Priorities and Challenges for Hydrogen Production and Application in the Energy Transition Era

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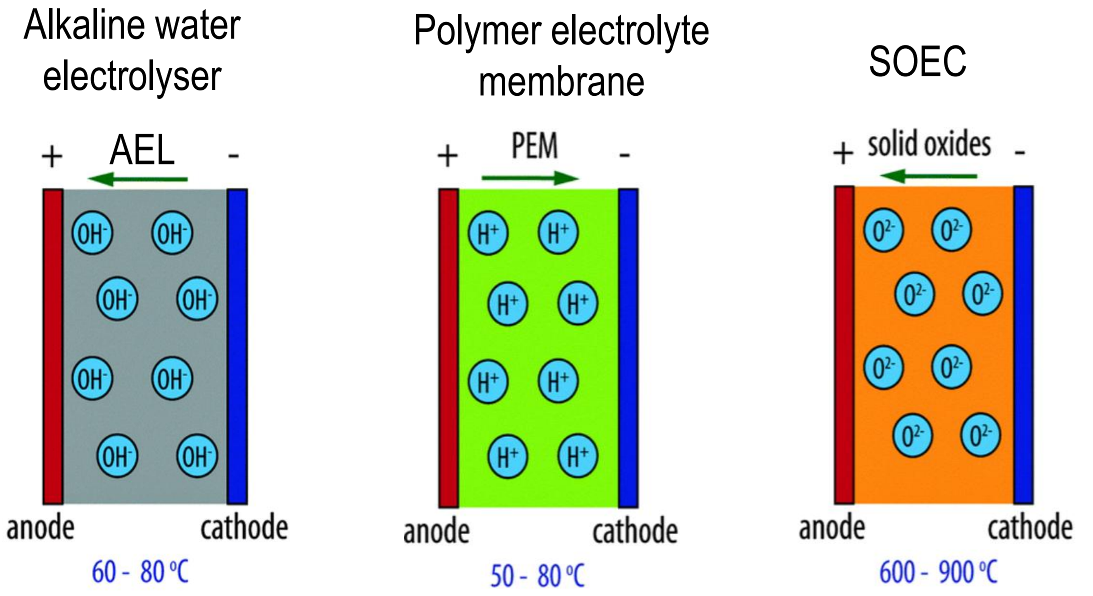
Market Studies	Marine Operations & T&I Engineering	Asset Integrity Management (AIM)	Wells Control, Mgmt., Eng. & Servicing
Lenders Technical Advisory	FEED	Marine Warranty Survey (MWS)	Well Plug & Abandonment
Contracts & Claims	Vessel Design, Conversion & Upgrade	Rig Operations & Inspections	Reservoir Management & Asset Evaluation
Owner's Engineering	Advanced Simulations & Analysis	Marine Surveys, Inspections & Audits	Resource Solutions Provider
Technical Due Diligence	Floating and Fixed Structures	DP & Critical Systems	Wellsite & Operations Geology
Technical Studies		Marine Advisory	Time, Cost, Risk Management Software
Engineering		Marine Casualty Management	Rig Scheduling Software
Geoscience		Expert Witness & Litigation	CCUS & geothermal
R&D		Energy Transition	HSEQ & Risk Consulting & Training

