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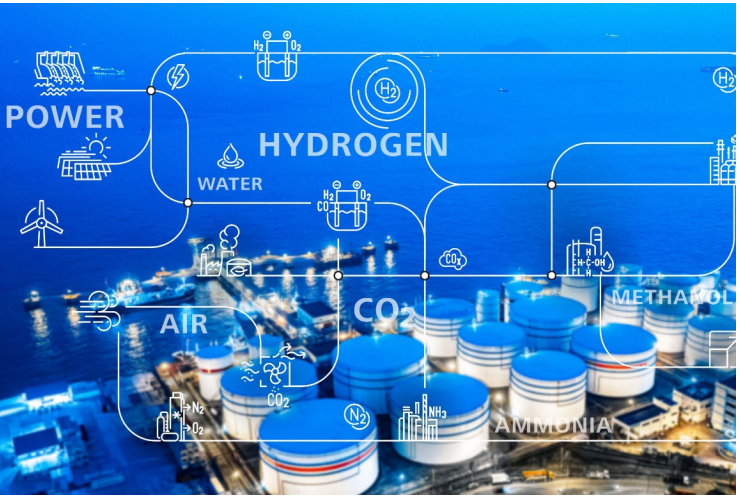


TrHyHub

Trilateral Hydrogen Innovation and Export Hub between Western Australia, the Netherlands and Germany

Robert Szolak, Lucas Edenhofer, Marius Holst, Tobias Eißler and Shima Fathi
Fraunhofer ISE, Business Area ‚Hydrogen Technologies'

TrHyHub Launch Event 18th September 2024, Perth

Supported by the
Federal Ministry for Economic Cooperation and Development

Power-to-X Country Analysis

On behalf of H2Global foundation

- **Western Australia** offers unique combination of great **renewable energy potential, low ammonia supply costs, high land availability and political stability**
- More **comprehensive and site-specific assessment** of the **Oakajee area** by means of a **detailed GIS analysis** in connection with a **supply chain extension to the end customer**

Spain

Product	€/MWh$_{LHV}$
H_2	134 - 146
NH_3	193 - 209
MeOH	216 - 231
FT Mix	189 - 200

Mexico

Product	€/MWh$_{LHV}$
LH_2	242 - 285
NH_3	215 - 233
MeOH	238 - 245
FT-Mix	210 -211
Jet fuel	406 - 430

Colombia

Product	€/MWh$_{LHV}$
LH_2	176 - 317
NH_3	190 - 265
MeOH	190 - 274

Brazil

Product	€/MWh$_{LHV}$
LH_2	171 - 207
NH_3	171 - 184

Brunsbüttel GER

Ukraine

Product	€/MWh$_{LHV}$
	56 - 180
	206 - 276

India

Product	€/MWh$_{LHV}$
LH_2	238 - 313
NH_3	223 - 248
MeOH	232 - 263
FT-Mix	220 - 232
Jet fuel	414 - 473

Australia

Product	€/MWh$_{LHV}$
LH_2	217 - 233
NH_3	172 - 184
MeOH	192 - 200
FT-Mix	166 - 181
Jet fuel	298 - 333

Hydrogen Hub 'TrHyHub'

Joint Initiative for Development of a **3 Mtpa Ammonia Export Hub** between Western Australia, the Netherlands and Germany

[1]: Christoph Hank, Marius Holst, Connor Thelen, Christoph Kost, Sven Längle Achim Schaadt, Tom Smolinka, *Site-specific, comparative analysis for suitable Power-to-X pathways and products in developing and emerging countries*, Fraunhofer ISE, 2023, commissioned by H2Global Foundation in cooperation with Gesellschaft für internationale Zusammenarbeit (GIZ). It was financed by the Federal Ministry for Economic Cooperation and Development (BMZ) → Link

