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# Economic Impact Assessment of Hydrogen generated from Offshore Wind:

# A Case Study for Belgium

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# INTRODUCTION

- Green hydrogen is a great way to store energy and help decarbonize industries (transport, agriculture,…).
- Green hydrogen cost must be evaluated to ensure competitiveness and economic viability.
- This domain is recent, and flexibility must be included to adapt to future progresses.

**Objectives:**

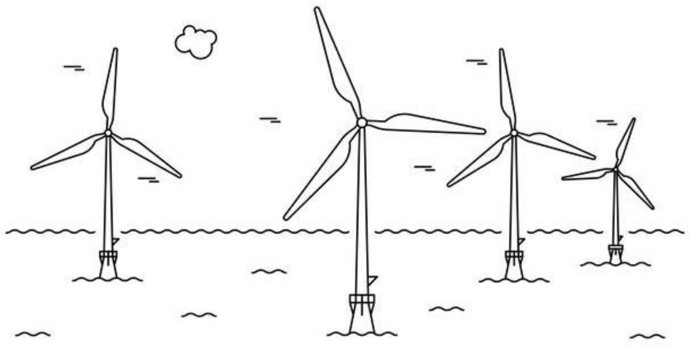
- Develop a detailed and flexible cost model for HRES
- Use this cost model on a selected case study

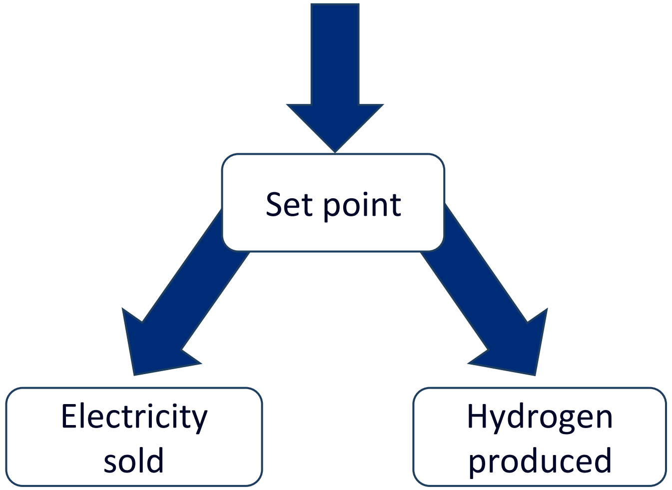
# MAIN ASSUMPTIONS

## Hybrid Renewable Energy System

- The wind farm foundations are **bottom-fixed**.
- Hydrogen production plant is **onshore**.
- The quantity of electricity sent to the hydrogen plant is **modifiable** (based on a set point).
- The electrolyser response is supposed to be **instantaneous**.
- A stack efficiency **degradation** is modelled.

## HRES Principle





# COST MODEL

## CAPEX Module

**Offshore Wind Farm:**

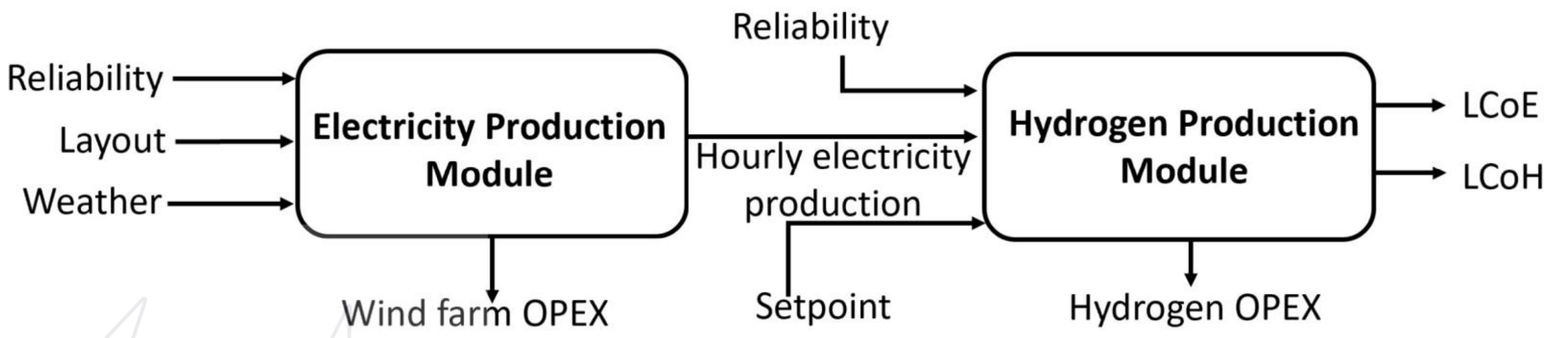
- Balance of Plant cost
- Turbine cost
- Installation Cost

