iPOSH

Innovative Process Design for Offshore Hydrogen

VoltaChem Open Online Conference

Joint study of H2sea, TNO and Bosch under TKI

26 June 2025

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TNO innovation for life

BOSCH

Sea the future

We plan, build and deliver
offshore hydrogen projects.

Why we exist

Our Drive

Advance Offshore Energy

Our Passion

Highly Skilled Engineering

Accurate Consultancy and Management

Initiative & Innovations

Our Supplementing Companies

H2sea®

Sea the future

We plan, build and deliver offshore hydrogen projects.

enersea®

Sea the future

We engineer, design and consult to advance offshore energy.

frequensea®

Sea the future

We locate, vibrate and remove offshore cables and pipelines.

iPOSH Project Methodology

Project Objectives:

- Optimization of offshore electrolysis plant with a focus on the “balance of stack” design
- Optimization of “stack” design and its operation
- Reduce the LCOH for offshore hydrogen by 10 % based on “model-based analysis”

Partners:

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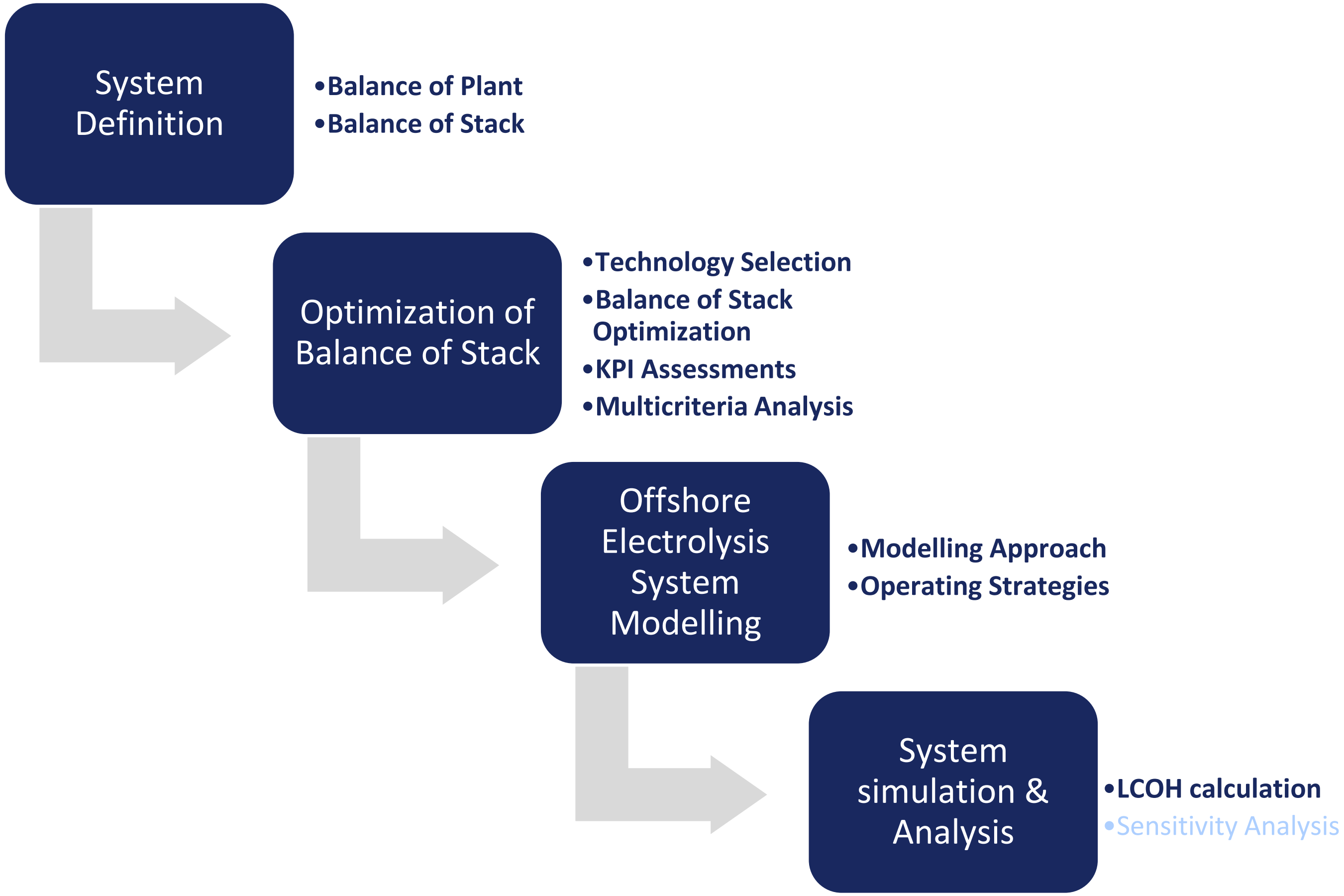
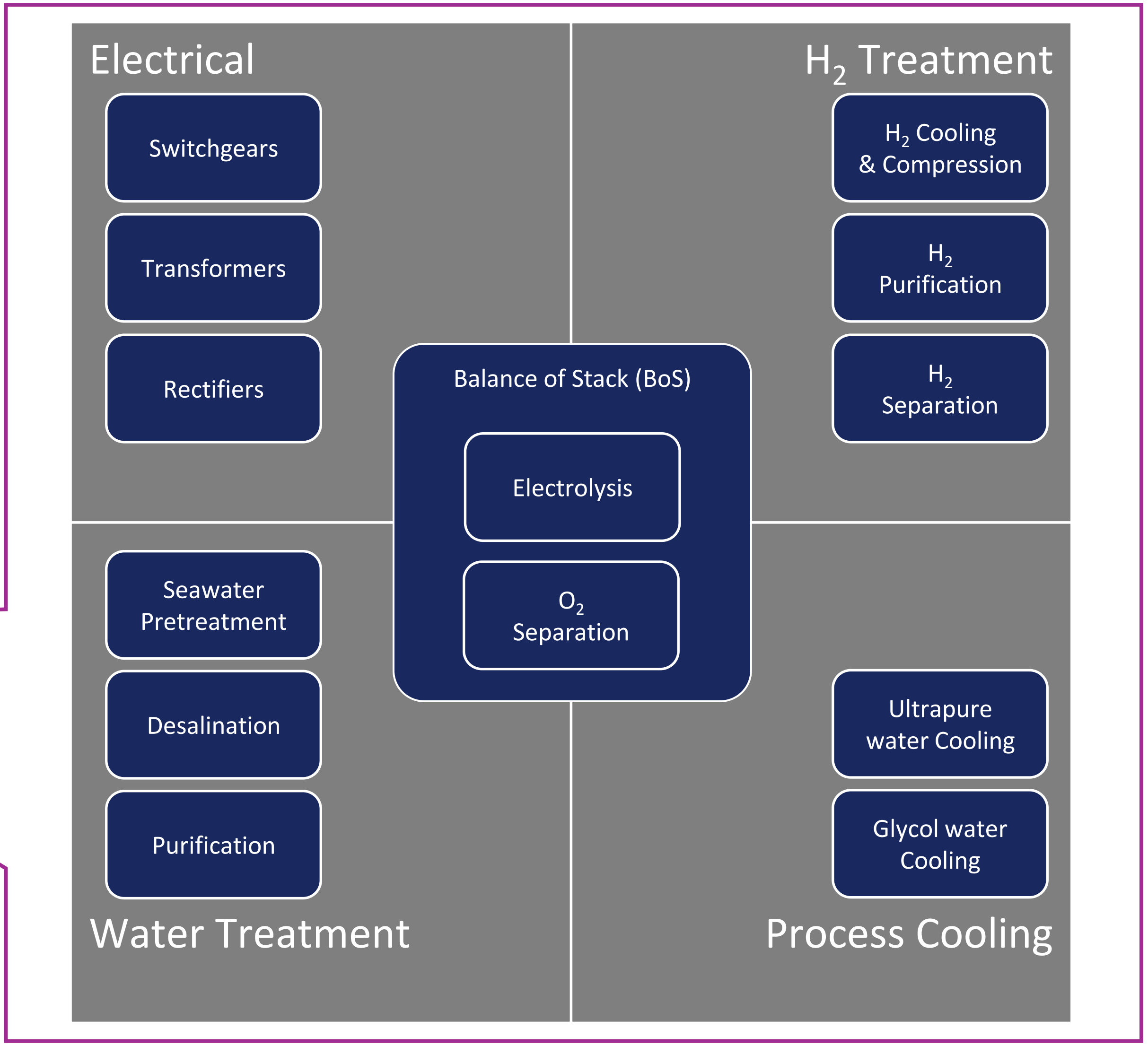
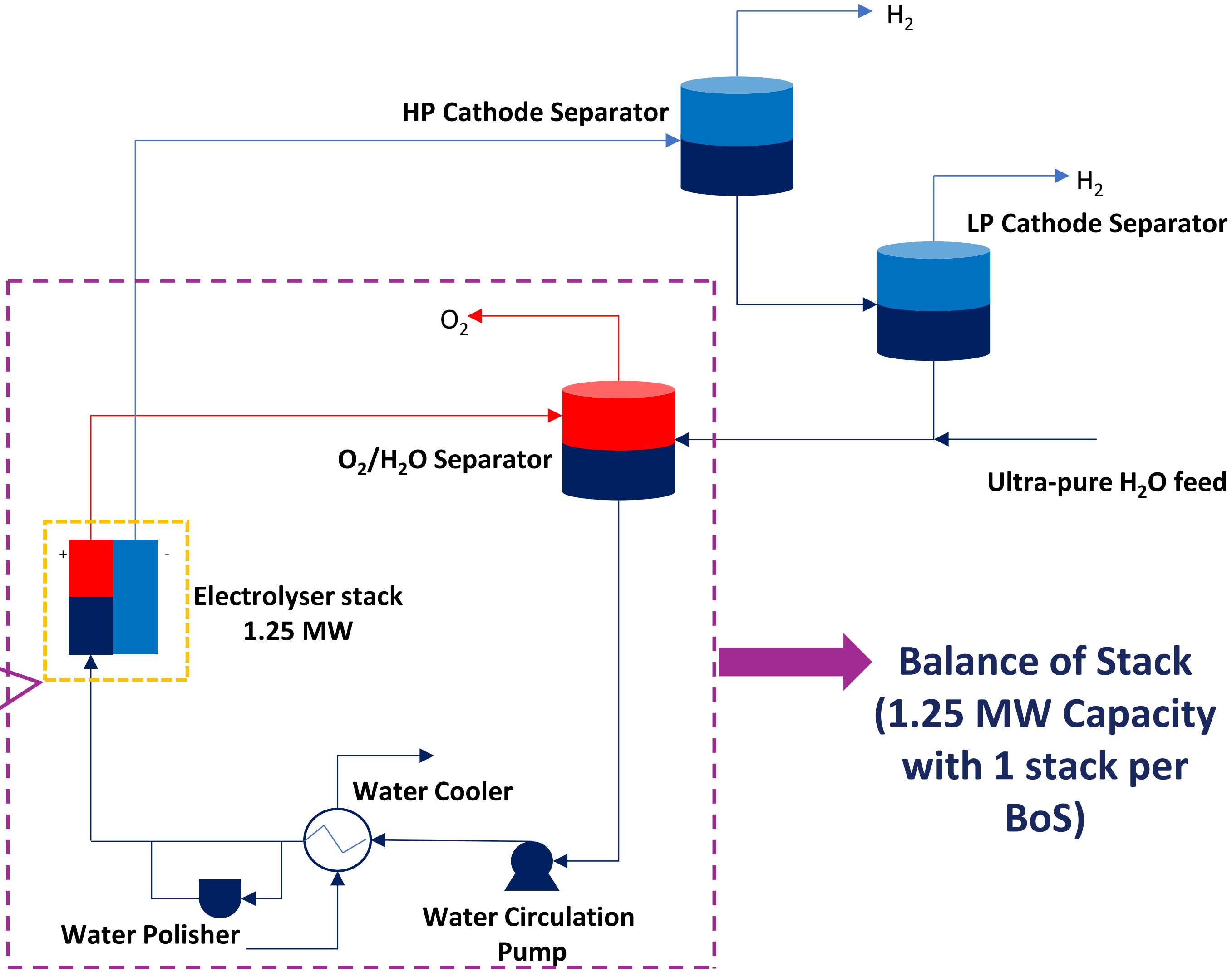