H2Global Stiftung Fraunhofer ISE

Regulatory framework - Requirements for RFNBO´s

Hydrogen and Derivatives from Australia to Europe

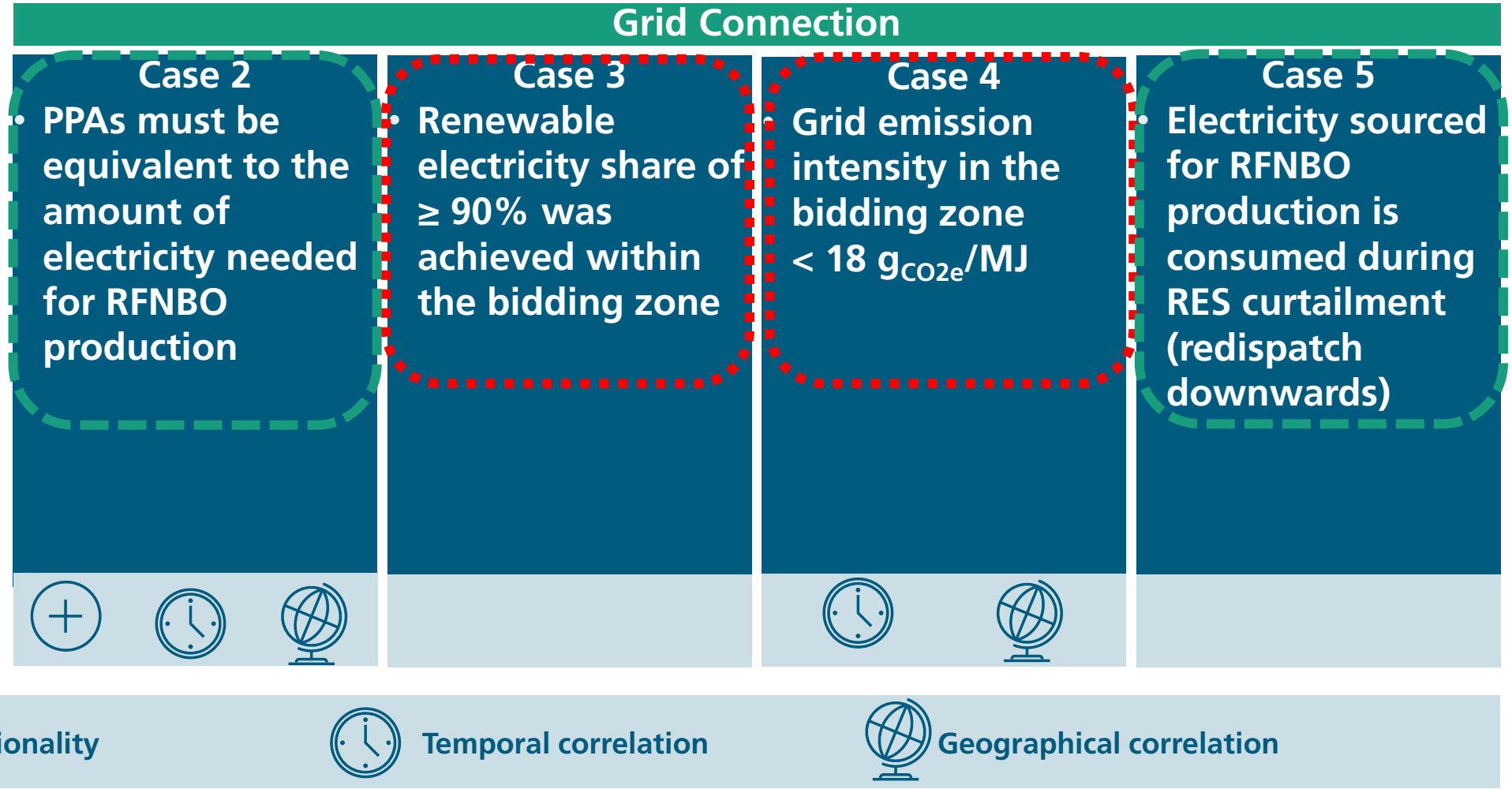
The export of green hydrogen and its derivatives to Germany and the EU is subject to a complex and changing regulatory landscape

- **Renewable Energy Directive II and III** (RED II and III), fundamental requirements for clean H_2 & derivatives, count towards the EU RE targets
- **Carbon Border Adjustment Mechanism** (CBAM) directly target industries by increasing the costs of carbon-intensive fuels and products
- **European Union Emissions Trading System** (EU ETS)
- FuelEU Maritime, ReFuelEU Aviation, RePowerEU, Fuel Quality Directive, Carbon Contracts for Difference, …