**Hydrogen production plant:**

- Balance of Plant cost
- Electrolyser cost
- Installation Cost

## OPEX and Revenue Module

A schedule-based model simulating every hour of the system's operational lifetime:



# STUDY CASE

## Mermaid wind farm

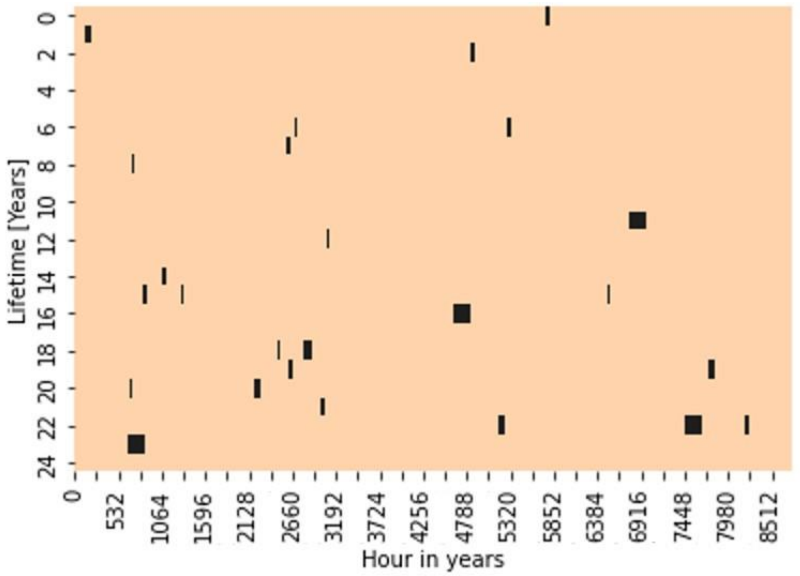
| | |
|---|---|
| Country | Belgium |
| Developer | Otary |
| Number of turbines | 28 |
| Capacity | 235MW |
| Hub Height | 107.5m |
| Distance to hydrogen plant | 54km |


## Virtual hydrogen production plant

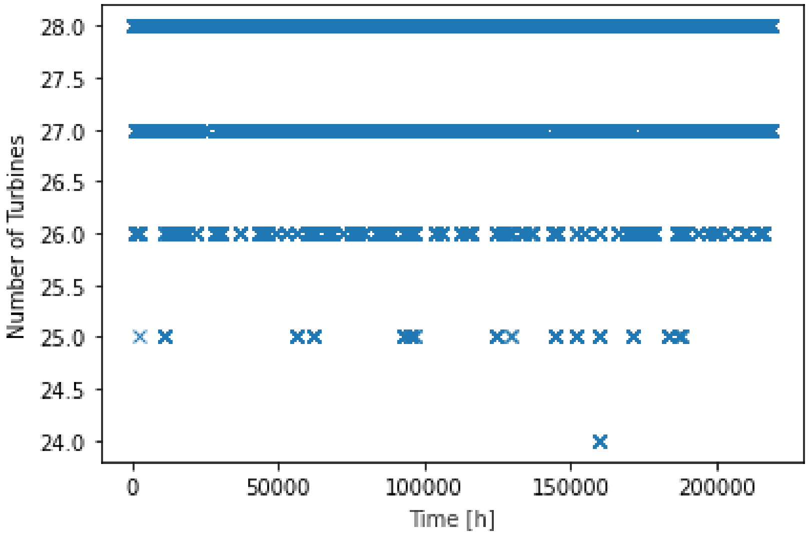
| | |
|---|---|
| Location | Zeebrugge |
| Capacity | 235MW |
| Type of electrolysis | Polymer Electrolyte Membrane |
| Lifetime | 25 years |
| Stack operational lifetime | 85,000 hours |
| Initial efficiency | 62% |
| Efficiency degradation | 0.1% every 1000 hours |

