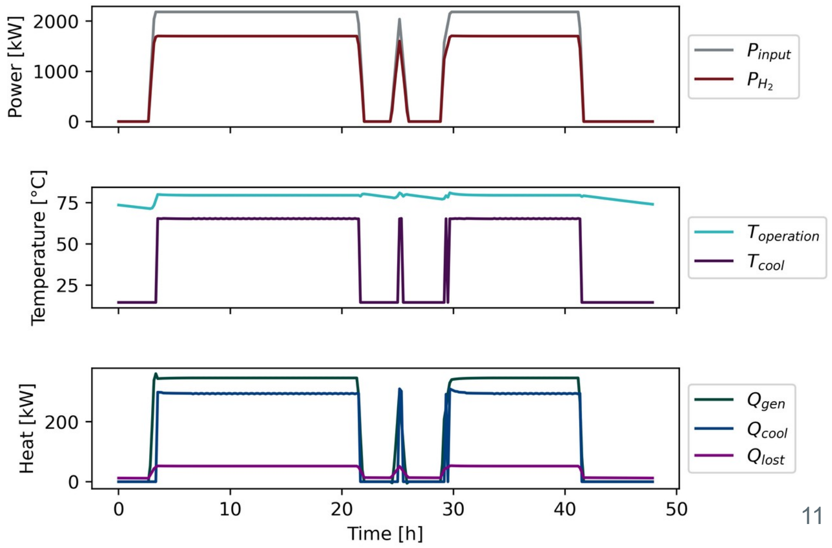
PV: 5 MW
Wind: 16.5 MW
Electrolyser: 2.13 MW

- Solar-powered electricity production leads to **lower hydrogen production in winter**
- Small **temperature variations** if power supply is not constant
- Beginning of operation phase ⇨ **peak** in heat generation ⇨ electrolyser heats up

Winter

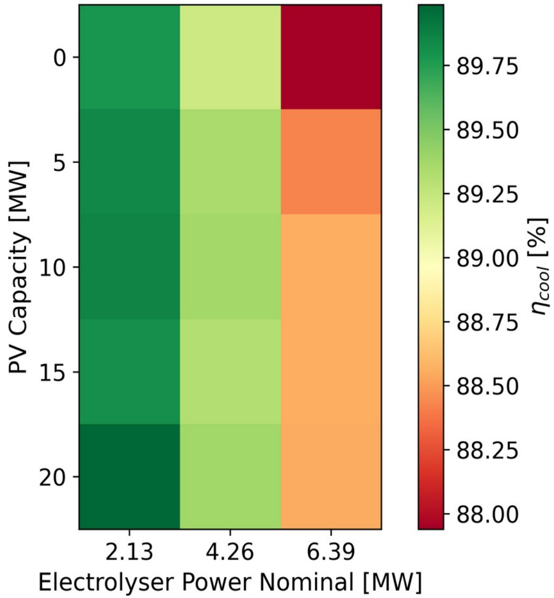


Summer

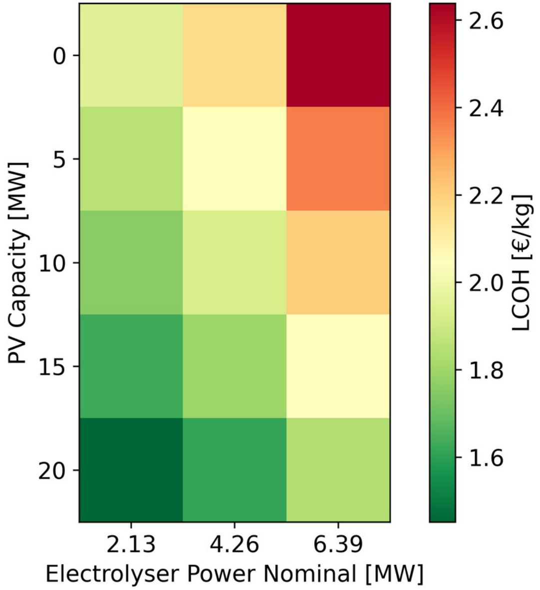


KPIs DEPENDING ON PV AND ELECTROLYSER CAPACITY

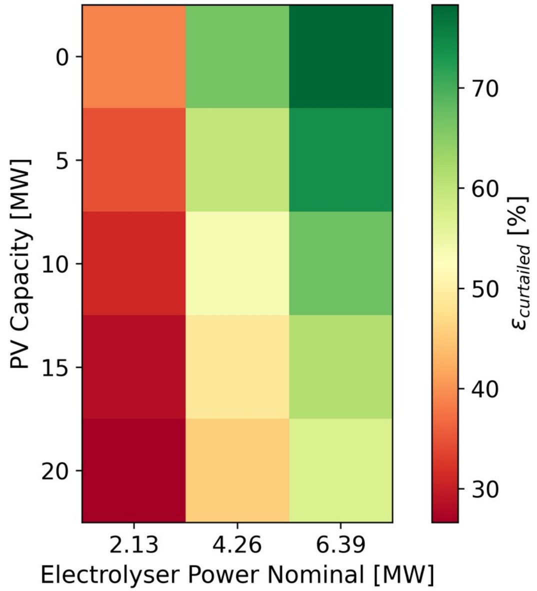
Efficiency incl. cooling



LCOH



Share of Re-Used Curtailment Energy



- Efficiency is **enhanced by roughly 12 % points** for a single electrolyser stack considering the potential of extracted heat
- **Electricity** is considered **free of charge** due to it being excess energy

HEAT SUPPLY TO DISTRICT HEATING NETWORK – IS IT VIABLE?