Balance of Plant (BoP)



Balance of Stack (BoS)

Ref: Bosch Transmission Technology B.V.

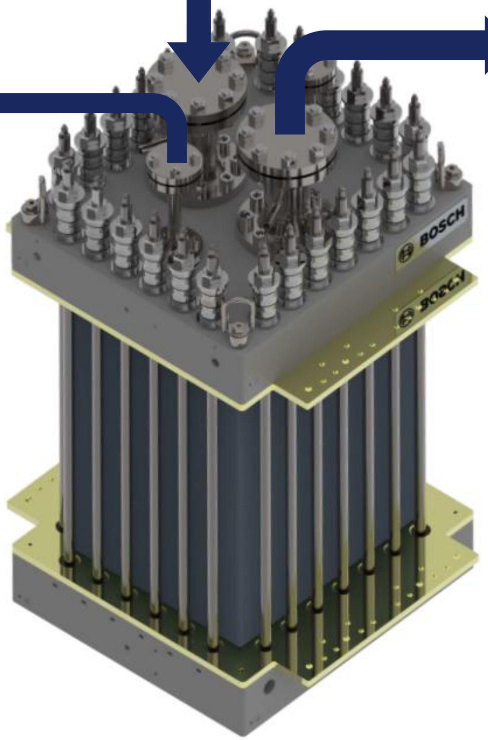


Balance of Stack (1.25 MW Capacity with 1 stack per BoS)

PEM Electrolyser stack

Anode inlet	Feed H_2O
P	2.5 barg
T	65°C
Flow (BoL)	50,000 kg/h
Flow (EoL)	96,000 kg/h

Cathode Outlet	$H_2 + H_2O$
P	Upto 40 barg
T	70°C
Flow	23 kg/h (H_2)