* RFNBO: Renewable Fuels of Non-Biological Origin

Requirements for Certification of RFNBO´s

RED II Delegated Act Art. 27(3) – Electricity Criteria for RFNBO* Production



* RFNBO: Renewable Fuels of Non-Biological Origin

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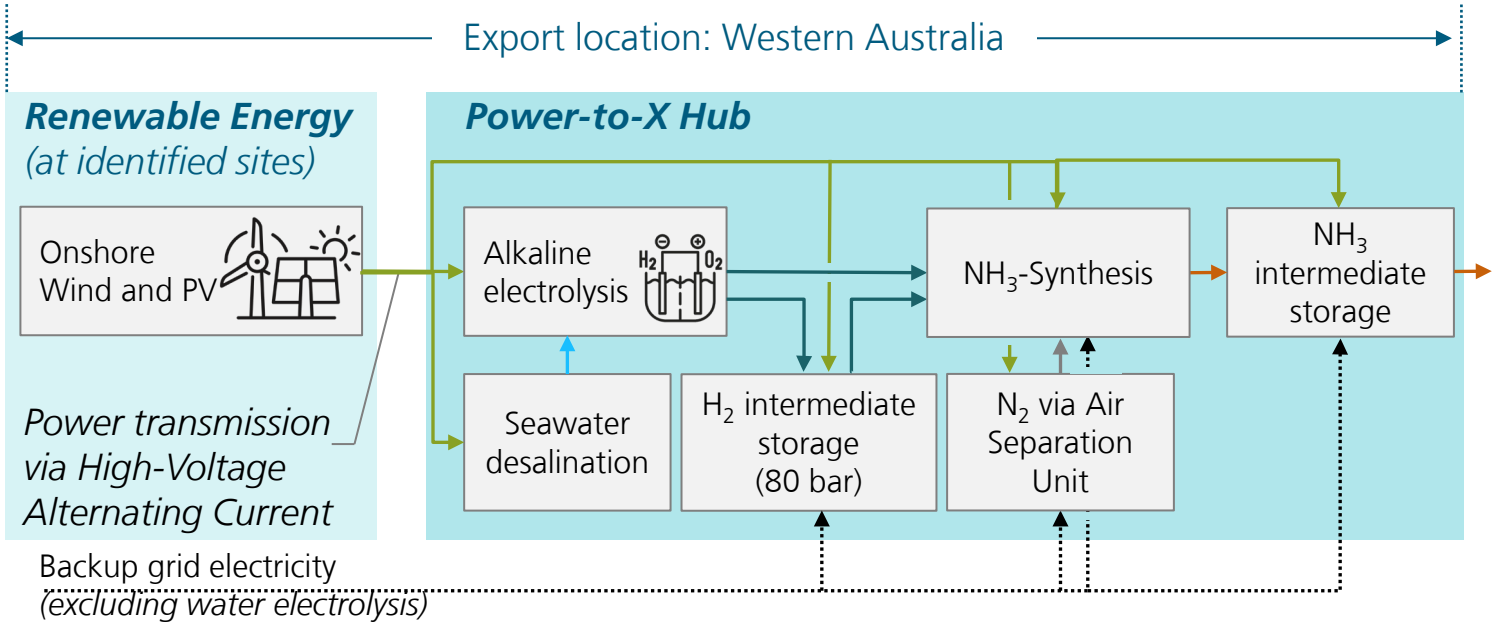
Direct Connection of RES to the Electrolysis

Meeting the Requirements for Certification of RFNBO´s

Direct connection

Case 1

- **RES must be connected to the electrolyser via a direct trans-mission line or located in the same installation**



Additionality **Temporal correlation** **Geographical correlation**

* RFNBO: Renewable Fuels of Non-Biological Origin

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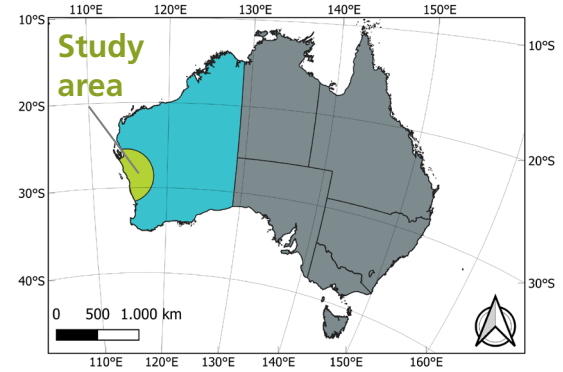
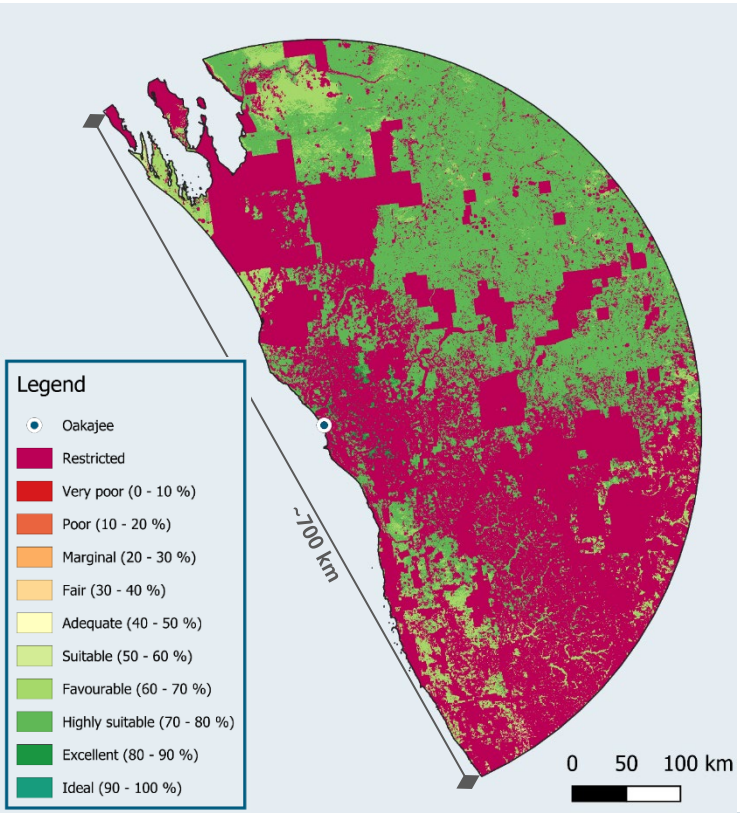
Renewable Energy

