KONGSTEIN GmbH

umlaut energy GmbH

Production & Transportation Costs for Green Hydrogen from OWF to Onshore End-User

Braunschweig, June 2021

Patrick Wienert, Philipp Wiener, Thore Schreiber

Agenda

1. Introduction
2. Background
3. Objectives
4. Transportation Scenarios
5. Cost Comparison and Evaluation
6. Methodology and Assumptions

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Our Speakers

Patrick Wienert
Head of Hydrogen
@umlaut energy GmbH

Areas of Expertise:
- Power2X Concepts
- Hydrogen Eco-Systems
- Upscaling Fuel Cell & Electrolyzer Technology

Thore Schreiber
Senior Project Manager
@KONGSTEIN GmbH

Areas of Expertise:
- Commercial Management
- Offshore Projects
- Offshore Logistics
- Marine Operations

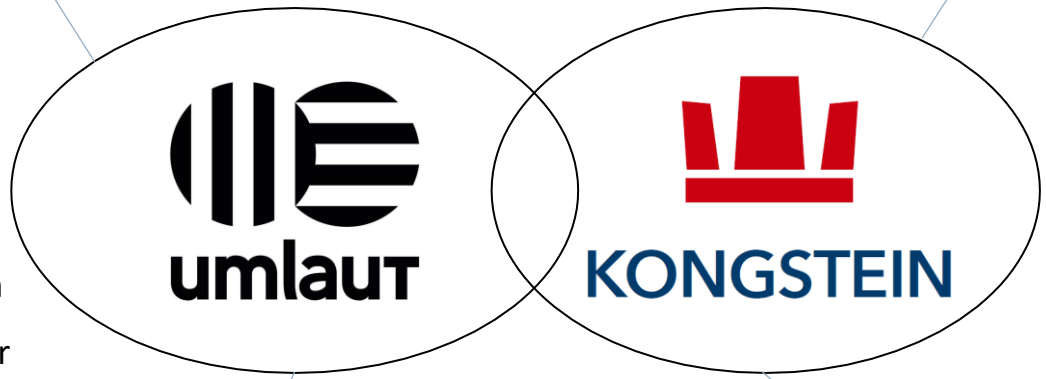
Philipp Wiener
Consultant
@umlaut energy GmbH

Areas of Expertise:
- Wind Power Concepts & Market Analysis
- PM & Product Development for Wind Power Projects

Our Combined Expertise

- End-2-end consulting & engineering services
- 400+ Mio. € annual revenue
- 4500+ employees from over 80+ Nations

- Maritime Technical Advisory and Project Management services
- Enable the green shift in the energy industry
- 20+ employees in northern Europe



- Consulting and engineering along the hydrogen and wind power value chain
- Techno economic hydrogen studies for public and private instances
- Onshore infrastructure concepts especially hydrogen refuelling
- EPCI and Tender Management for offshore wind projects

- Combining Norwegian and German maritime expertise
- Consulting and engineering in the offshore wind and maritime industry
- Offshore logistics concepts and studies for wind and hydrogen

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Background

Green hydrogen will play a key role in the world's future energy production and energy consumption.

2020

- In June, the German Government published **"The National Hydrogen Strategy"**
- Emphasizes importance of **hydrogen** as key factor to meet its climate goals

2030

- Implement **20 GW** of offshore wind capacity
- Also paves the way for **alternative energy production** offshore

2050

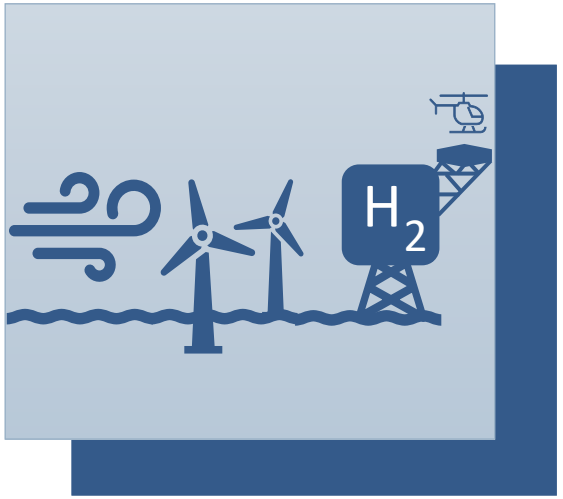
- **Germany's goal is to become carbon neutral by 2050**

Photo credit: Principle Power

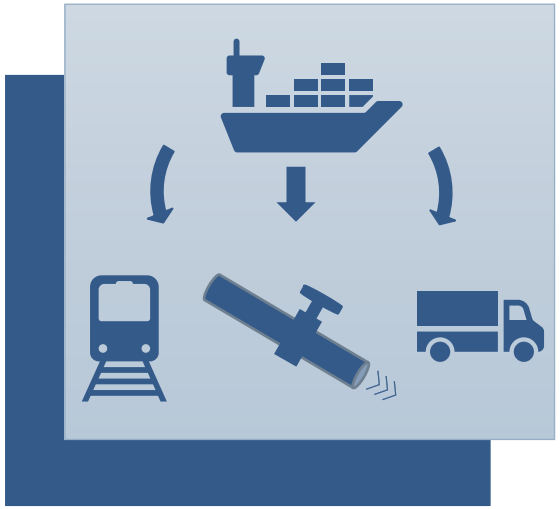
Green Hydrogen: Decarbonizing Multiple Sectors

- Green hydrogen enables the **decarbonization** of **multiple sectors** such as the mobility, energy and industrial sectors.