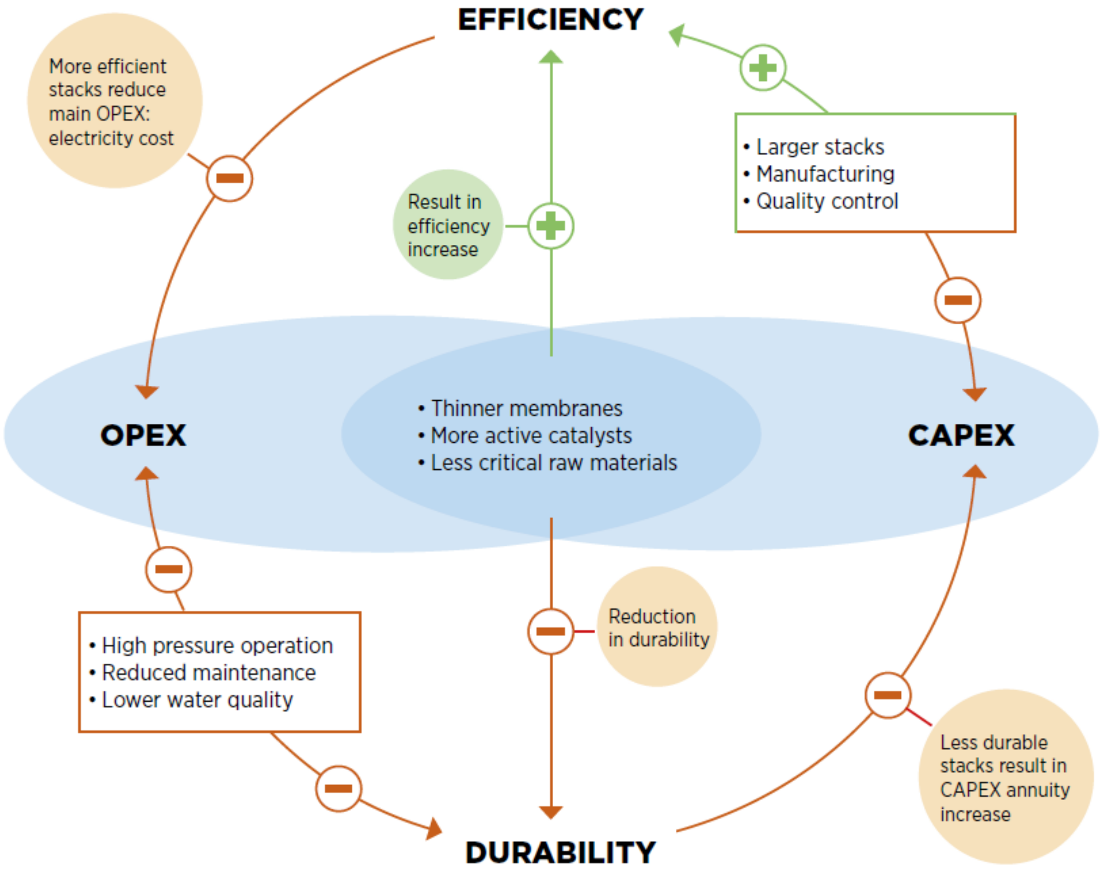
Main Electrolyser technologies for green hydrogen production