Production Potential and Site Suitability Assessment

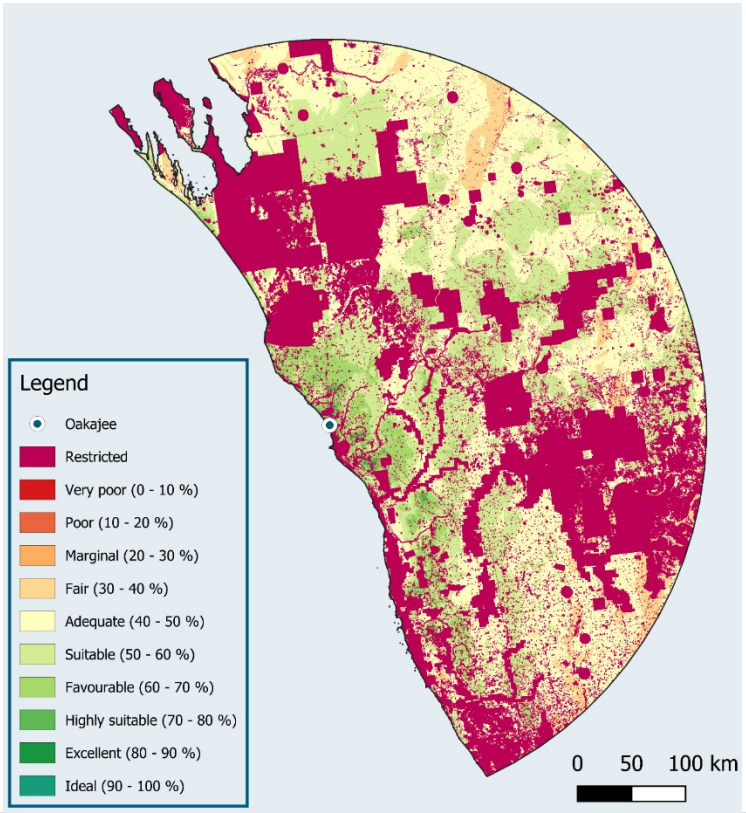


Identification of suitable large-scale sites for onshore wind and ground-mounted PV in terms of economic competitiveness and project feasibility

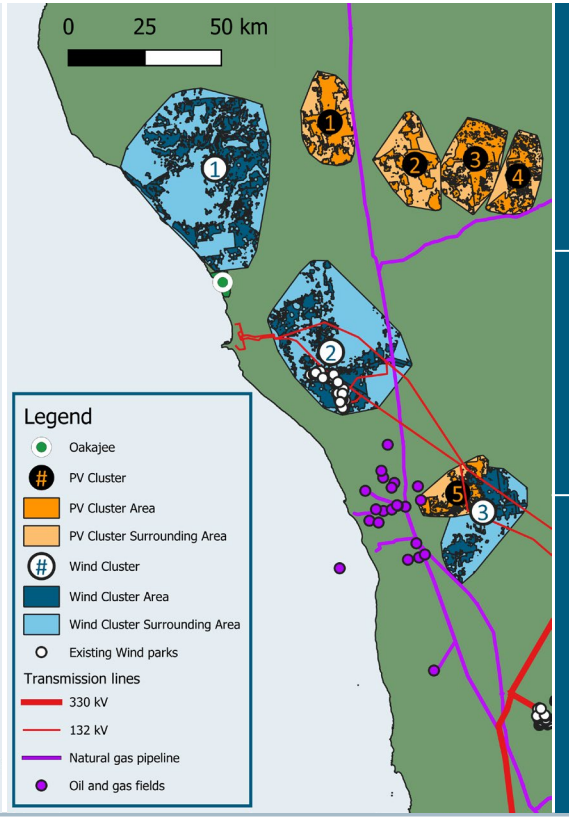
Ground-mounted PV



Onshore wind



Clustering & site selection



5 PV clusters identified:

- 1,005 km² / 55 GW_{el}
- Mainly rangeland

3 onshore wind clusters:

- 1,364 km² / 20 GW_{el}
- Crop and rangeland

Potential RE production capacities to increase the planned renewable ammonia production capacity from 3 Mtpa to over 15 Mtpa

- ✓ **High land availability for renewable electricity production**
- ✓ **Enormous renewable energy production potential near Oakajee**

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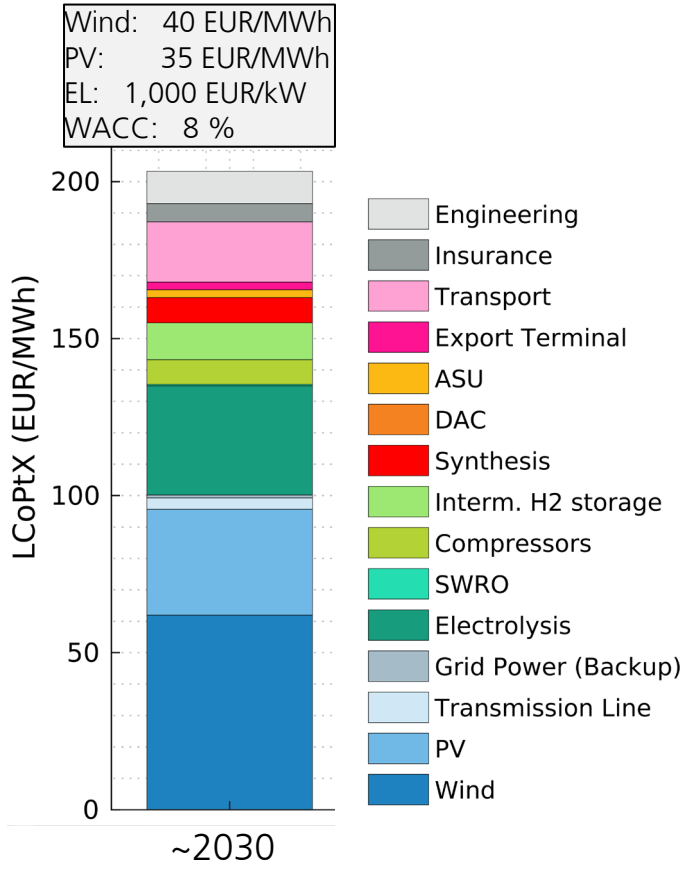
Power-to-Ammonia Supply Chain

System Optimization Results

- **Ammonia supply costs to the PoR** of **203 EUR/MWh (325 AUD/MWh)** (equivalent to 1,053 EUR/t_{NH3} or 1,685 AUD/t) for the base case in 2030
- **50 % of final costs** are related to the **power supply**, with **5.5 GW onshore wind** having the higher share in total costs compared to **6.8 GW PV**
- **4.4 GW alkaline electrolysis** as the second largest contributor to total cost with **6,260 full load hours**
- **Maritime transport** to Rotterdam requires **9 vessels** and does not constitute a significant cost factor (9% of total expense)

- **RE overcapacity with 18%** of the power production must be curtailed or fed into the national grid
- Limited part load capability of the **Haber-Bosch synthesis** (80%) increases the demand for intermediate H_2 storage (925,000 m³) and RE overcapacity