# OPEX AND REVENUE MODULE

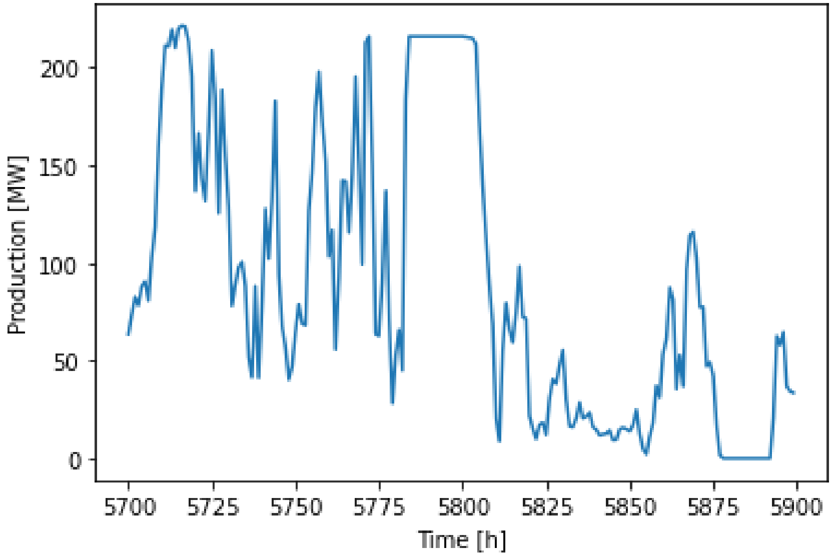
## 1-Simulate Failures




## 2-Find Wind Farm Availability



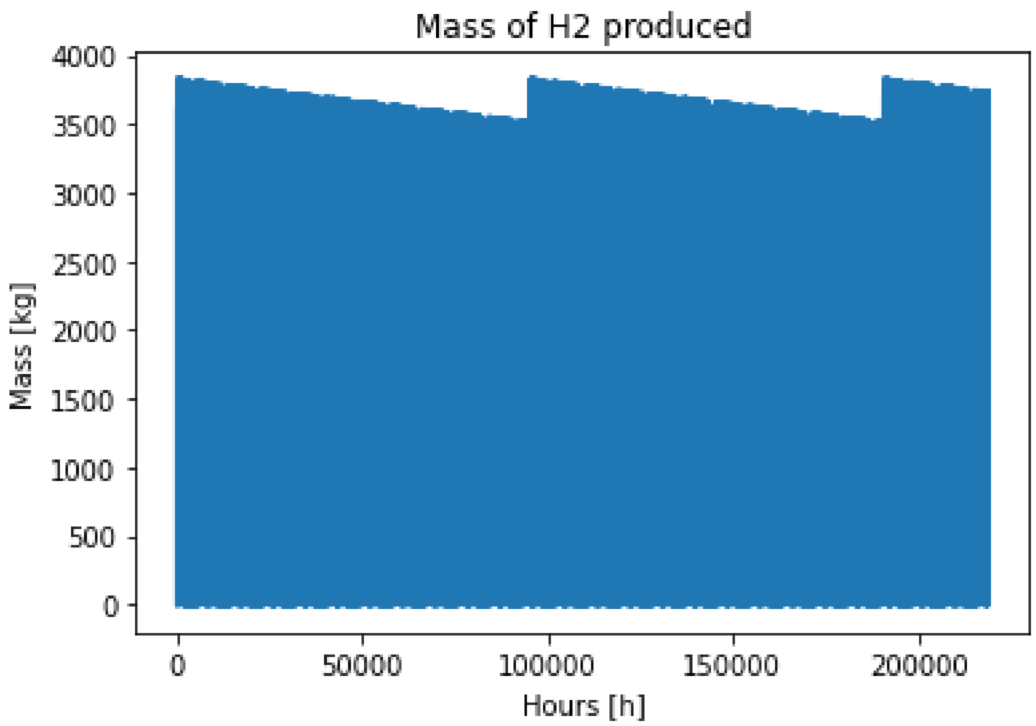

## 3-Evaluate Production




**Average hourly production**: 96.3 MWh

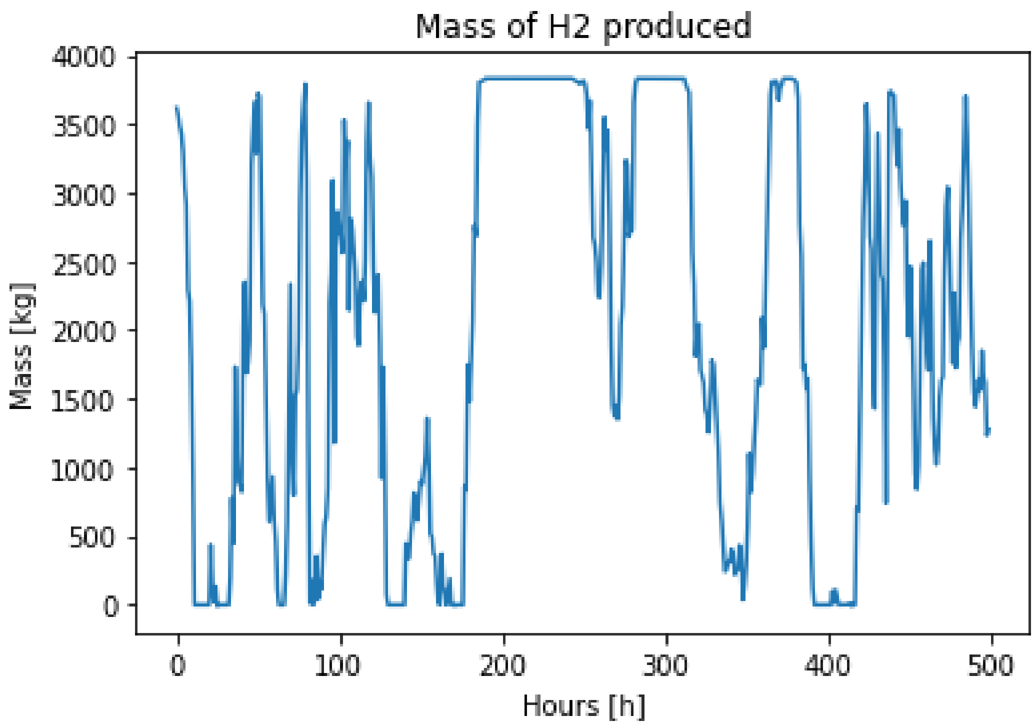
# OPEX AND REVENUE MODULE

## Hydrogen production



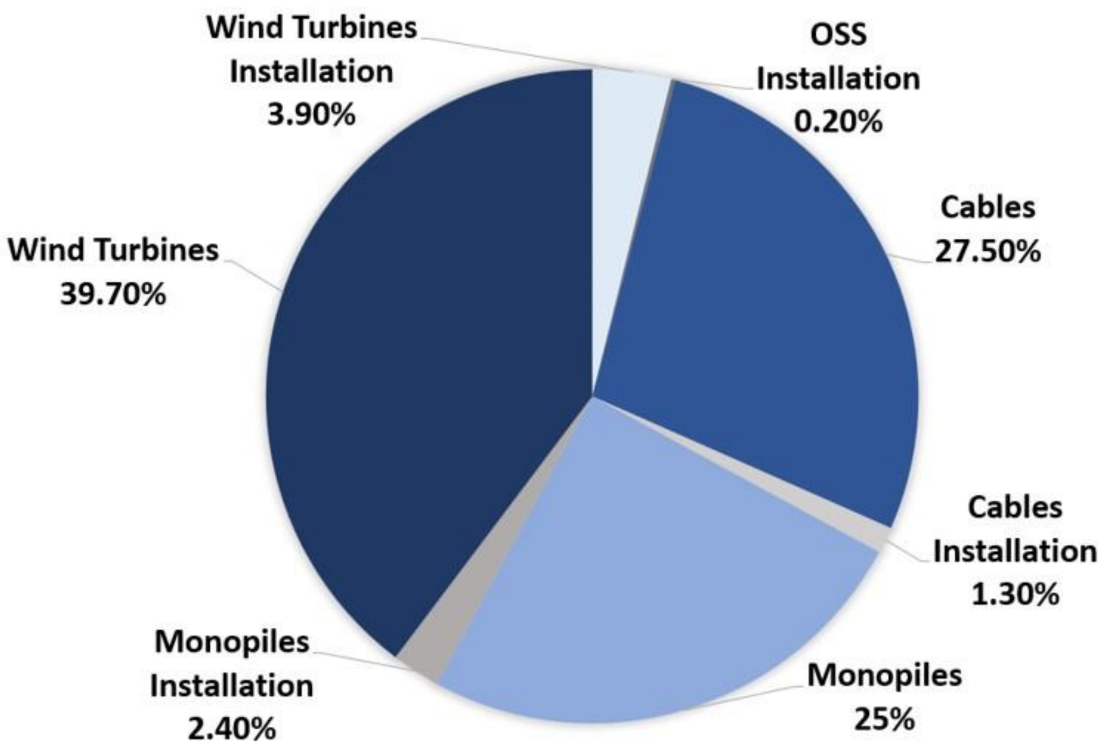

**Average hourly production**: 1555 kg

## Hydrogen production during 500 hours



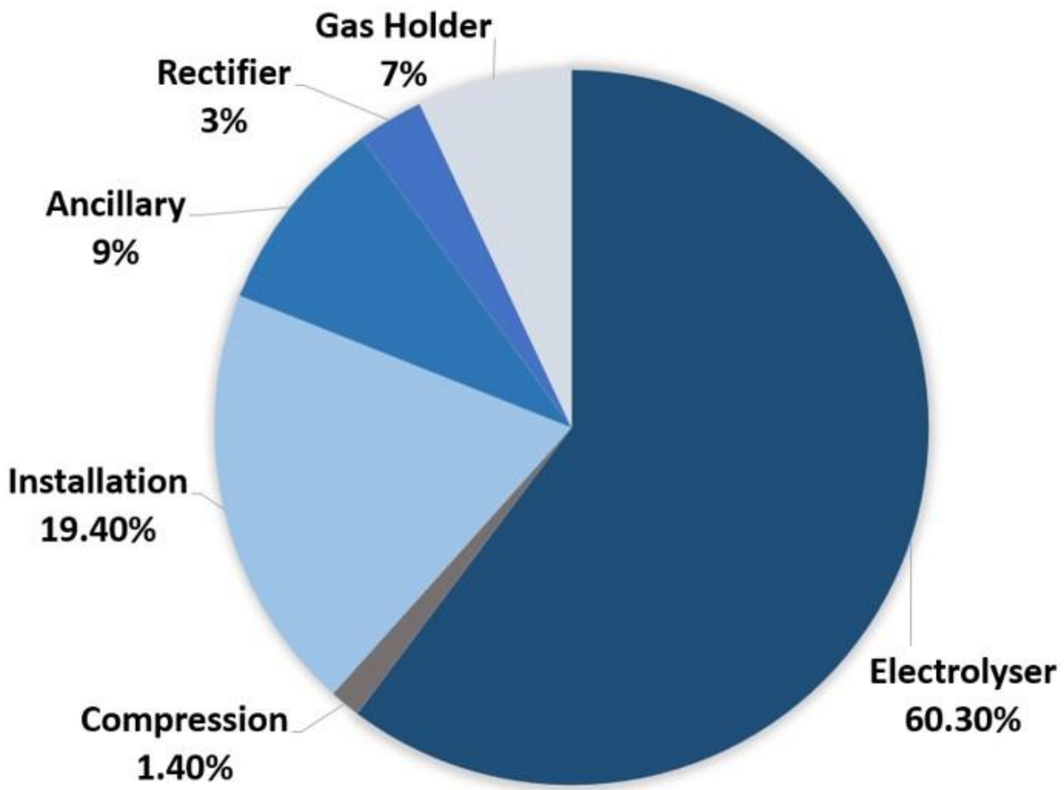