- Currently, strong focus on **industrial production sites**
  - Green hydrogen can offer significant and tractable improvement on CO_2 output due to production
  - Demand of long-term secured supply of H2 on centralised sites



A closer look at the transportation and production costs of green hydrogen to such sites is necessary.



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Primary Objective

Cost Assessment

Determine which end-to-end transportation methodology for green hydrogen is the most economical for a major industry consumer in Germany.

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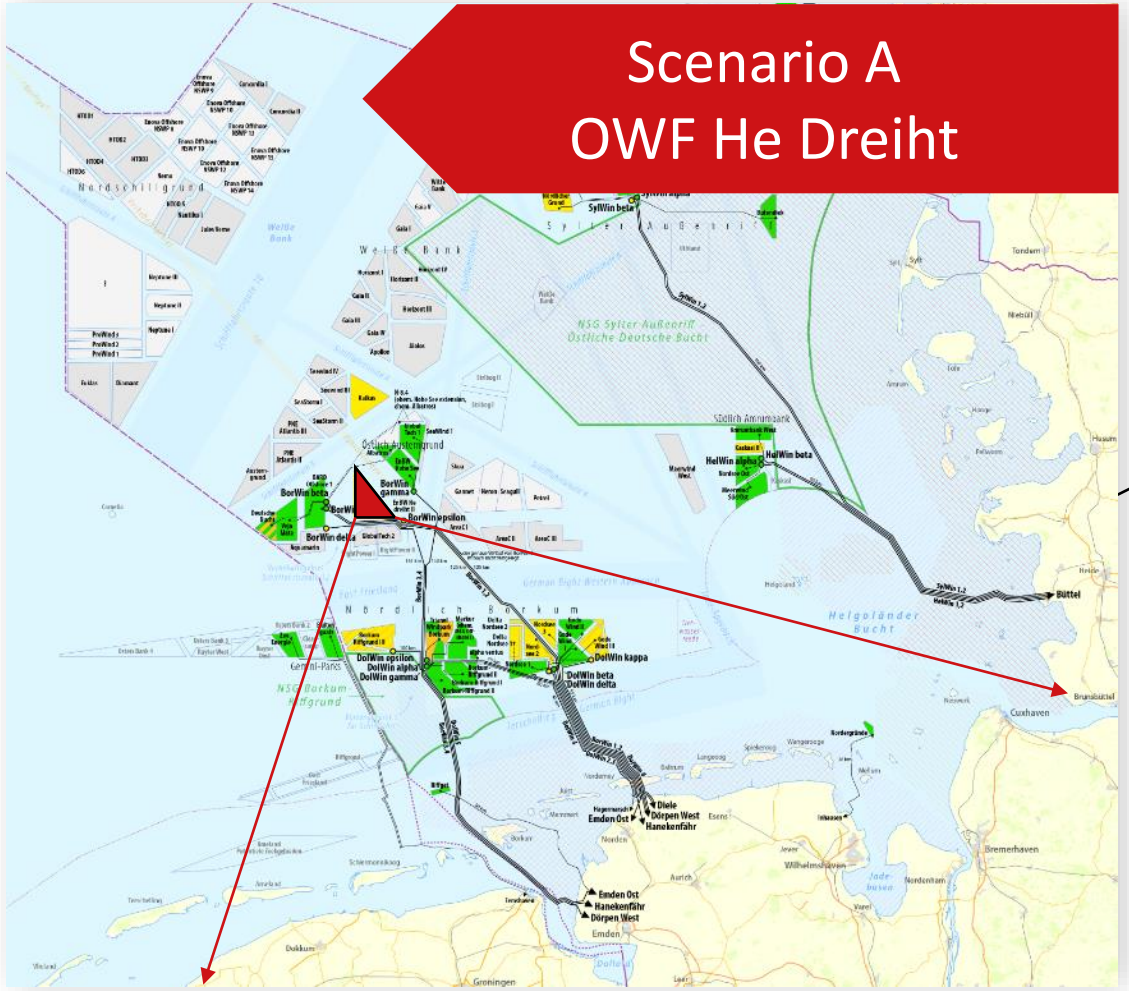
Two reference Wind Farms in the German Bight