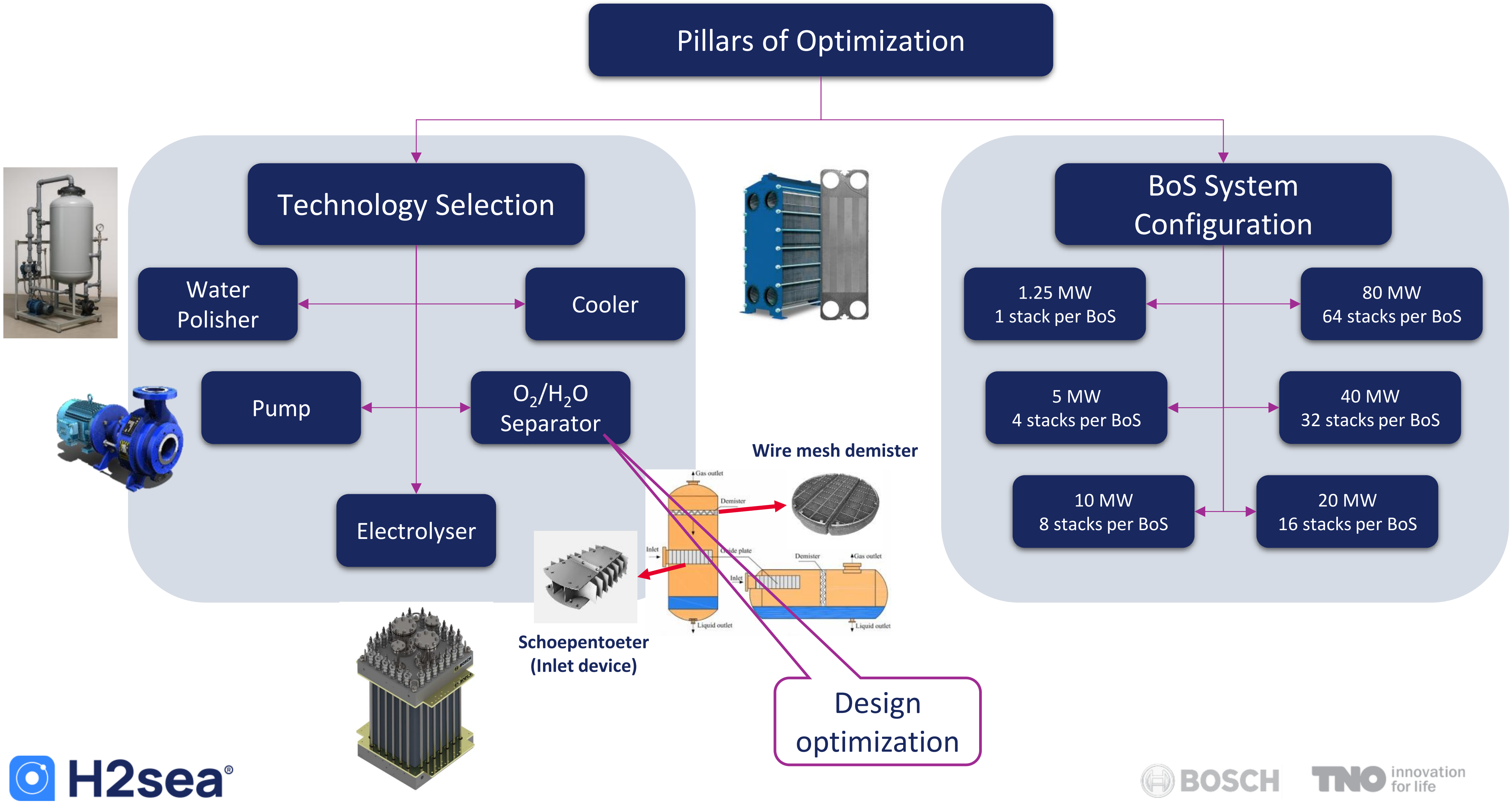


Anode Outlet	$O_2 + H_2O$
P	2.3 barg
T	70°C
Flow	182 kg/h (O_2)

Stack capacity	1.25 MW
H_2 Production flow	23 kg/h
Max. delta T (across stack)	5°C
Max. power BoL	1.25 MW
Max. power EoL	1.5 MW

Ref: Bosch Transmission Technology B.V.

Scope for Optimization

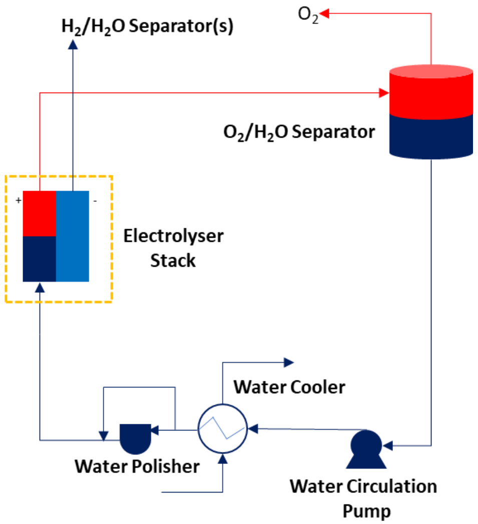


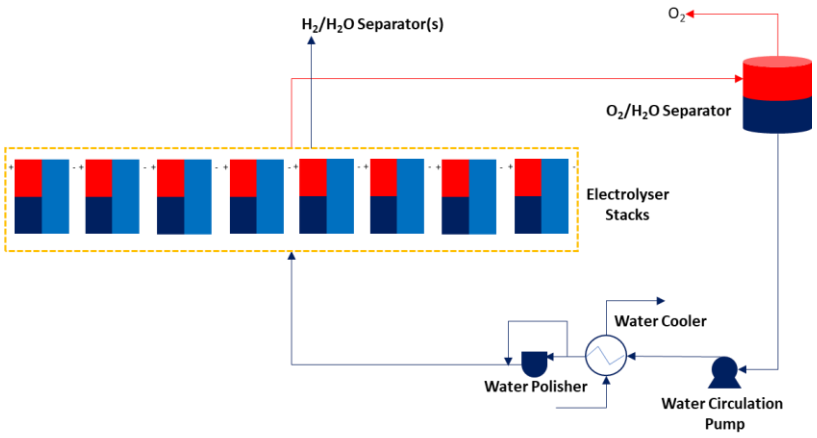
Scope for Optimization

Pillars of Optimization

1 stack per O_2/H_2O separator

8 stacks per O_2/H_2O separator





BoS Capacity = 1.25 MW
64 BoS units for 80 MW plant

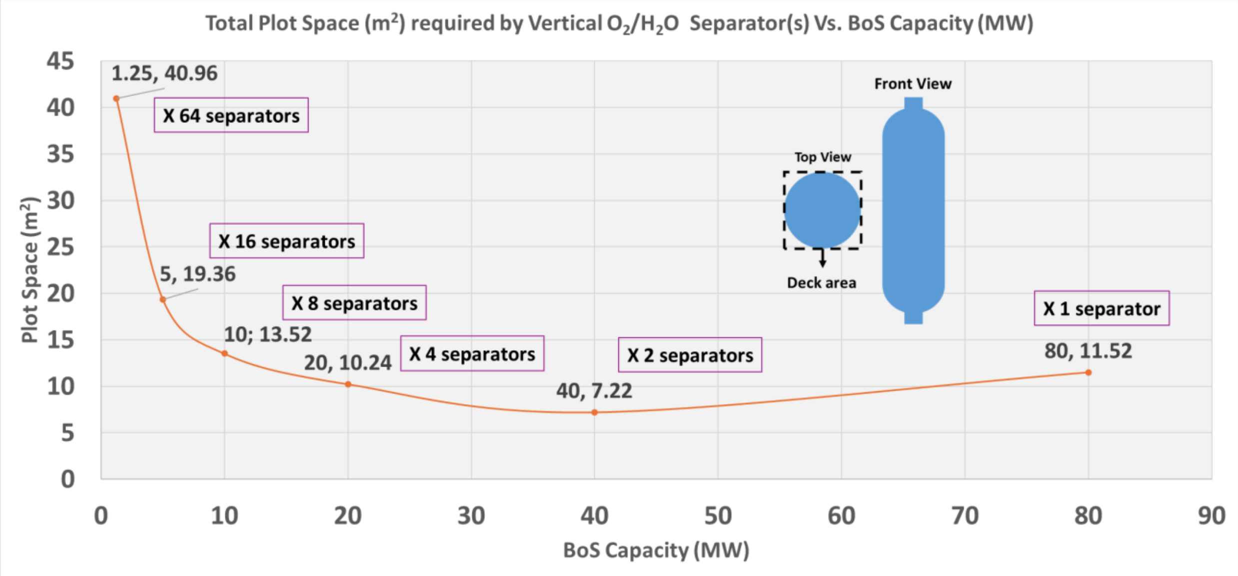
BoS Capacity = 10 MW
8 BoS units for 80 MW plant