Current Electrolyser Technologies



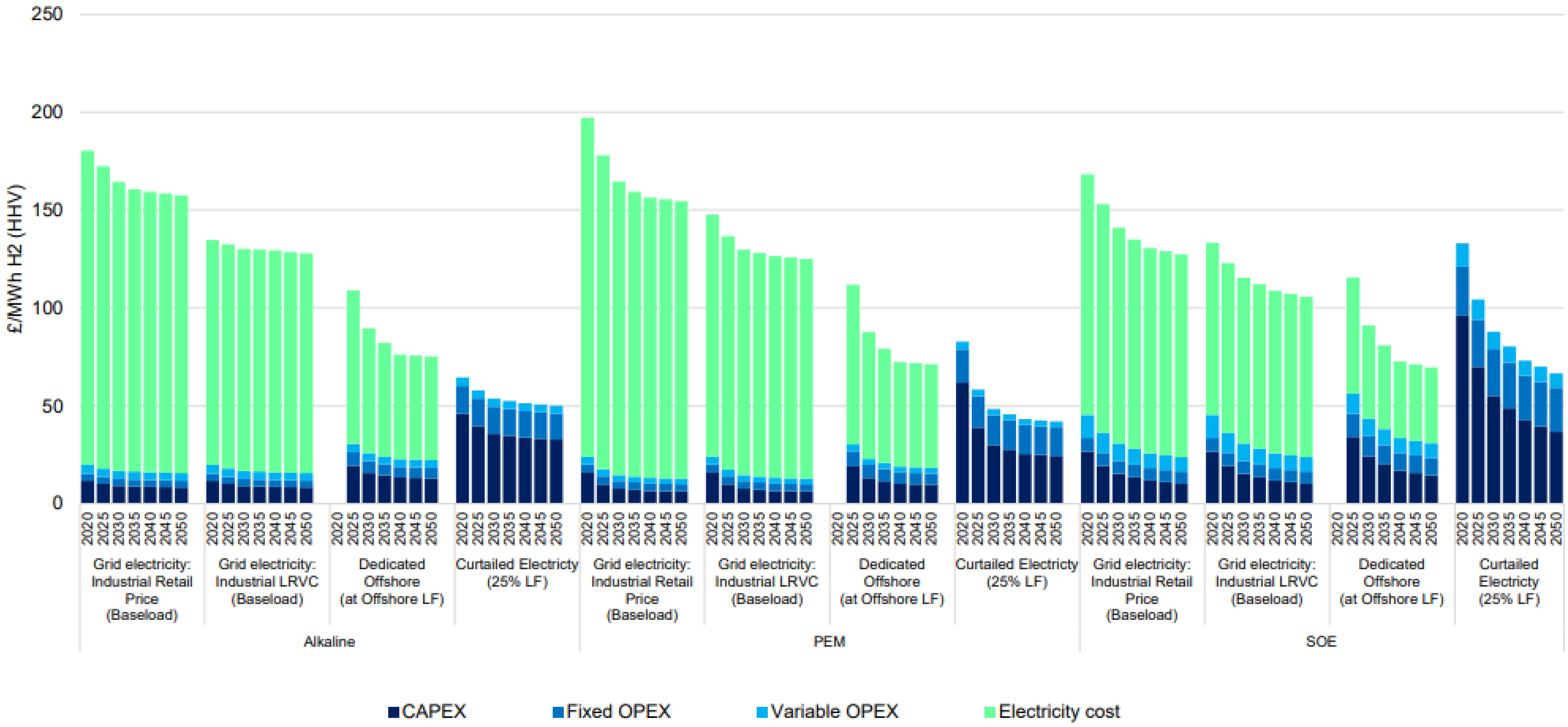
Key information	Alkaline	PEM	SOEC
Current Density ($A\ cm^{-2}$)	0.2-0.4	0.6-2.0	0.3-2.0
Production Rate ($m^3_{H2}\ h^{-1}$)	<760	<40	<40
System Response	Seconds	Milliseconds	Seconds
Cold-start Time (minutes)	<60	<20	<60
Maturity	Mature	Commercial	Demonstration

Electrolyser Design Trade-offs



Ref: Green Hydrogen: reducing the cost needs scaling up of electrolyser plants - Energy Post

Hydrogen cost breakdown forecast to 2050



Ref: UK Department for Business, Energy and Industrial Strategy: Hydrogen Production Costs 2021.

Note: 39.4 kWh of H_2 (HHV) = 1 kg of H_2.

Four Aspects of Hydrogen

Fuels

Production

Vessels

Chain

Hydrogen and derived fuels market studies

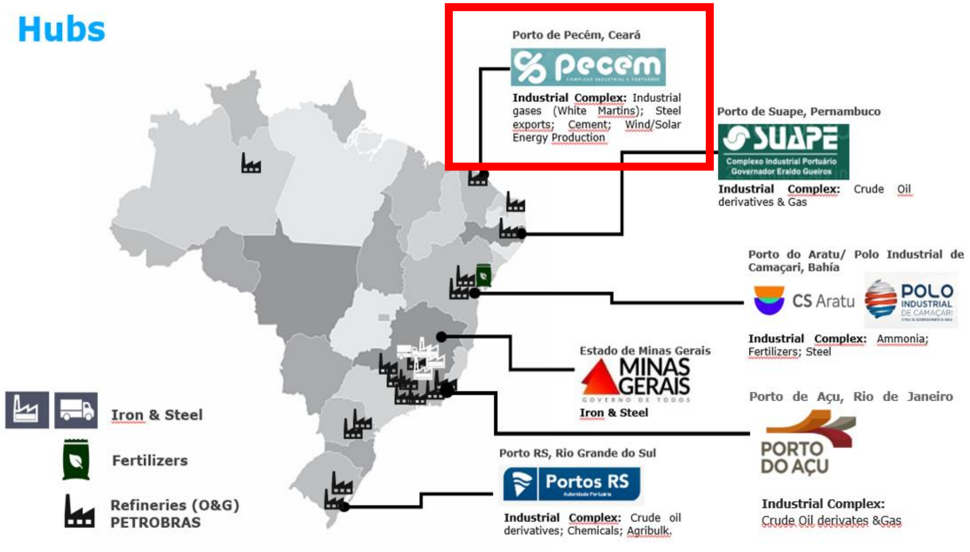
Application of Hydrogen, Ammonia & Methanol for maritime transport sector in Indonesia - WB