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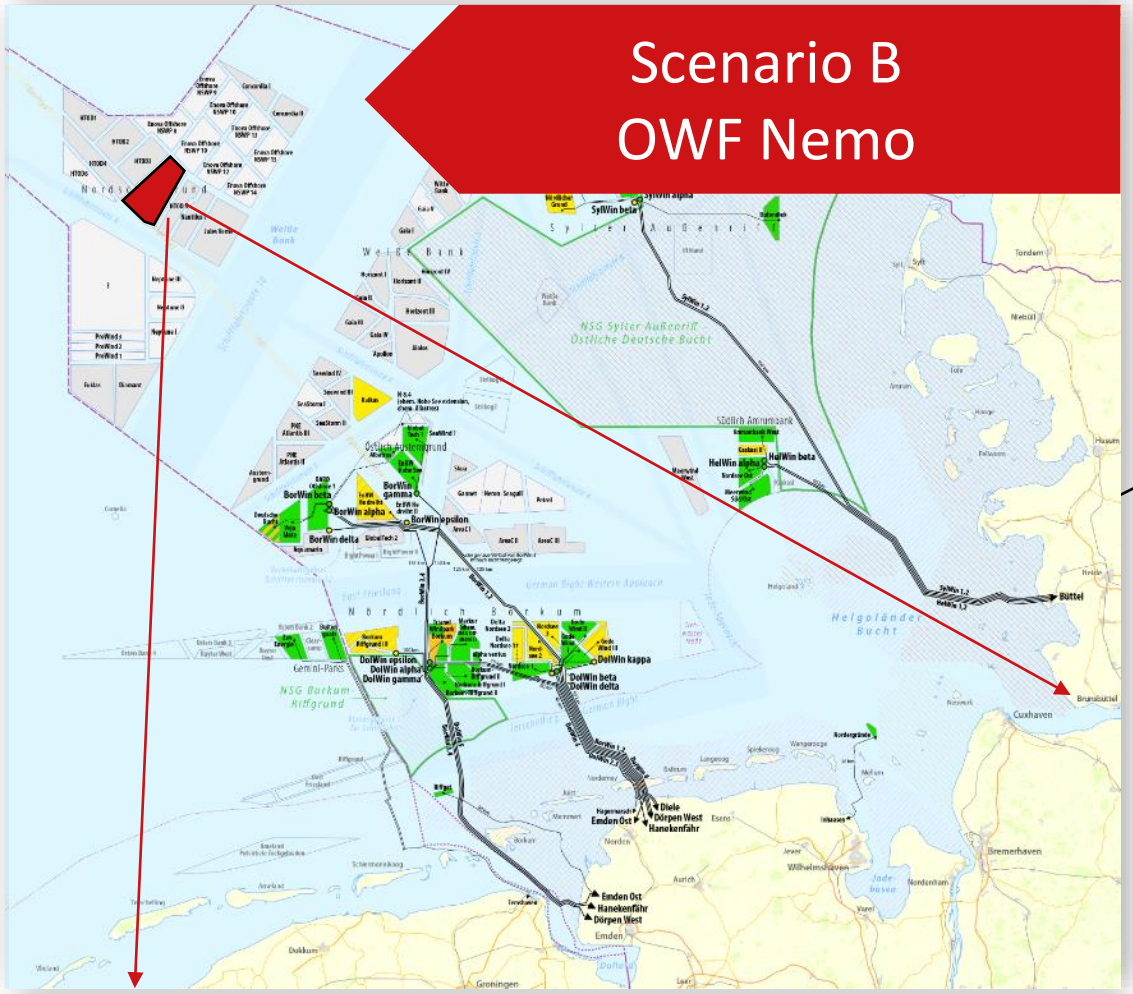
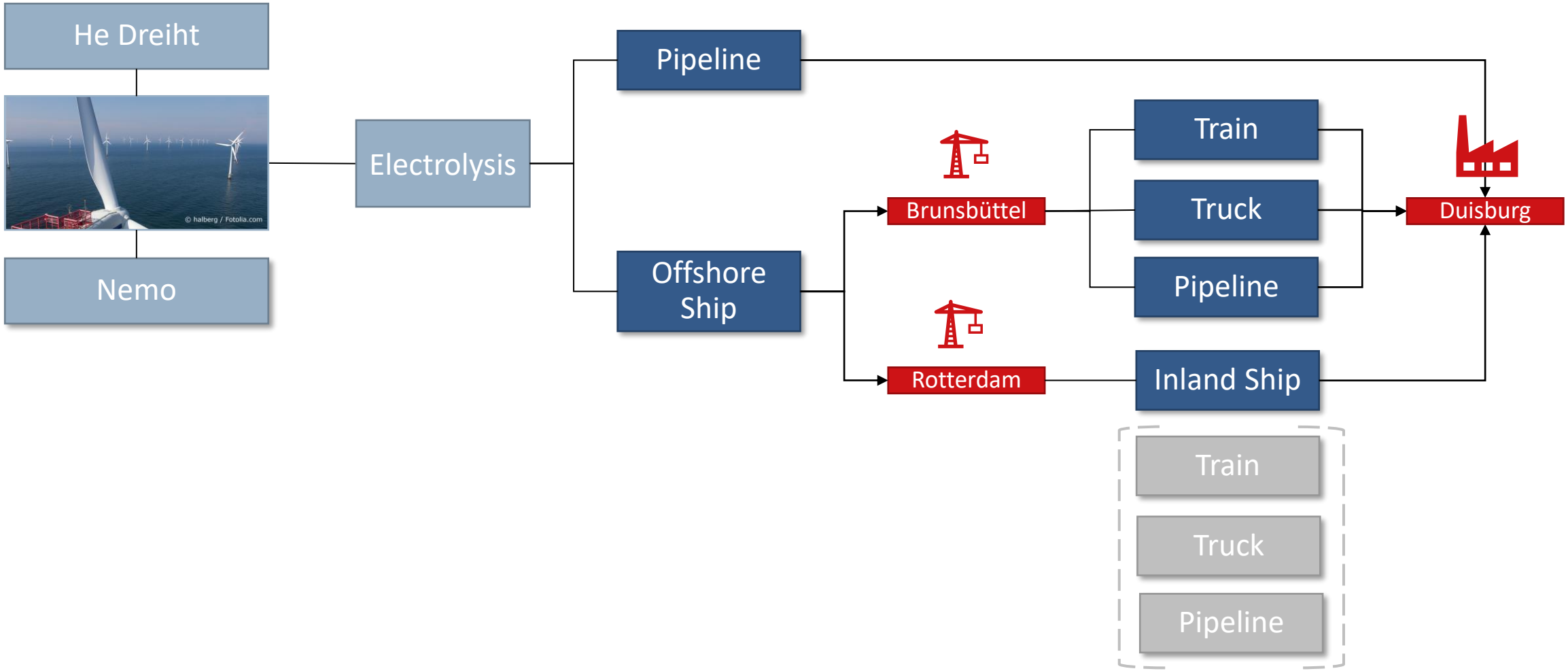