BoS System Configuration

- 1.25 MW
  1 stack per BoS
- 80 MW
  64 stacks per BoS
- 5 MW
  4 stacks per BoS
- 40 MW
  32 stacks per BoS
- 10 MW
  8 stacks per BoS
- 20 MW
  16 stacks per BoS

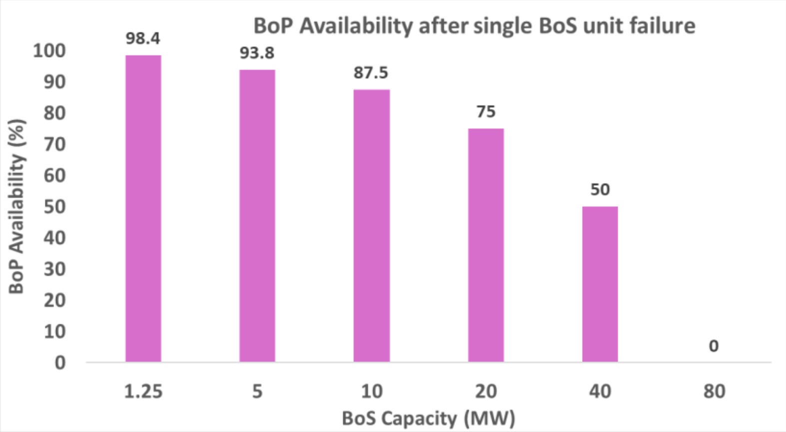
Optimization of the BoS

CAPEX



**Plot space is calculated for total number of separators in an 80 MW plant for different BoS capacities.*

Revenue



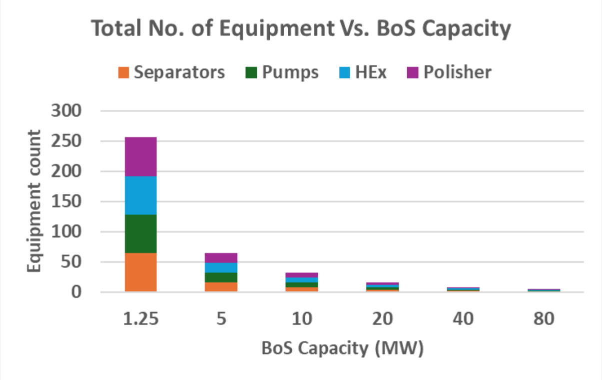
Plant (or facility) availability is calculated as follows,

$$BoP\ Availabilty\ (\%) = \frac{Planned\ runtime - Unplanned\ downtime}{Planned\ runtime}\ X\ 100$$

Where:

Planned runtime	=	Runtime when all BoS units are operational
Unplanned downtime	=	Downtime when one BoS unit fails

OPEX



- Greater the no. of equipment, higher the transport logistics costs for onshore servicing
- Maintenance frequency for equipment is expected to be the same irrespective of the size of equipment

Multicriteria Analysis (MCA)

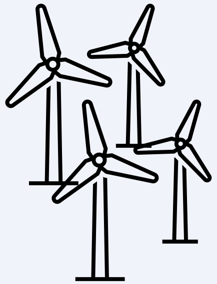
The 10 MW BoS scores the highest, followed by the 20 MW BoS. The reference design, which is the 40 MW BoS, ranks third.

Concept Ranking

				Criteria		
				1 (CAPEX)	2 (Revenue)	3 (OPEX)
Concepts		Ranking	Total score	19.5%	53.7%	26.8%
1	1 BoS per stack (1.25 MW)	4	5.84	1	10	1
2	1 BoS per 4 stacks (5 MW)	4	5.84	1	10	1
3	1 BoS per 8 stacks (10 MW)	1	6.42	4	10	1
4	1 BoS per 16 stacks (20 MW)	2	6.20	7	7	4
5	1 BoS per 32 stacks (40 MW)	3	5.97	10	4	7
6	1 BoS per 64 stacks (80 MW)	6	4.58	7	1	10

- The maximum possible score is 10.
- OPEX is considering 30 years of operation.
- Revenue represents earnings from hydrogen sales. It is assumed to cover both CAPEX & OPEX ensuring profitability.

Reference System Layout



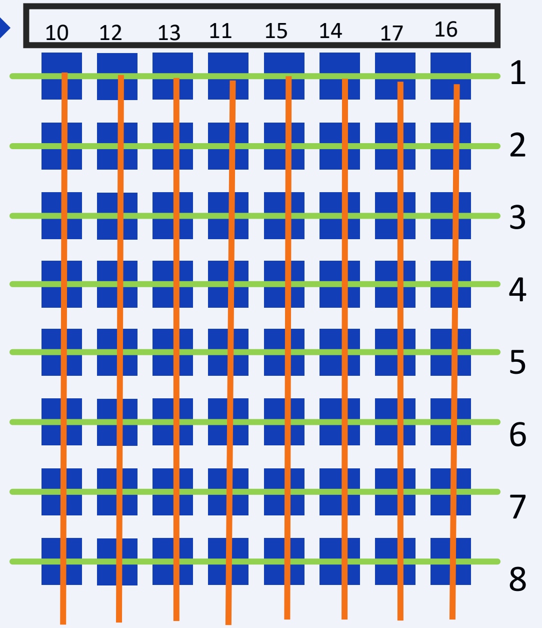
80 MW offshore wind farm

Scaled 1:1

80 MW PEM Electrolyzer system

Plant layout

These numbers here represent the water flow through each sack (in m3/h) at time "t"



Total water flow required for BoS string 1 is 108 m3/h

This water flow will be the same for all the BoS

Direction of water flow

All the stacks in this direction will have the same BoS

Direction of power supply

8x8 Electrolyzer matrix comprising 64 X 1.25MW electrolyzer stacks

Cost Grouping

Direct Cost (DC)

Total Equipment Cost (TEC)

Balance of Stack

- Electrolyzer
- Separators
- Circulation pump
- Heat Exchanger
- Water polisher

Balance of Plant

- Water treatment
- H2 treatment system
- Cooling system
- Utilities
- Electrical
- Instruments & control
- Piping

Compression

- Compressor

Platform Cost

- Platform

Dependent parameters

Indirect Cost (IC)

- Construction
- Transport & Installation
- Hook-up & Commissioning

31% of TEC

Cost for the owner

- Engineering
- Project Management
- Certification & Inspection

19% of (DC+IC)

Contingency

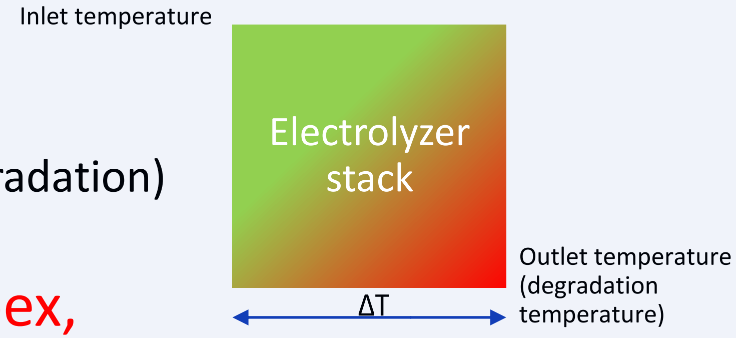
12% of (DC+IC+CoO)

Focus: Cooling requirement/load

Impact: CAPEX of Electrolyzer system (excluding stack)