"Prefeasibility study on application of low carbon alternative fuels (Hydrogen, Ammonia and Methanol) for maritime transport sector in Indonesia".

Scope of work:

- Pre-feasibility study on hydrogen application to domestic ships and port operation like fuel supply facility in Indonesia, from technical, financial and regulatory aspects, to identify prospective investments which could be supported by ADB.
- Evaluate potential contribution to NDC and SDG7 via decarbonization of energy use in urban areas. Life cycle assessment, CO2 reduction potential (fuel transportation and operations) and HSE analysis including reduction potential of air pollutants like SOx and NOx.
- Knowledge sharing with local stakeholders in Indonesia and other DMCs.
- **News and more info:** https://www.longitude-engineering.com/news/longitude-to-support-pertaminas-low-carbon-shipping-drive/

Green Hydrogen Hub – Brazil - WB



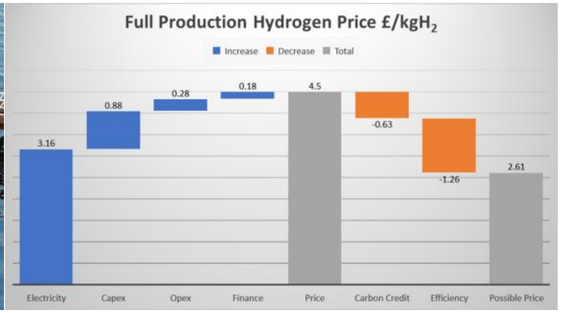
Phase 1: Map value chain, Identify infrastructure bottlenecks, Case study maritime and export markets

Phase 2: Pre-feasibility of Green Hydrogen hub in Port of Pecem.

Hydrogen Production

Green Hydrogen Production Barge

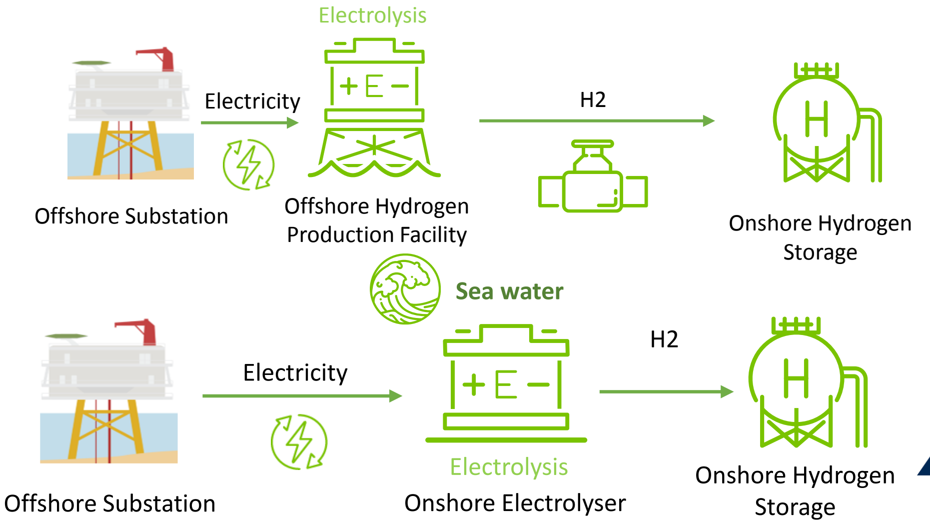
- To develop concept design solution for local hydrogen production within a typical medium sized commercial port/harbour readily installable, with minimal infrastructure, to support the adoption of hydrogen as a marine fuel.
- To validate the modelling assumptions such that other UK ports can be evaluated for suitability and roll out of the concept.
- To develop barge concept designs to suit a range of demand sizes.
- To further develop a selected concept detail to prepare for a future demonstration phase.