Transportation Concept Scenarios



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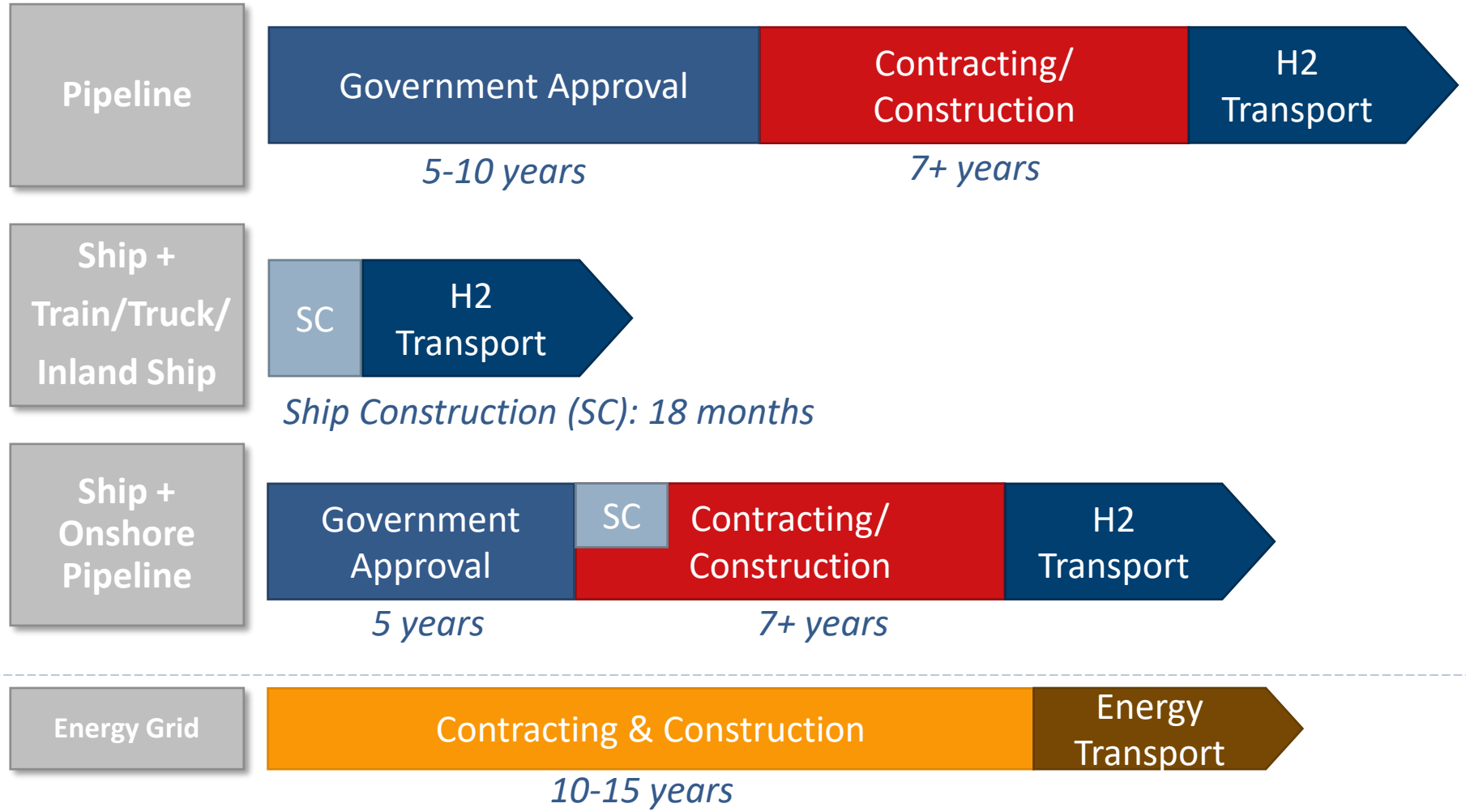
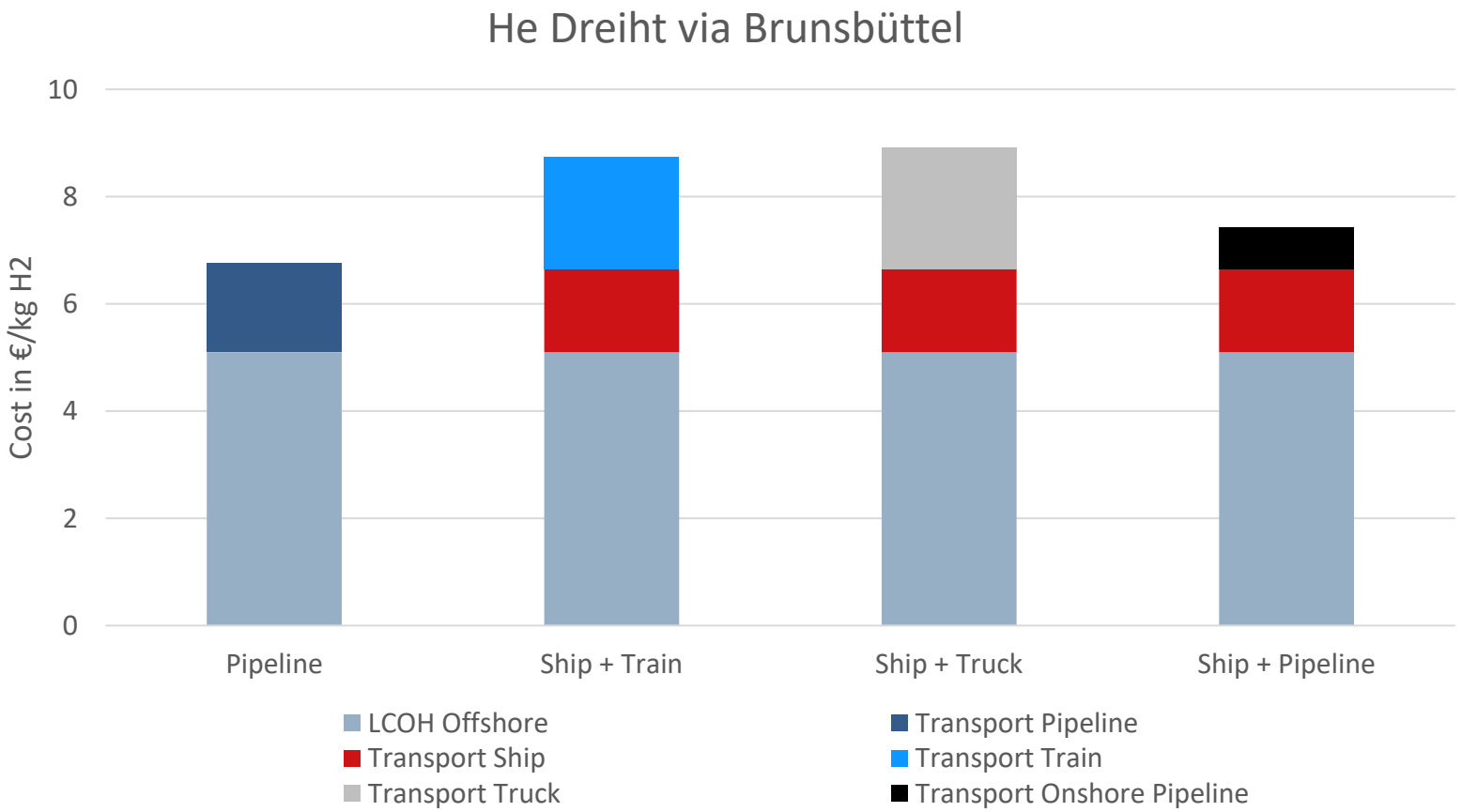
Expected Implementation Timeline