Operating Strategies

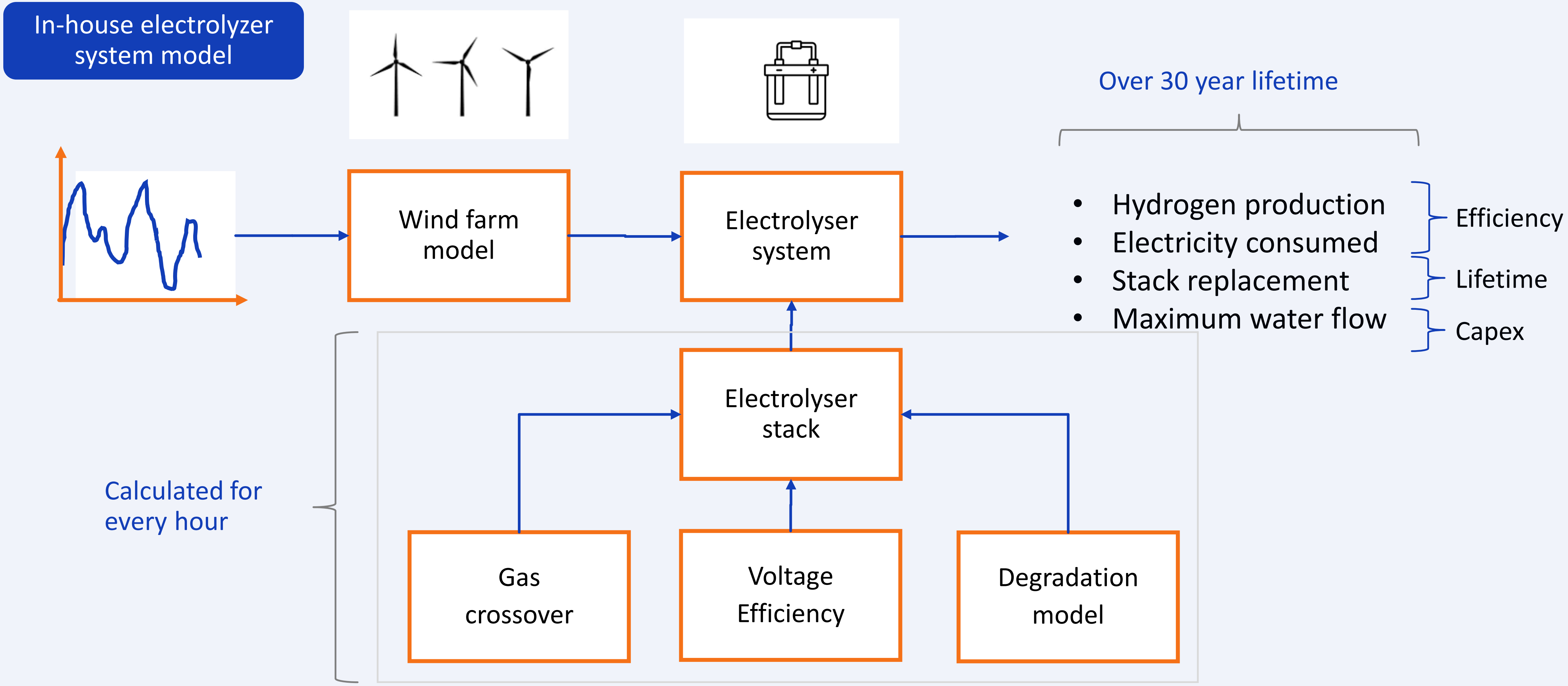
- Operating strategies in the context of this study are defined as a set of input parameters aimed at **<u>reducing the cooling requirements</u>** of the electrolyzer system.
- The various ways considered to vary the cooling load are:
    1. Varying temperature difference over the stack (ΔT)
    2. Varying operating temperature of the stack (average temperature over the stack)
    3. Varying End of life criteria over the stack
    4. Heat curtailment through smart stack replacement
    5. Varying scaling of electrolyzer capacities



Varying temperature has an impact on performance (efficiency) & lifetime (degradation)

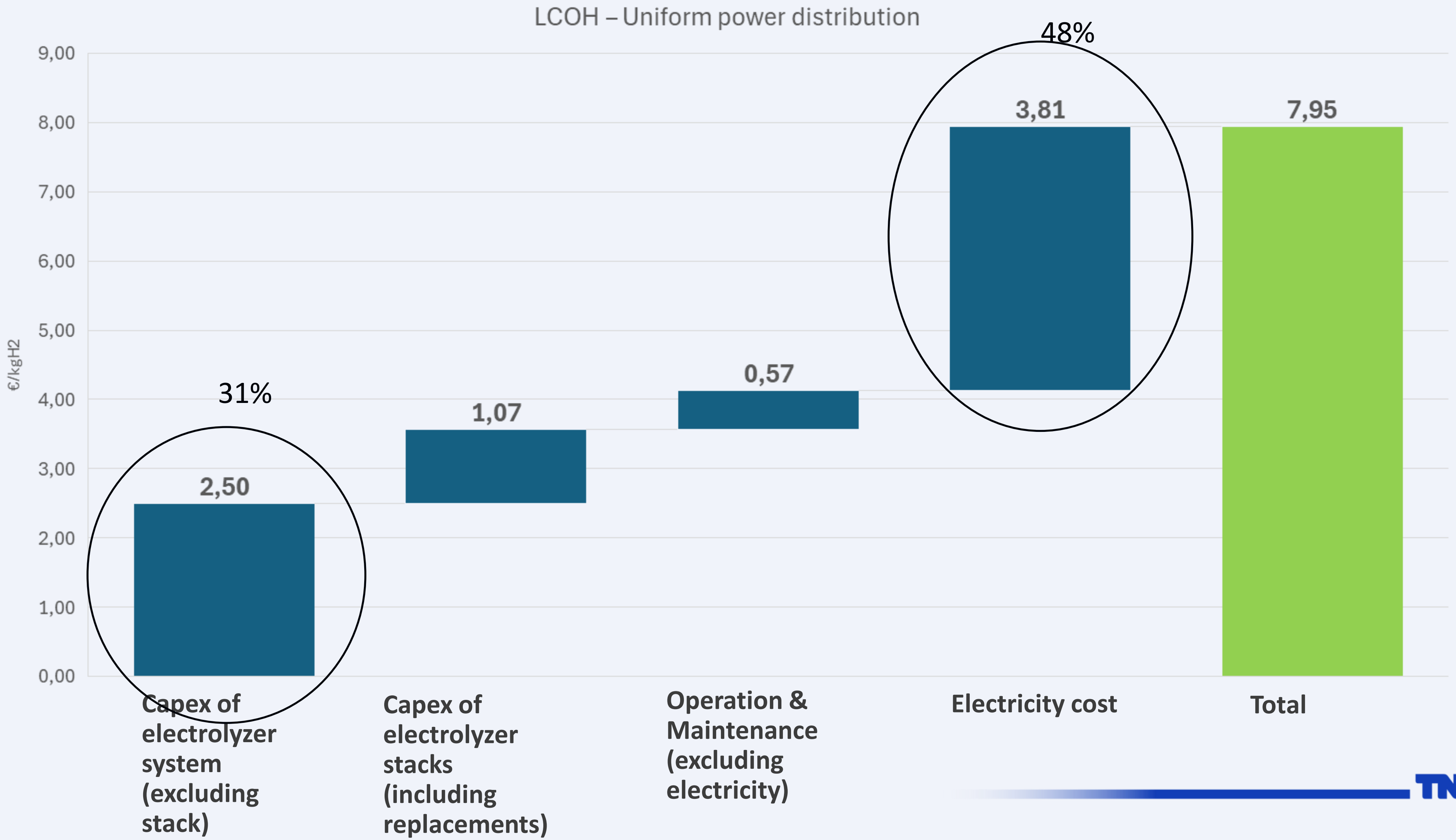
How do we study the trade-off between system Capex, performance, and lifetime?