Offshore wind "Power to X" concept & Pre-FS

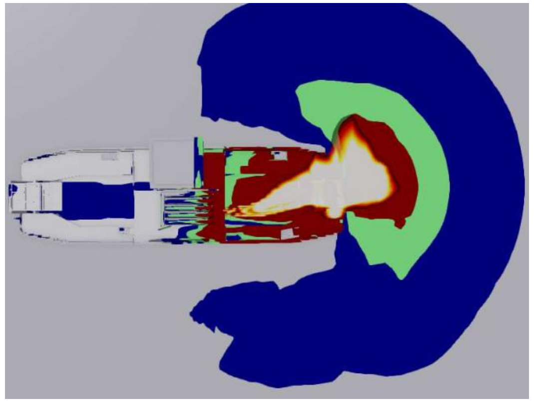
OW PtX concept & pre-FS of two projects:

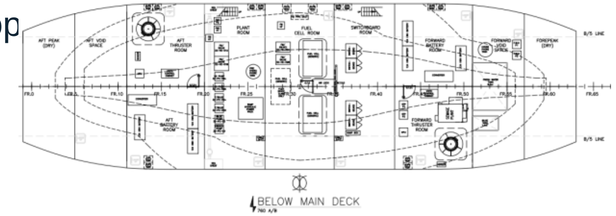
- 700 MW in confidential country 1.
  - Average 52 kt H_2/year & 1.92×10^8 L of seawater/year.
- 1,500 MW in confidential country 2
  - Average 107 kt H_2/year & 1.97×10^9 L of seawater/year.
- Site preliminary assessment
  - Market study (H_2, NH_3 & derivatives)
  - Transportation analysis
  - Option analysis (optimized LCOH & NPV, electrolyser size & maturity, water required, BOP complexity & other pros/cons, **4 options**)
  - Electrical concept (SLDs)
  - Process engineering (equipment, PFDs)

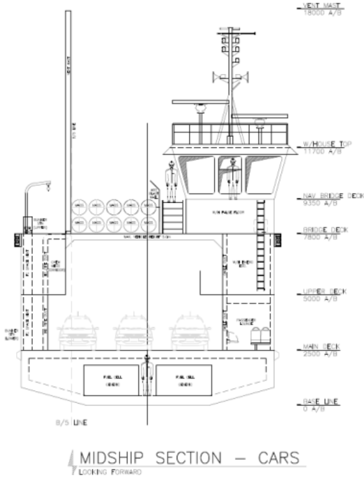


HySeasIII Concept – Double ended roro ferry

- Concept design and procurement specification
- Achieved *Approval in Principle* from DNV
- Combined Hydrogen and Battery system design
- Internal vs external hydrogen tank storage considered in depth
  - Evacuation of any leak and potential to create explosive atmosphere.
  - Proximity of H_2 to personnel
  - Creation of a hazardous area within the hull, requiring dedicated ventilation and bilge systems
  - Large storage of energy due to the compressed gas. Sudden release of which could exceed the design values of bulkheads and structure
  - Ability to inspect, maintain and replace / service storage tanks in a confined space and with limited removal options.
  - Location of tanks in an unmanned potentially inerted space raises redundancy and maintenance issues.
- Dispersion analysis
- Blanketing system
- HazID and safety philosop