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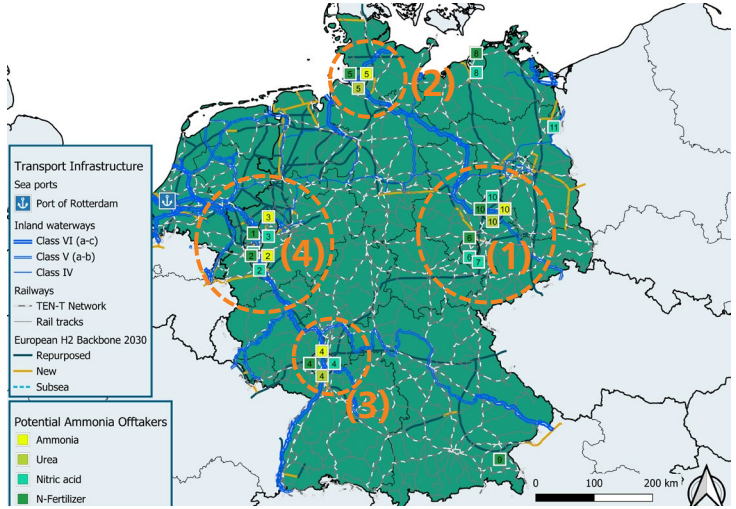
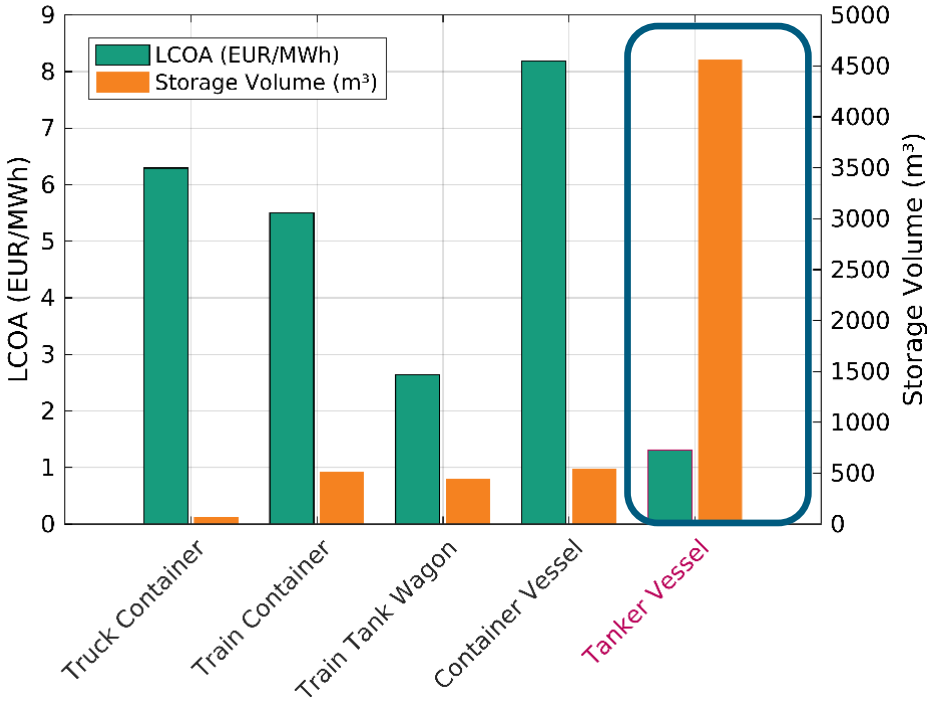
Ammonia and Hydrogen Offtake in Germany

Offtake assessment and supply chain analysis

- Identification of **large-scale ammonia and hydrogen offtakers** in Germany
  - Current German ammonia production of ~ 3 MTPA
  - Current **ammonia, urea, nitric acid and N-fertilizer** production sites
  - Future ammonia demand in **maritime sector** and **power supply**
  - Large-scale **hydrogen** demand in **chemical industry and steel sector**
- **Inland transport** of PtX carriers
  - Adds **marginal additional ammonia costs** with **less than 1%** of total supply costs
  - Differences between transport options
  - **Tanker** vessel via inland waterways and **railway** – suitable and **cost-effective transport options** within Germany
    - **Tanker Vessel: 1.4 EUR/MWh (2.2 AUD/MWh)**