Overall Wind-Electrolysis System Modelling

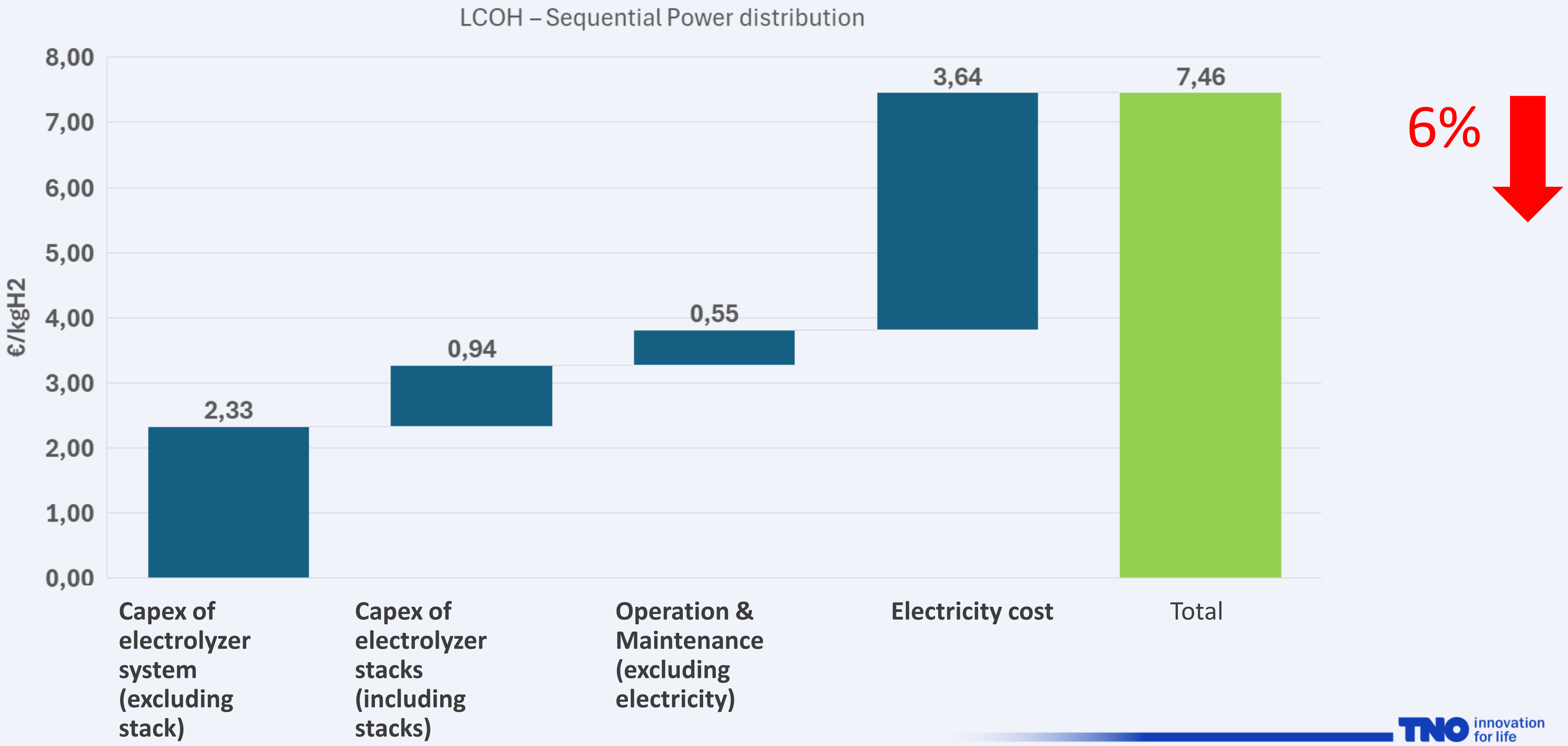


Off-shore system modelling

Base case

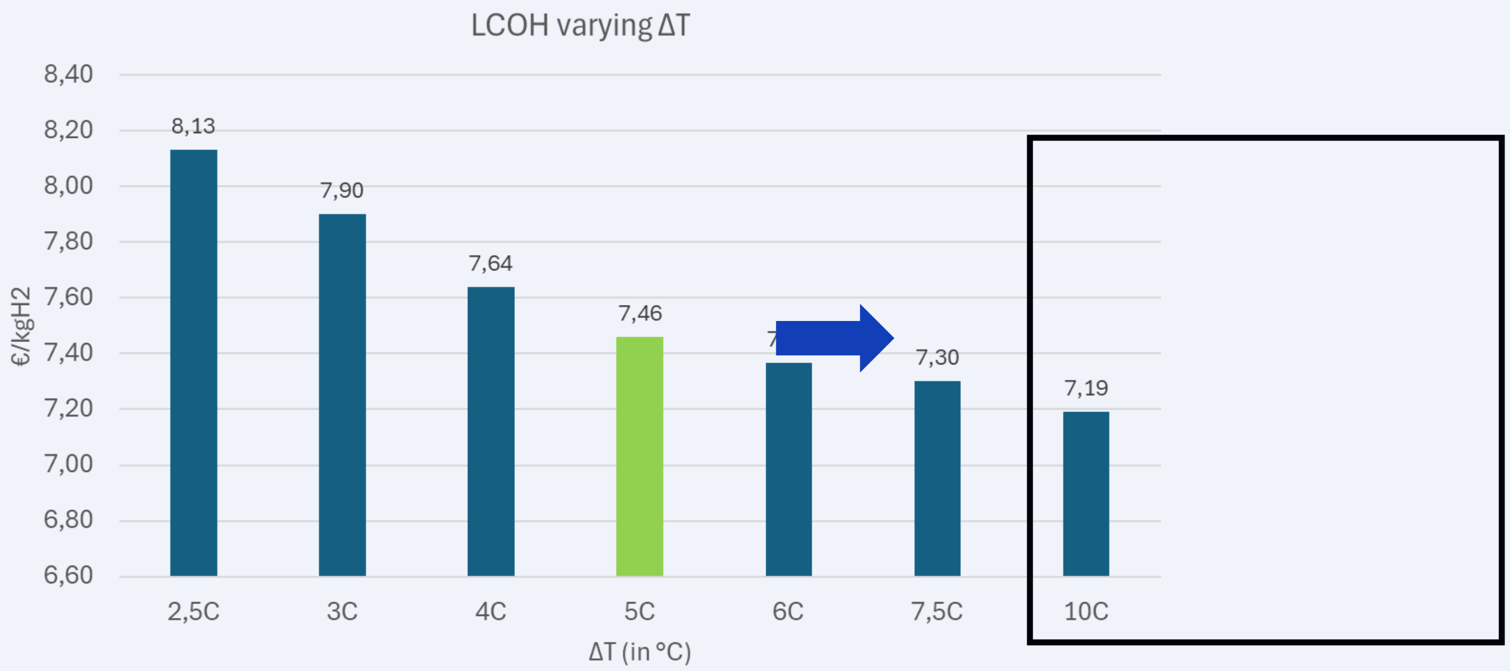


Optimizing power distribution



Varying Temperature difference over the stack

- In these simulations the operating temperature is kept constant while the inlet and outlet temperatures are varied simultaneously.