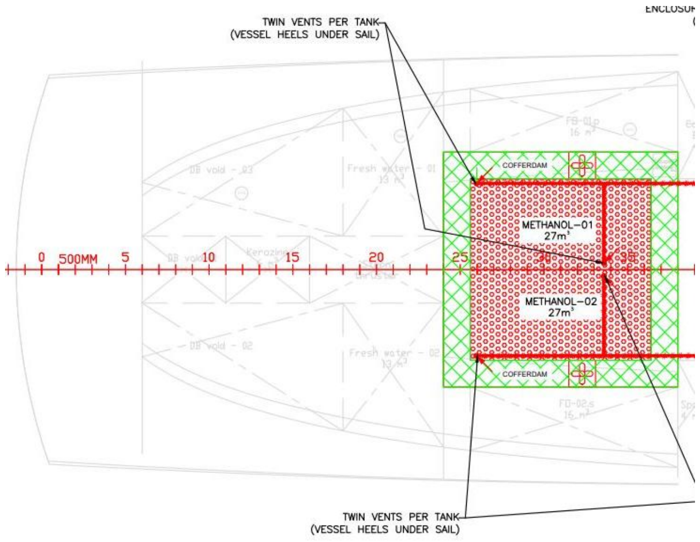


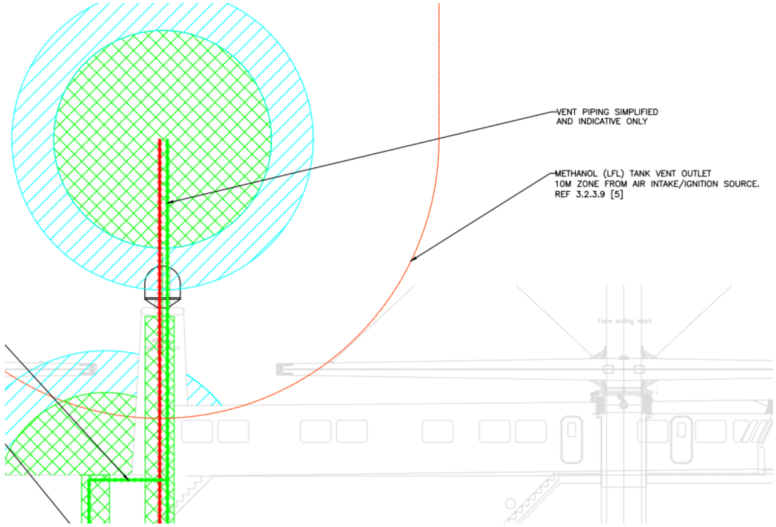


Client:
EU-funded HySeas III & Scottish ferry company Caledonian Maritime Assets (CMAL)

Methanol, hydrogen, battery and wind propelled research vessel

- Longitude developed marine system aspects including compressed hydrogen and methanol.
- Project basic design has been approved by DNV under *Alternative Design Approval* route.
- Project currently being tendered by yards
- Availability of engines suitable for methanol conversion / dual fuel operation in required power bracket.
- Low energy density of methanol and requirement for cofferdams increases volume of hull taken up by tanks.
- Extent of hazardous areas integral to the development of the General Arrangement and ship functionality.
- Space, weight, power and cost of auxiliary systems (tank blanketing, contaminated bilge, ventilation, leak detection) need to be factored in.





Client:
Confidential

Power-to-X

3GW Onshore wind–H_2–Ammonia–Pipeline– Ports

- Site pre-assessment (Canada, ~3 GW wind)
- Owner's lead for Pre-FS
- Pre-FS scope:
  - Wind resource assessment
  - Wind farm works
  - Electrical (incl. transmission & substations)
  - Hydrogen production & storage
  - Review of ammonia plant, pipeline and port
  - Wind equipment ports
  - Sizing & Costs
  - Project plan