5 MW PV Capacity

	Electrolyser Capacity [MW]		
	2.13	**4.26**	**6.39**
η [%]	77.7	77.8	78.1
η_{DH} [%]	88.2	84.7	82.3
LCOHeat [€/MWh]	8.8	15.6	31.4

Heat Sale Scenarios

Optimistic: 40 €/MWh

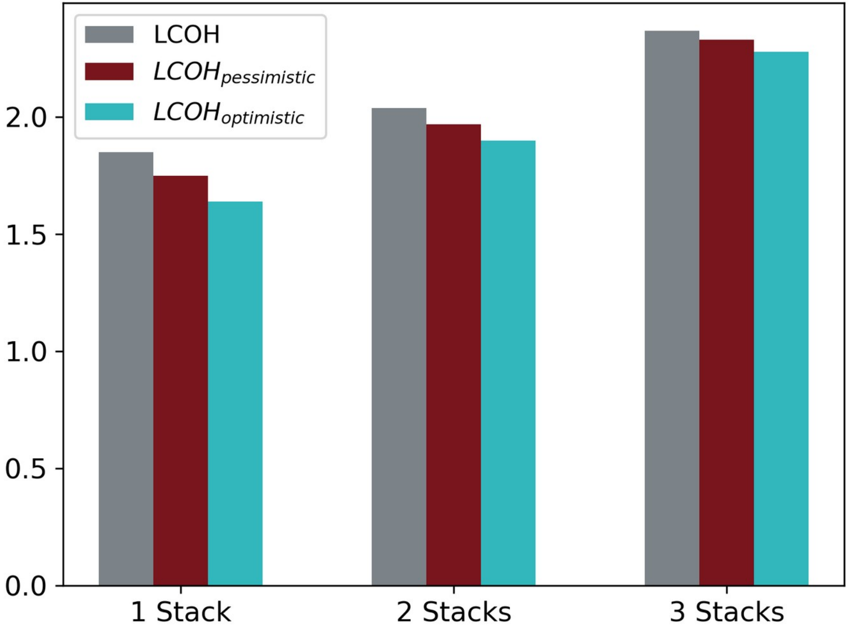
Pessimistic: 25 €/MWh

Based on: [7]

- Efficiency is **enhanced** by **over 10 % points** for a single electrolyser stack considering the **supplied heat to the DH network**
- **Selling heat is viable** for small electrolyser capacities
- **Non-feasible outcome of biggest electrolyser** is due to simplified cooling strategy

LCOH IMPROVEMENT WITH HEAT SALE

LCOH = Levelized Cost of Hydrogen



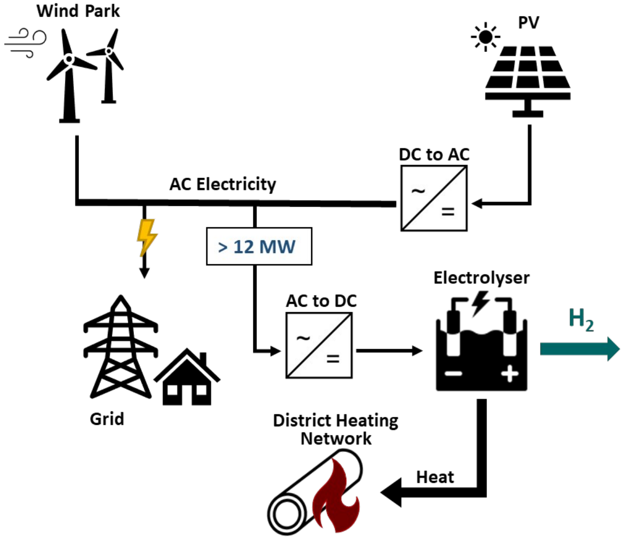
	Electrolyser Capacity [MW]		
	2.13	**4.26**	**6.39**
LCOH [€/kg]	1.9	2.0	2.4
$LCOH_{optimistic}$ [€/kg]	1.6	1.9	2.3
$LCOH_{pessimistic}$ [€/kg]	1.7	2.0	2.3

- Maximum LCOH improvement: ~ **11 %**
- Minimum, pessimistic LCOH improvement: **~ 2 %**
- Increasing electrolyser size leads to lower price reduction

CONCLUSION

An Electrolyser powered by surplus renewable energy has future potential in hydrogen and heat generation under certain conditions.

- Results motivate the implementation of a more **complex cooling strategy**
- **Heat Storage** could be benefical due to **high heat demand in winters**



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THANK YOU!

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