Impact: Reduced CAPEX >> Increased replacements

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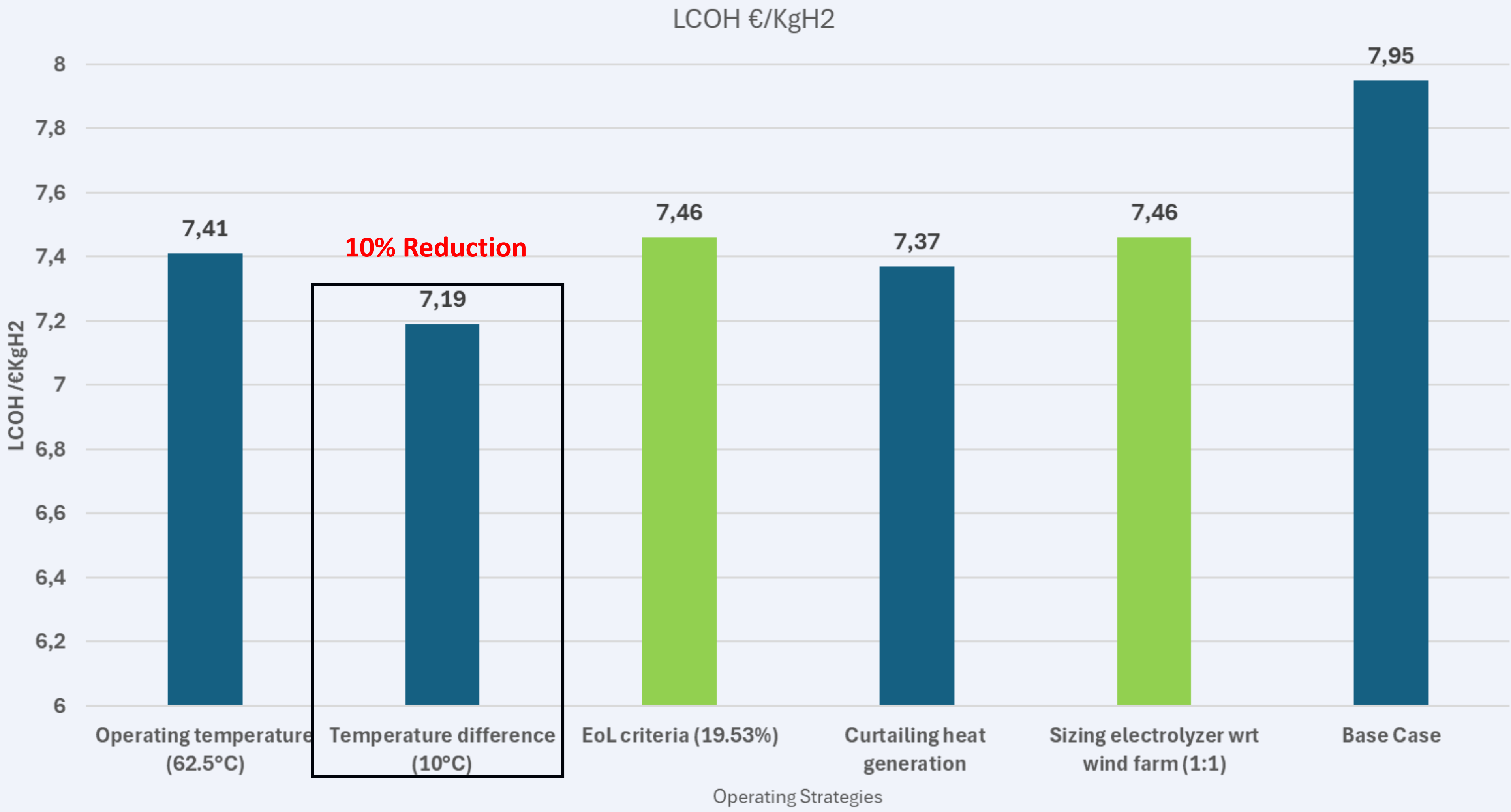
Impact of different operating strategies



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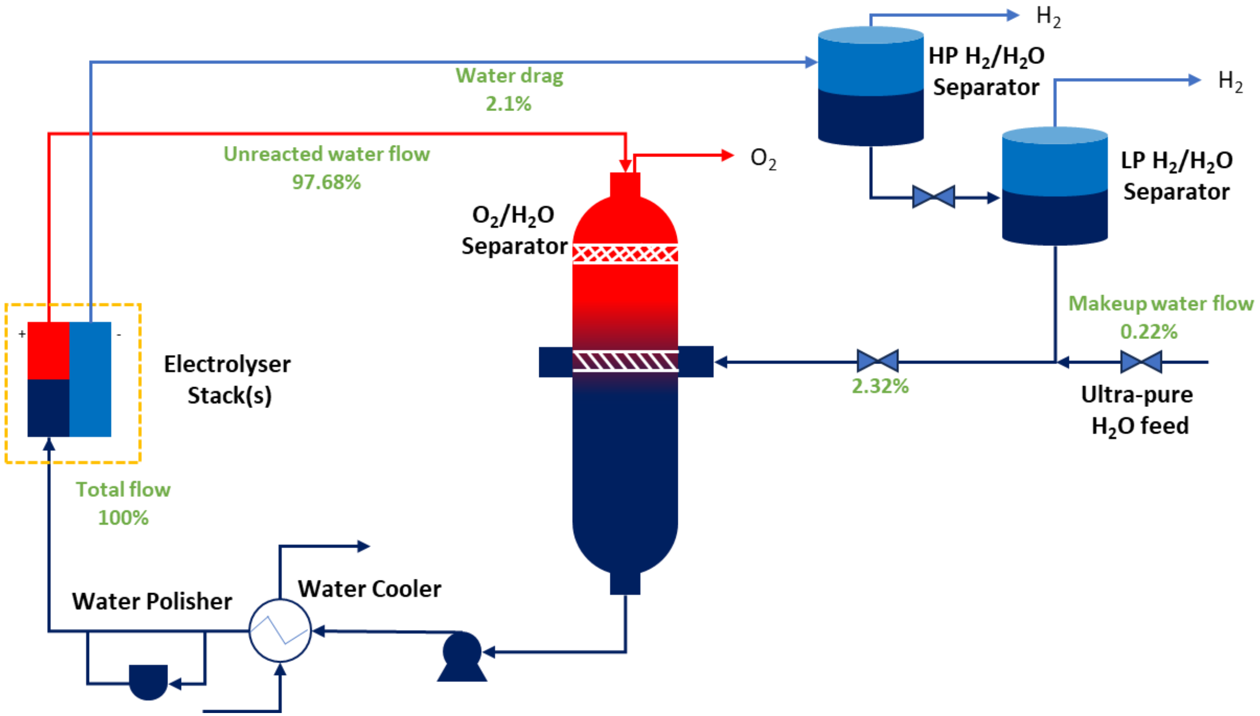
Key takeaways

- The total impact of the measures optimizing the electrolyser and stack design leads to a cost reduction of 10%.
- The change in LCOH is limited in quite a broad range when varying the EoL criteria or, for example, the operating temperature → **Flexibility in scheduling maintenance, replacement, and operational parameters**
- The design of the electrolyser stack should indeed take into account the integration with the total system to come to an optimal combination.

Optimization of O_2/H_2O Separator Design



	Standard oil & gas sizing	*H2SEA's Optimization*
Holdup Volume	100 % flow (Total flow)	**2.32 %** flow (Water drag + Makeup water flow)
Holdup Period	5 minutes	5 minutes
Diameter Reduction	→	$x\ \frac{1}{3}$
Plot Space Reduction	→	$x\ \frac{1}{6}$