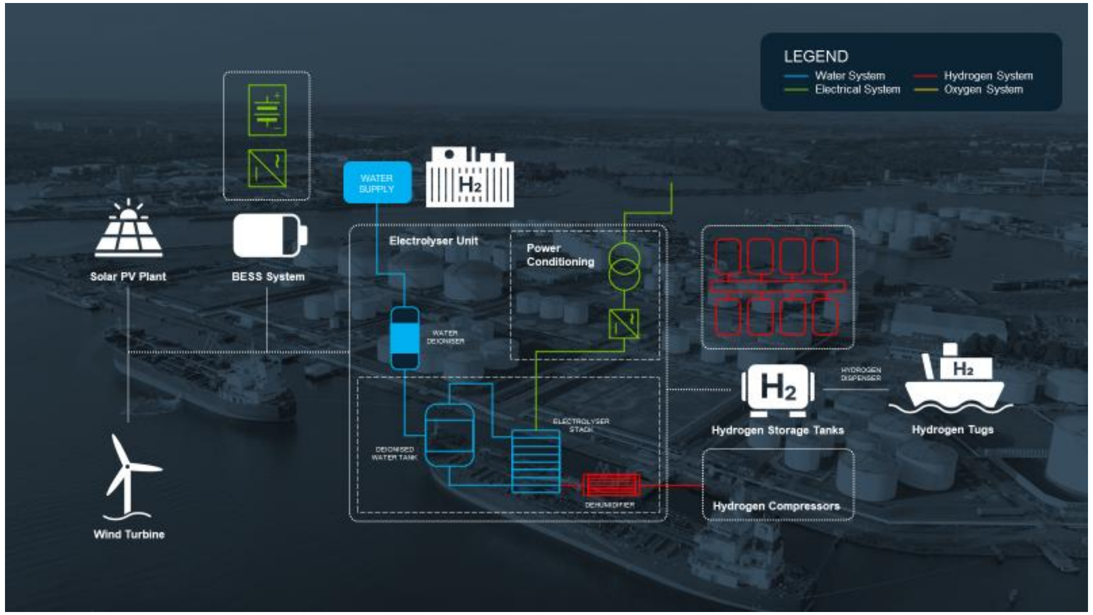
Feasibility of Ammonia-Fueled Ammonia Carrier (AFAC)

- Project is performed on behalf of Japanese interests looking to import green hydrogen from Australia in the form of ammonia.
- Ammonia handling
  - Development of cargo-fuel operational paradigm and safe handling principles and emergency procedures
  - Risk analysis covering the design and operation of AFACs
- Techno-commercial feasibility study addressing costs and impact on greenhouse gas emissions
- Assessment of digital technologies to optimize the AFAC supply chain, including optimization of ship and terminal logistics.

Feasibility Study for Decarbonisation of Tugs in Tanker Operations

Three aspects to the project.

1. Demand side: Evaluation of hydrogen use in port tugs to determine viability of hydrogen tugs and hydrogen demand.
2. Supply side: Hydrogen production and storage from onsite wind and solar PV to meeting hydrogen demand.
3. Economic evaluation of CAPEX and OPEX.