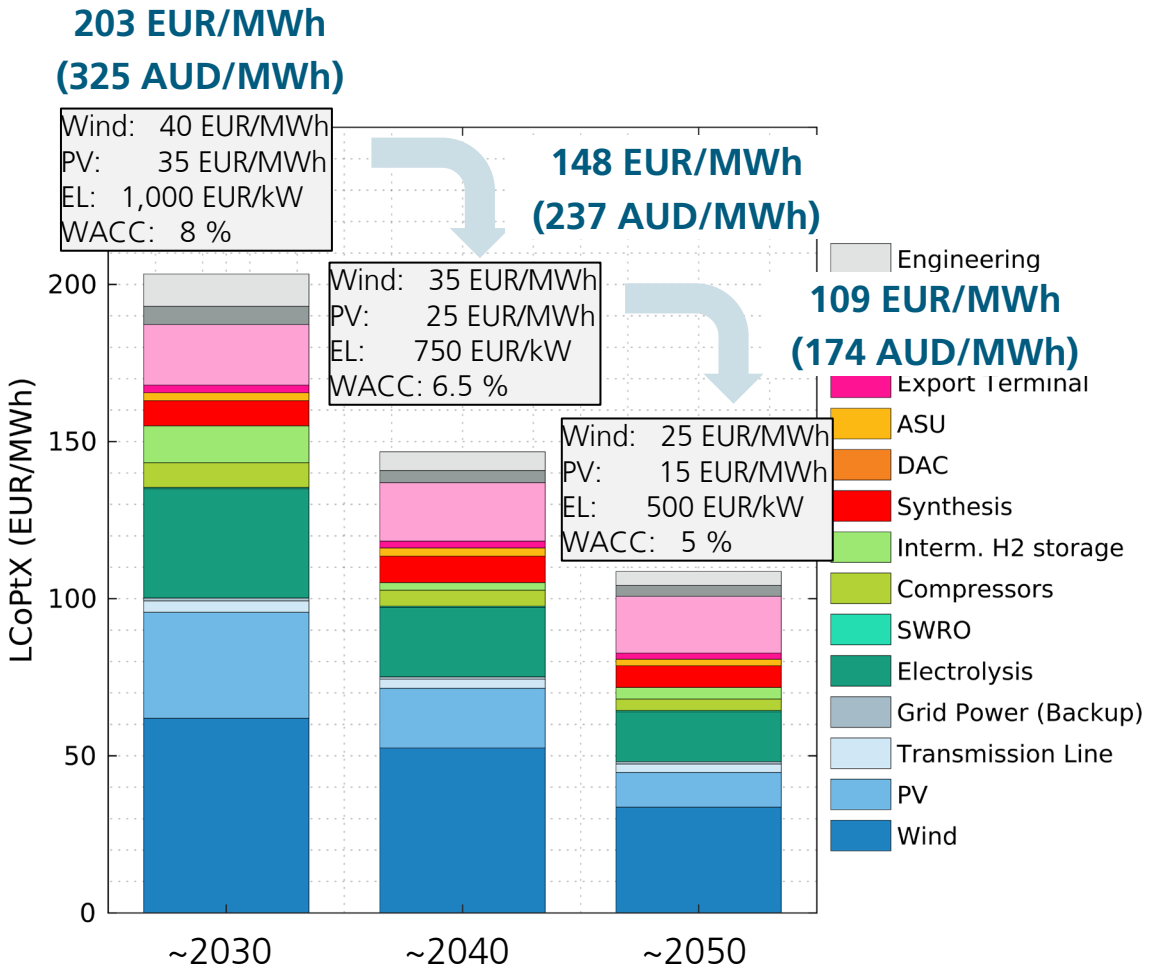
Power-to-Ammonia Supply Chain

System Optimization Results

- **Technology cost reduction**
  - Lower costs for renewable power generation
  - Electrolysis scale-up just at the beginning
- **Technical improvements**
  - Higher efficiency of components (e.g. SEC electrolysis)
  - Larger operation window of Haber-Bosch synthesis
  - Higher component lifetime
- **Costs of capital**
  - Weighted Average Costs of Capital effects all components → high influence on total costs
  - Technology risk decreases with time