# CAPEX RESULTS

## Wind Farm CAPEX




$$CAPEX_{WF} = 627\ M€$$

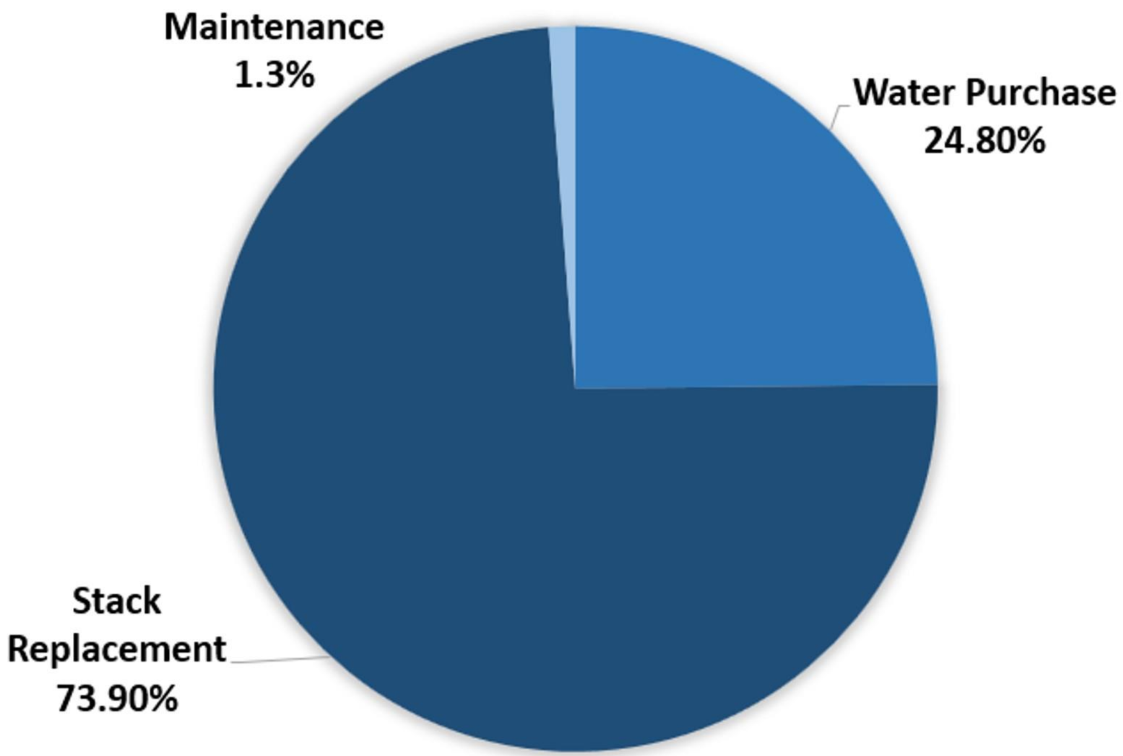
## Hydrogen Plant CAPEX




$$CAPEX_{H2} = 145.5\ M€$$

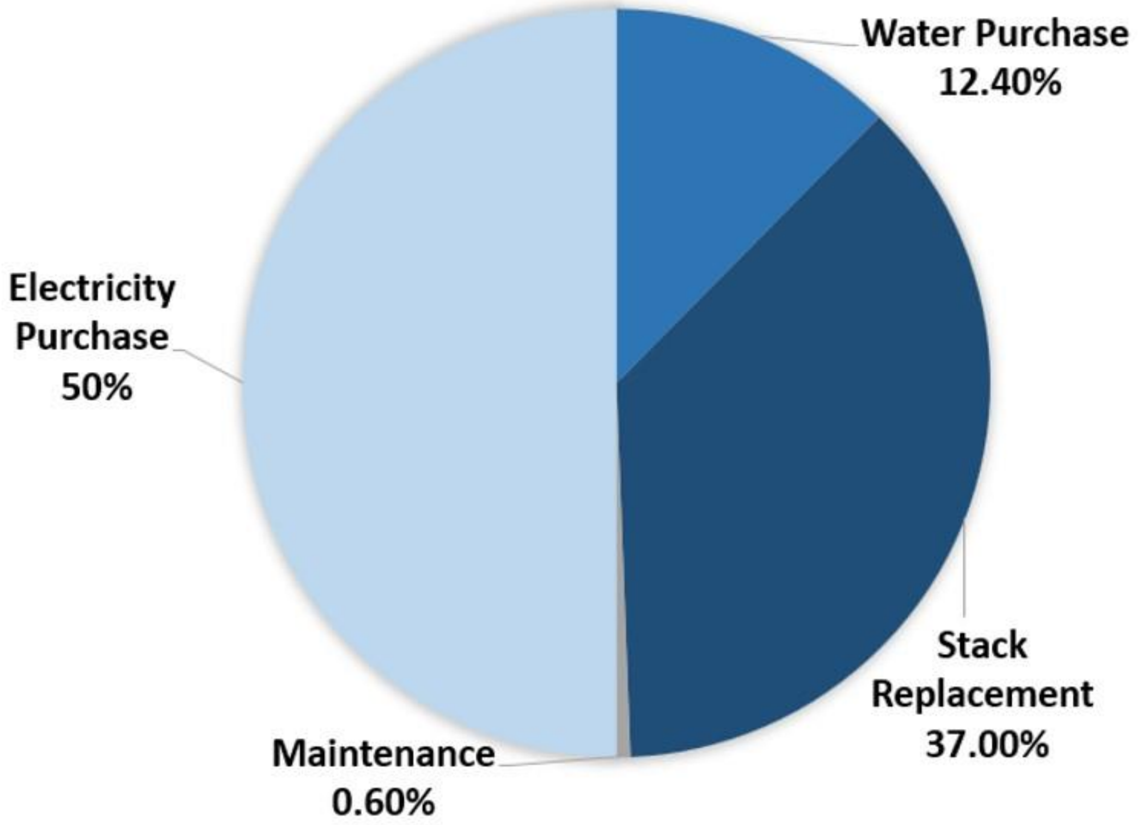
# OPEX RESULTS

### Hydrogen from offshore wind OPEX




$$OPEX_{H2} = 73.1\ M€$$

### Hydrogen from grid electricity OPEX




$$OPEX_{H2} = 146\ M€$$

# RESULTS

## LCoE and LCoH

- LCoE from Mermaid wind farm