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Client: EGPC

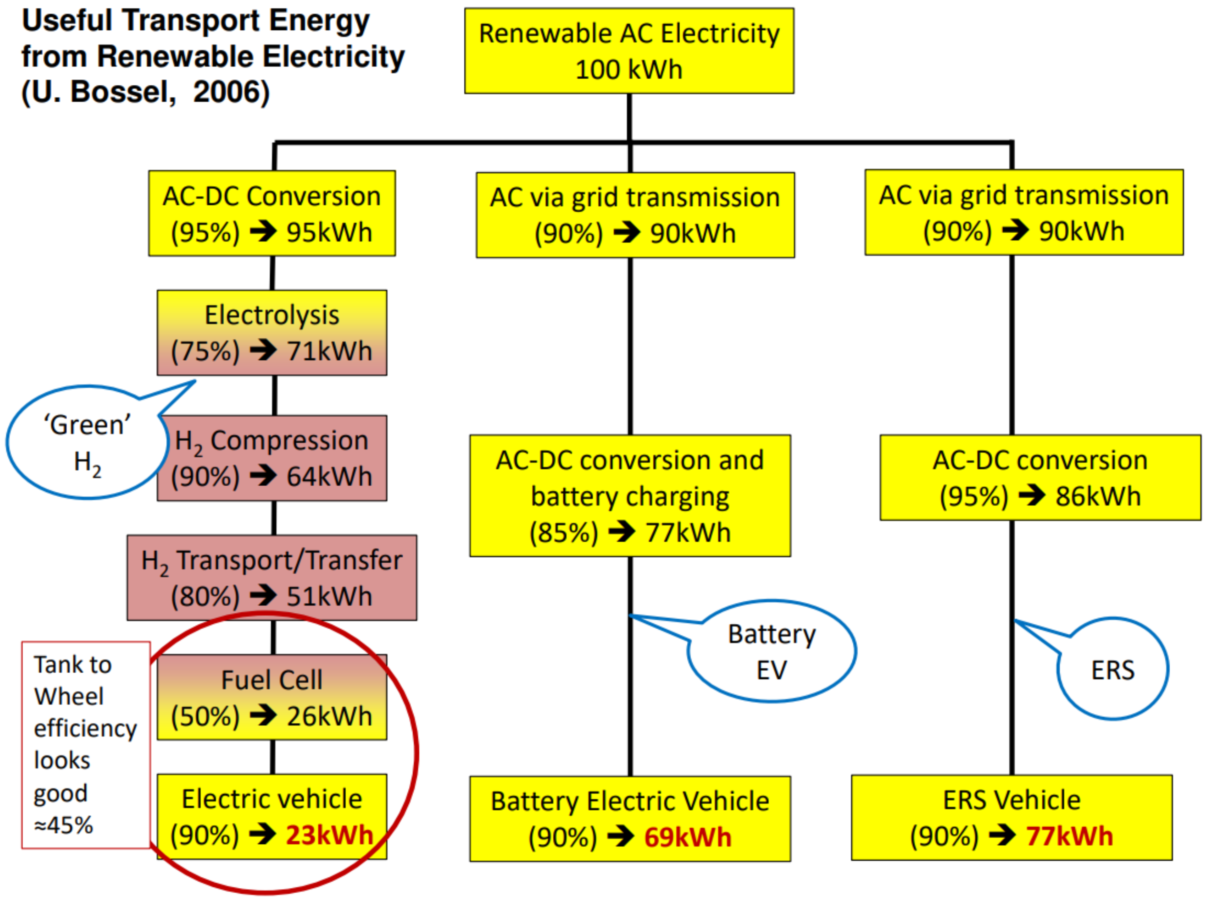
Conclusions

- Alkaline and PEM electrolysers are the main commercially available electrolysers.
  - We have found a tendency in industry for PEM electrolysers where renewable power is used.
  - However, the choice of electrolyser technology needs to be based on the specifics of the project.
  - The pro’s and con’s of each technology for a particular application are not widely or fully understood.
- Electrolyser technology is developing rapidly with novel designs and technologies changing the landscape.
- It is not yet clear which design trade-offs will result in the lowest LCOH.
- OPEX costs of electrical power dominate hydrogen production.
- Our experience in the hydrogen industry suggests:
  - Interest in green hydrogen is expanding rapidly around the globe.
  - The type of work has developed in the last few years from mainly market study, pre-feasibility and small-scale projects to large scale and more detailed design work.
  - As a marine fuel, hydrogen derived fuels such as ammonia and methanol now receive more focus than hydrogen.
  - Initially most projects were stand-alone, however, recently a much greater focus from clients about what the complete hydrogen chain will look like.

- *And now for couple of provocative observations………*

Why is hydrogen a bad idea for road transport

Efficiency



Commentary

- Green hydrogen in a road vehicle is 3 times less efficient
- Even long-distance road transport is better with an Electric Road Transport system
- Cost £19bn

Where can Hydrogen be the “no-regret” solution

Green molecules needed?	Industry	Transport	Power sector	Buildings
No-regret	· Reaction agents (DRI steel) · Feedstock (ammonia, chemicals)	· Long-haul aviation · Maritime shipping	· Renewable energy back-up depending on wind and solar share and seasonal demand structure	· Heating grids (residual heat load *)
Controversial	· High-temperature heat	· Trucks and buses ** · Short-haul aviation and shipping · Trains ***	· Absolute size of need given other flexibility and storage options	
Bad idea	· Low-temperature heat	· Cars · Light-duty vehicles		· Building-level heating

* After using renewable energy, ambient and waste heat as much as possible. Especially relevant for large existing district heating systems with high flow temperatures. Note that according to the UNFCCC Common Reporting Format, district heating is classified as being part of the power sector.

** Series production currently more advanced on electric than on hydrogen for heavy duty vehicles and buses. Hydrogen heavy duty to be deployed at this point in time only in locations with synergies (ports, industry clusters).

*** Depending on distance, frequency and energy supply options

Agora Energiewende, 2021