✓ **Not time reduces costs, but global ramp up and development does**

✓ **Transport distance is outweighted by excellent RE potential**



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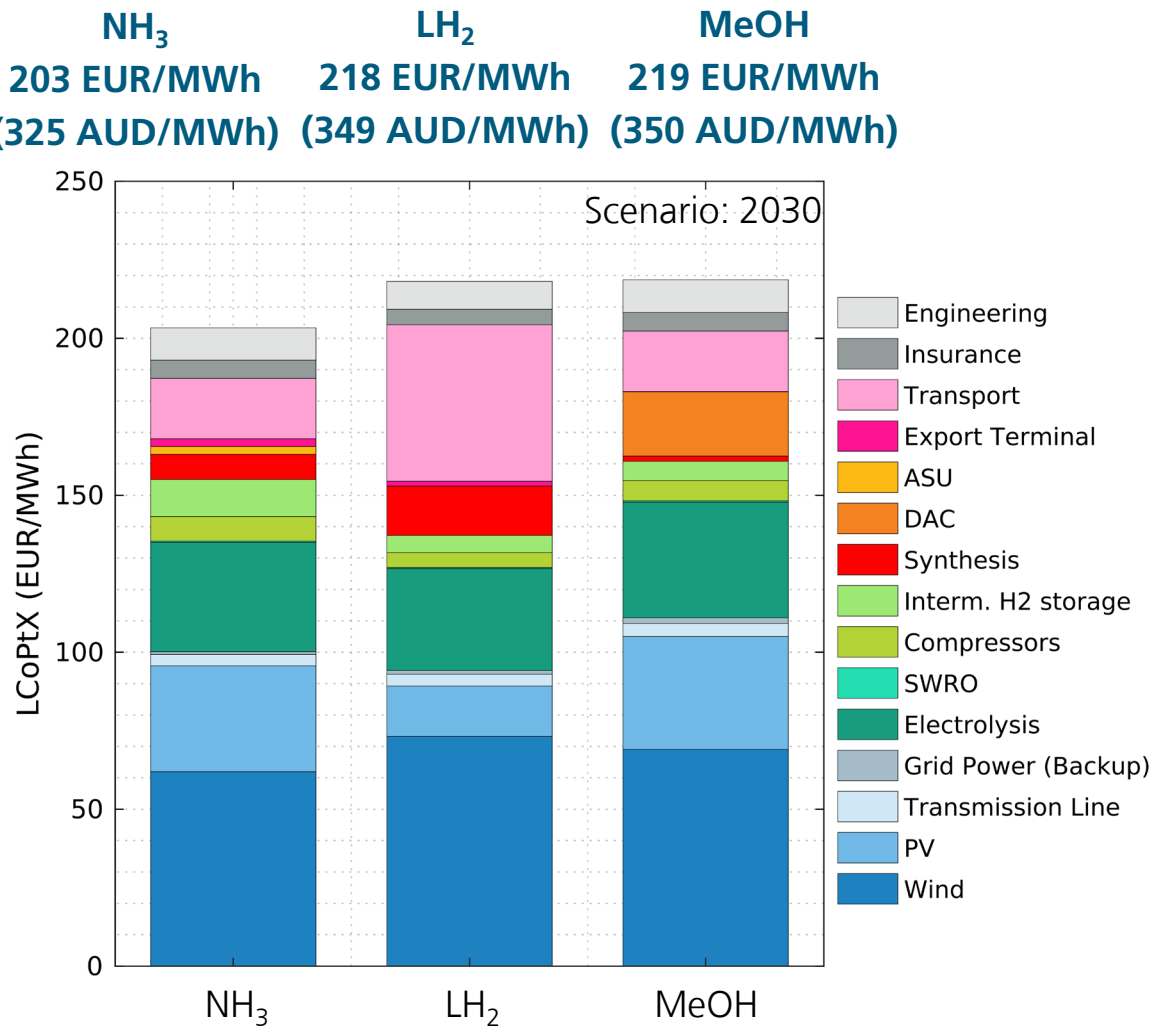
System Optimization Results

Comparison of energy carriers

- Additional analysis of **Liquid Hydrogen (LH_2) and Methanol (MeOH)** production and transport, with lower level of detail
- **Liquid hydrogen** not possible in 2030, but future option
  - Large-scale LH_2 carriers probably not available in 2030
  - Development of large-scale single storage and liquefaction capacity required
  - High costs for hydrogen liquefaction and transport
- **Methanol** production and transport state of the art
  - CO_2 generation with DAC is a bottleneck
  - DAC is a cost driver (equipment costs + power demand)

✓ **Ammonia is the most suitable energy carrier for Oakajee**

✓ **Ammonia reforming leads to cost increase in hydrogen supply costs**



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Summary

Global Production and Supply Costs of Green Hydrogen and Derivatives from Western Australia

- **Renewable hydrogen and ammonia** will become the **energy currency of the defossilised energy and industry system** in Germany
- **Enormous hydrogen production potential in the Australian Mid West region** could cover the major part of European hydrogen demand by 2050
- **Outstanding renewable energy production sites near Oakajee** could increase the planned ammonia production capacities
- **Regulatory framework** will help **to close the competitiveness gap** between fossil and renewable ammonia from 2030 onwards but not sufficient to close the gap completely
- **Ammonia supply costs of 203 EUR/MWh** (325 AUD/MWh) for 2030 to the Port of Rotterdam. The elevated **maritime transport costs** are **offset by the exceptional solar and wind conditions**
- **Future cost reduction** will be realized through global scale-up and technological improvements ➔ **we have to start now to make it happen**

Joint media release: $660m to advance Australia and Germany's cooperation on energy and climate

13 September 2024

The Hon Chris Bowen, Minister for Climate Change and Energy

The Hon Robert Habeck, German Vice Chancellor and Minister for Economic Affairs and Climate Action

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Australia and Germany have signed an historic deal to deepen cooperation on new green hydrogen supply chains through a $660 million (€400 million) H2Global funding window to guarantee European buyers for Australia's renewable hydrogen producers.

The deal comes as the two countries agreed to elevate their existing Energy Partnership to an Energy and Climate Partnership, advancing joint work in climate action and cooperation, energy efficiency, the net zero transition and energy security, along with expanded cooperation on renewable hydrogen trade.

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