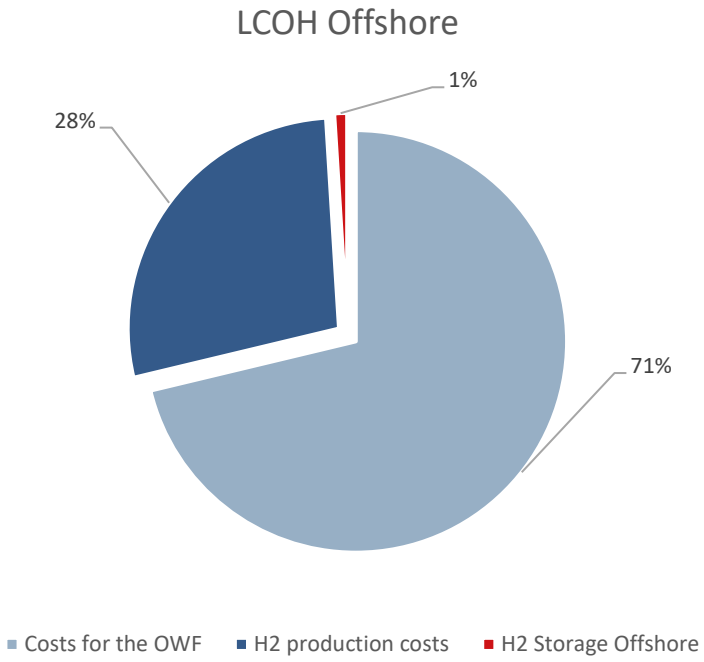


KEY TAKEAWAYS

- Offshore pipeline could add up to a lead time of more than 12-17 years
- Using a vessel + existing logistics infrastructure (train/truck/inland ship) has shortest lead time
- Onshore pipeline faces significant challenges due to numerous shareholders

Cost Comparison for Transport Scenarios

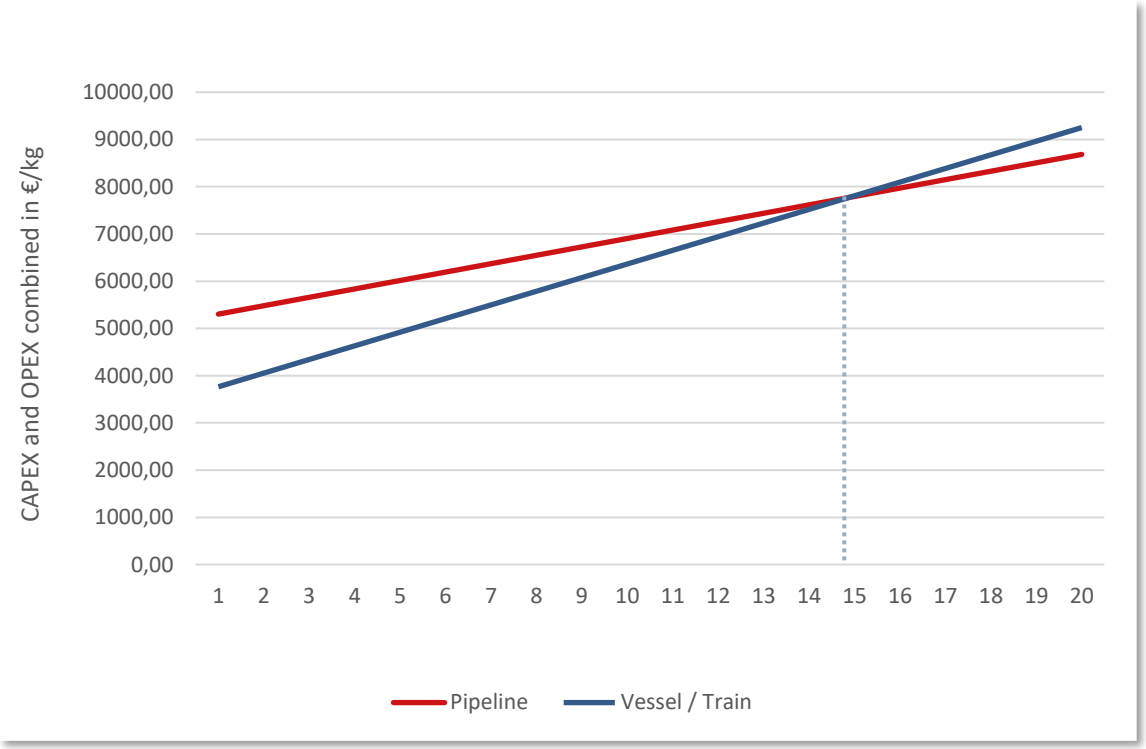




Breakeven Comparison: Pipeline vs. Vessel / Train Transportation

He Dreiht

- Pipeline is more profitable after approx. 15 years of operation
- Vessel + train solution most profitable in the first 15 years of operation



Overview Cost Estimates

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OWF He Dreiht via Brunsbüttel

Scenario	CAPEX [M€]	OPEX [M€ p.a.]	LCOH [€/kg]
Pipeline	5.128	177	**6,81**
Ship / Pipeline	4.615	203	**7,43**
Ship / Truck	3.475	297	**8,93**
Ship / Train	3.475	288	**8,76**

OWF He Dreiht via Rotterdam

Scenario	CAPEX [M€]	OPEX [M€ p.a.]	LCOH [€/kg]
Ship / Ship	4.068	254	**8,05**
Ship / Truck	3.475	247	**7,91**
Ship / Train	3.475	240	**7,77**