  LCoE = 101.3 €/MWh

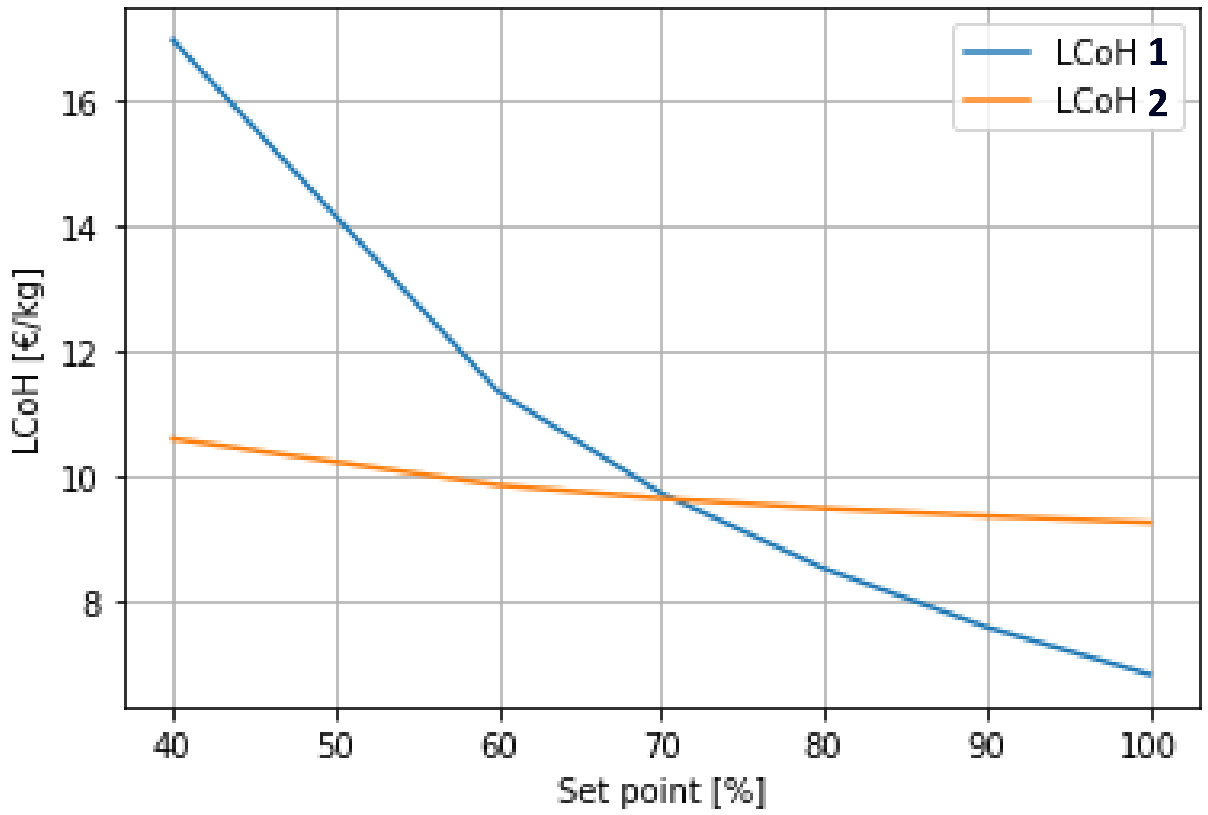
- LCoH 1 | Using wind farm electricity

  LCoH 1 = 6.76 €/kg

- LCoH 2 | Using grid electricity

  LCoH 2 = 9.26 €/kg

## Setpoint effect on LCoH




$$\textbf{Set point} = \frac{\text{Electricity sent for H2 production}}{\text{Total electricity produced}}$$

# KEY FINDINGS

- Comparing hydrogen generation strategies coupled or decoupled with an offshore wind farm is **possible**.