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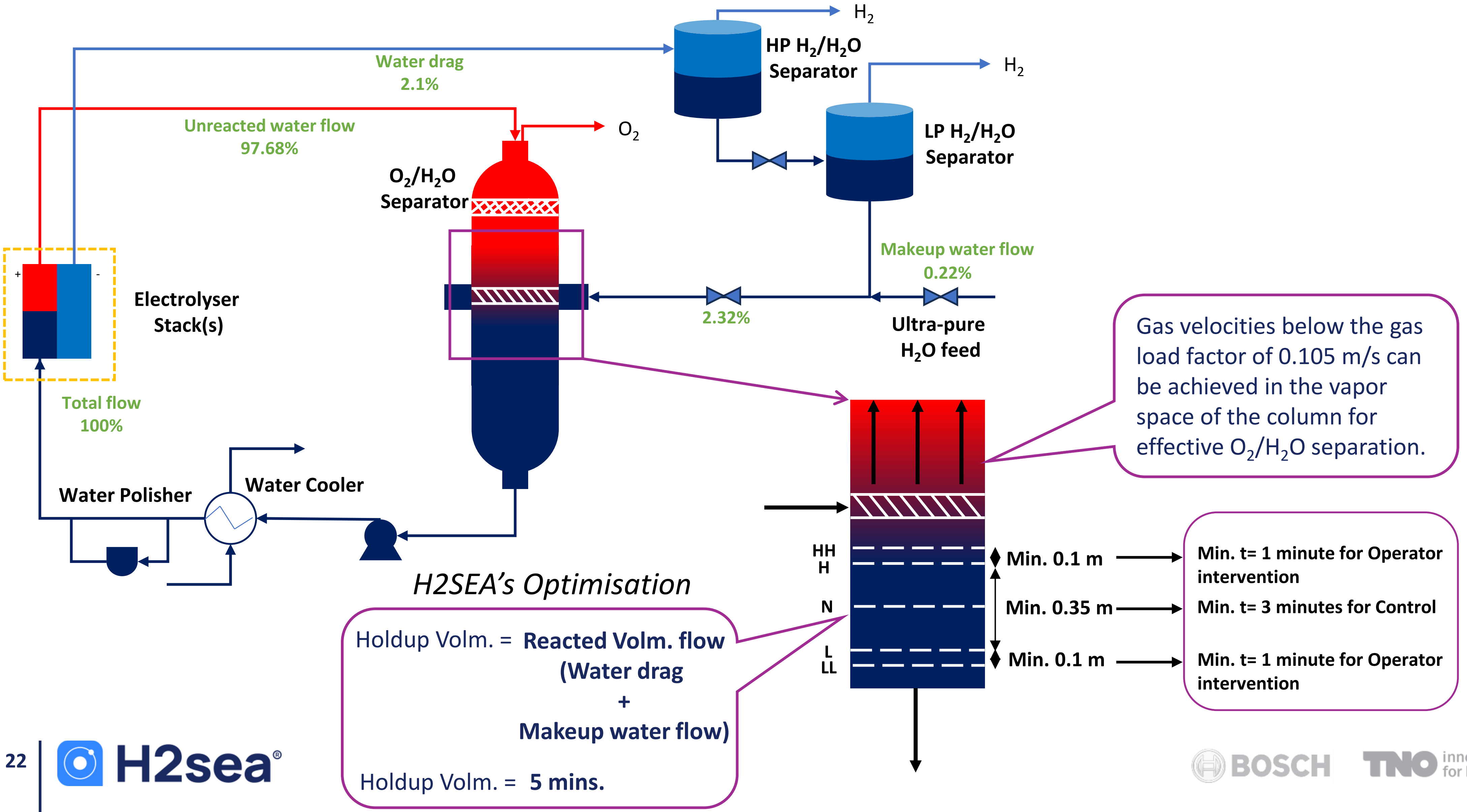
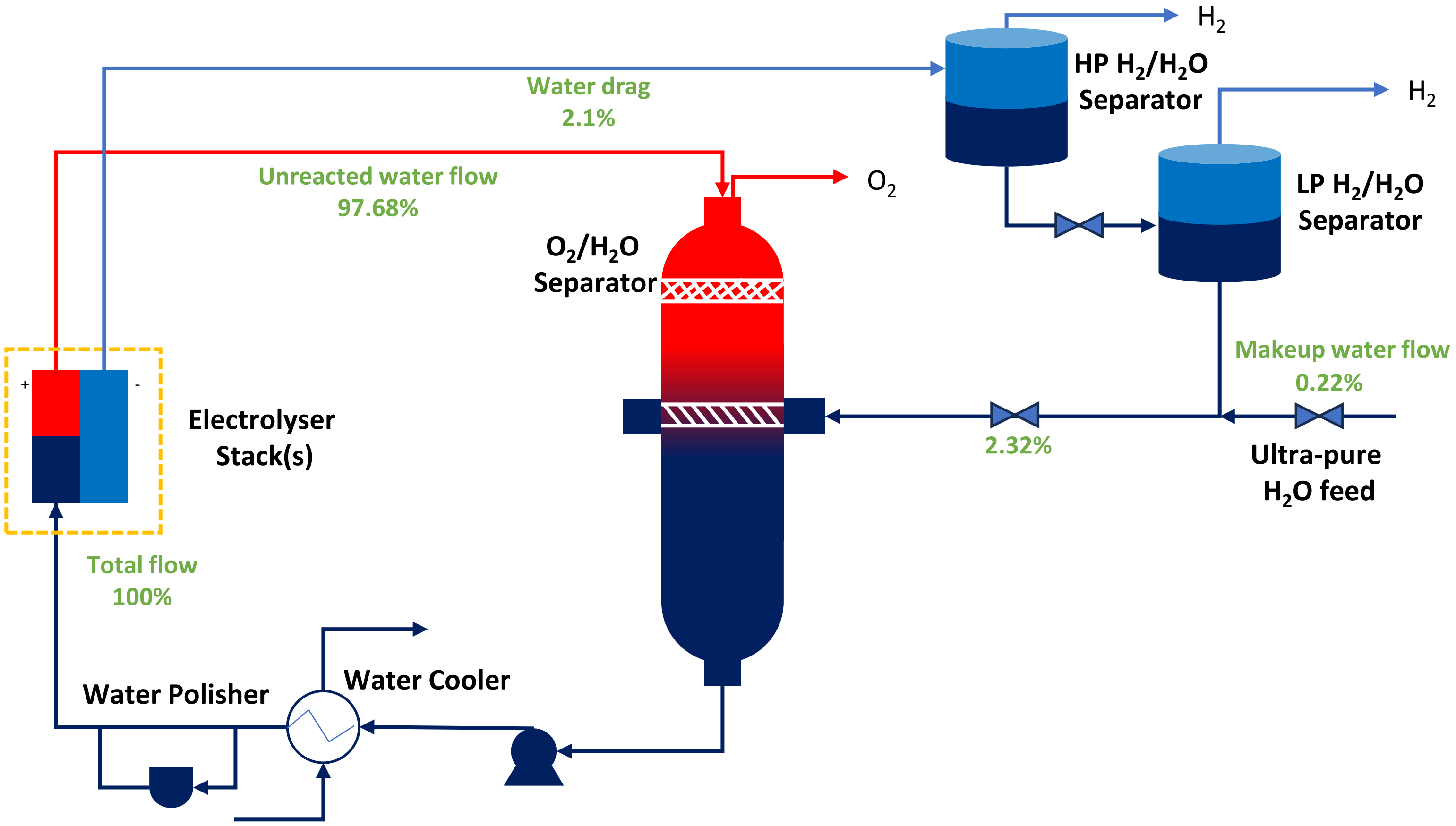
Sizing of O_2/H_2O Separator



Optimization of O_2/H_2O Separator



Cost functions

- Cost functions define how the costs of certain elements scale with cooling requirements
- Implementing the operating strategies does not only have a direct affect on the cooling system, but also on:

Components
Electrolyzers
Separators
Heat exchangers
Water polisher
Water treatment
H2 treatment system
Cooling system
Utilties
Electrical
Instruments & control
Piping
Compressor

Any change in the components (cost) will have an impact on the following dependent parameters

Dependent parameters

Indirect Cost
Cost of Owner
Continency

How do we study the trade-off between system Capex, performance, and lifetime?

Overall Wind-Electrolysis System Modelling

Over 30 year lifetime

- Hydrogen production
- Stack replacement
- Electricity consumed
- Maximum water flow

$$LCOH\ (€/kgH_2) = \frac{\left(\frac{CAPEX_{(system)} * T_1}{a1} + \frac{CAPEX_{(stacks)} * T_2}{a2}\right) + O\&M_{system} + (LCOE * Electricity\ Consumed)}{Hydrogen\ Yield}$$