OWF Nemo via Brunsbüttel

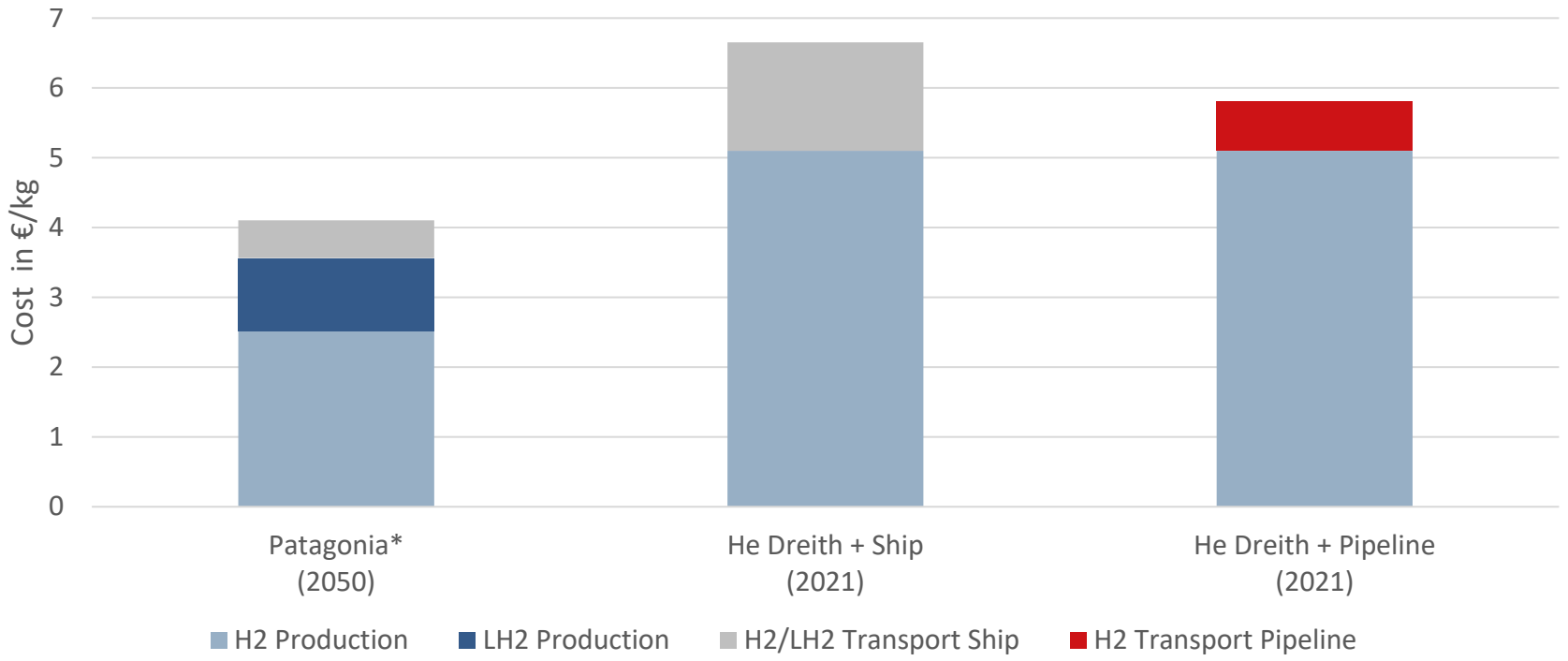
Scenario	CAPEX [M€]	OPEX [M€ p.a.]	LCOH [€/kg]
Pipeline	5.739	189	**7,31**
Ship / Pipeline	4.615	205	**7,46**
Ship / Truck	3.475	298	**8,96**
Ship / Train	3.475	290	**8,79**

OWF Nemo via Rotterdam

Scenario	CAPEX [M€]	OPEX [M€ p.a.]	LCOH [€/kg]
Ship / Ship	3.475	255	**8,06**
Ship / Truck	3.475	248	**7,93**
Ship / Train	3.475	241	**7,79**

Comparison of LCOH

Production and Transportation of Hydrogen to Port Hamburg



KEY TAKEAWAYS

- With a moderate cost reduction He Dreith can almost achieve competitive H2-prices while offering a secure supply
- further cost reduction of domestic produced H2 can be expected