- The cost model is **versatile**: study case can be changed.
- LCoH is shown to be **highly dependent** on the electricity source.
- With **technological progress,** green hydrogen is expected to be competitive.

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# Thanks for listening

## Q&A

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# SENSITIVITY ANALYSIS

## Results

| Criterion | Base Case | New Scenario | Effect on LCoH1 | New LCoH1 [€/kg] |
|---|---|---|---|---|
| Basic LCoH | | | | 6.76 |
| Discount rate | 6% | 3% | -14.35% | 5.79 |
| Discount rate | 6% | 9% | +15.5% | 7.81 |
| Total CAPEX | 772.5M | 695.25M | -6.1% | 6.35 |
| Total CAPEX | 772.5M | 849.75M | +6.1% | 7.17 |
| Stack Efficiency | 62% | 52% | +19.1% | 8.05 |
| Stack Efficiency | 62% | 72% | -13.8% | 5.83 |
| Stack Degradation | 0.1%/1000h | 0.05%/1000h | -1.8% | 6.64 |
| Stack Degradation | 0.1%/1000h | 0.2%/1000h | +3.55% | 7.00 |
| Water Cost | 3.7 €/$m^3$ | 3.4 €/$m^3$ | -0.15% | 6.75 |
| Water Cost | 3.7 €/$m^3$ | 4 €/$m^3$ | +0.15% | 6.77 |
| Failure Rate H2 | Base Case | Base Case * 10 | +5.3% | 7.12 |

# CAPEX MODULE

### Turbine Cost (Romeo Project)

$$Cost_{Turbines} = ((3 * 10^6)ln(MW) - 662400) * 1.16$$

### Electrolyser Cost (Singlitico et al.)

$$Cost_{Electrolyser} = P_{elec} RC_{elec} (\frac{P_{elec}.10^3}{RP_{elec}})^{SF_{elec}}$$

# OPEX AND REVENUE MODULE LOOP

## Failure Loop