*Source: Hydrogen – opportunities, potentials & challenges

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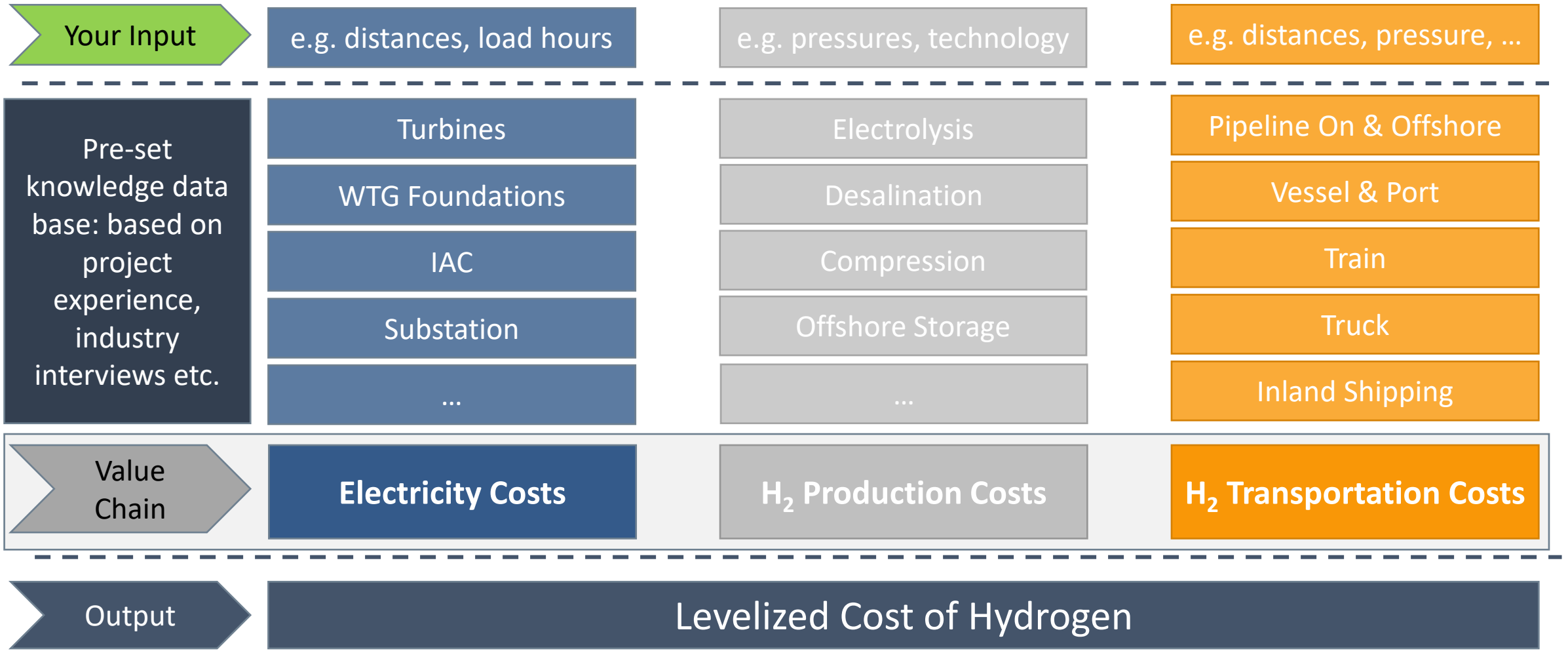
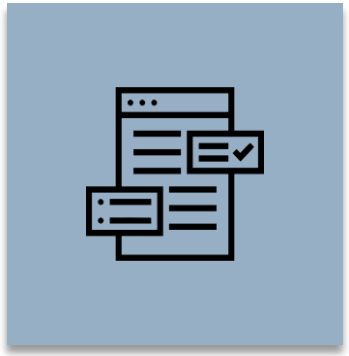
Overview Calculation Environment

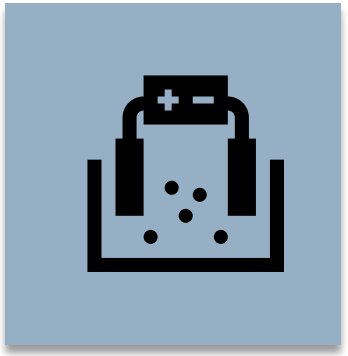


General Assumptions



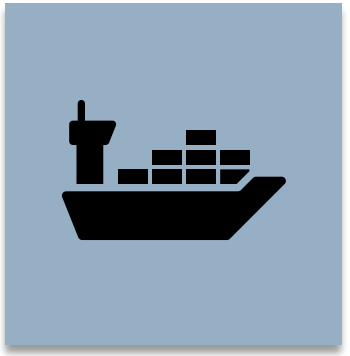
Power Generation

- Both wind farms will have a total capacity of 900 MW
- Conservative setting regarding Full Load Hours of 4000h
- OPEX set to 7% of CAPEX p.a.
- Each turbine connected to one offshore substation via inter-array cables



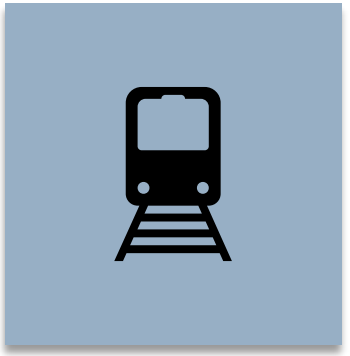
Hydrogen Production

- PEM electrolysis capacity set to 80% of wind farm nominal power
- CAPEX set to 0,8 mio. € per MW
- OPEX set to 3% of CAPEX p.a.
- Saltwater treatment, compression to 60 bar & low pressure storage taken into account
- Electrolyser lifetime set to 80.000 hours



Maritime Logistics

- Vessel Operating lifetime of 30 years
- Pipeline Operational lifetime of 50 years
- Vessel capacity of 160 t H_2
- Vessel offload-rate: 50t H_2/h



Onshore Logistics

- Train, truck and inland vessel as ground transportation (one way) assumed
- 20ft with 300bar containers to be used for transportation
- Lifetime port infrastructure of 15 years

Key Take Aways

Industry will have a large demand for long-term secured supply of H2 on centralised sites

Largescale hydrogen offshore production offers already competitive LCOH of less than 7 € per kg H2

Vessel based solutions are more profitable for the first 15 years and would be ready from 18 months on

After 15 operational years pipeline solutions seem to be most profitable and are well scalable

We are looking forward for an exchange, discussion, criticism or comments from you.

Feel free to contact us!

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