Offshore Green Hydrogen Production: State of the Art and Hazard Analysis

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Introduction

Green hydrogen, produced using renewable electricity, is as a promising zero-emission energy carrier. Using **offshore wind power** is particularly advantageous due to the strong consistent wind resources.

Transmitting electricity through subsea cables over long distances can be costly and prone to energy losses. Producing hydrogen directly at offshore wind farms offers a compelling alternative: it reduces volatility pressures on the electricity grid and minimizes energy losses through pipeline transport.

However, designing safe and efficient offshore hydrogen production systems presents significant technical challenges.

Methodology

The literature study involves a comprehensive review of current academic papers, technical reports, and industry projects related to offshore green hydrogen production. Key activities include:

- **Current Projects:** Analyzing existing and planned hydrogen production projects, with a focus on projects around the North Sea.
- **Electrolysis Systems**: Reviewing literature to evaluate offshore applicability of various electrolyser technologies.
- **Hazard Analysis:** Examining literature on safety challenges, such as flammability, leakage risks, and explosion resilience.

Objectives

- **Develop a foundational understanding** of offshore green hydrogen production technologies, focusing on electrolysis systems, platform design, and associated safety challenges.
- **Identify the most suitable electrolysis technology** for offshore applications,
- **Evaluate safety challenges unique to hydrogen**, including flammability, leakage risks, and the need for tailored design frameworks to mitigate these hazards effectively.
- **Provide a foundational basis for thesis research** by assessing existing knowledge, identifying gaps, and key challenges in offshore green hydrogen production to inform subsequent research and design efforts.

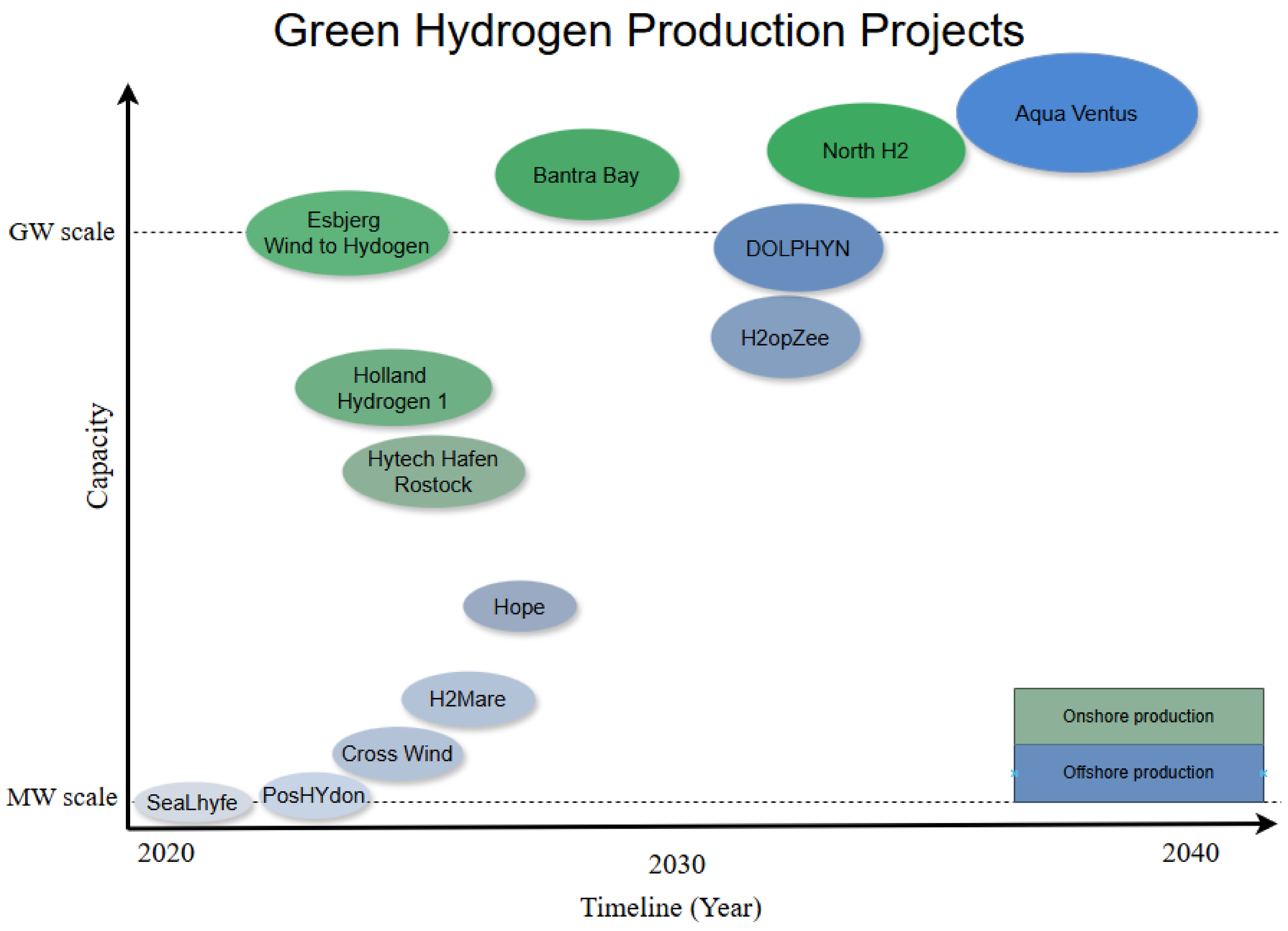
Results

Overview of Hydrogen Production Projects

A visual overview of current hydrogen production projects around the North Sea, comparing project capacities and expected commissioning timelines to highlight emerging trends.

Key observations include:

- Onshore hydrogen production is ahead of offshore development, with GW-scale projects planned before 2030.
- Offshore green hydrogen production platforms are projected to reach GW-scale capacity in the future.



Electrolyser systems

A comparative table provides a snapshot of the key technologies for offshore hydrogen production. The table focuses on operational flexibility, efficiency, and suitability for offshore environments [1].

	AEC	PEMEL	SOE
TRL	9	9	6
Average stack lifetime (Hours)	70,000	55,000	21,250
Electrolyser Unit Footprint (m2/MW)	25	10	30
Operational Flexibility	Limited, ramps 5–25% to 100%	Very fast, ramps 5–25% to 100%	Preferred constant operation
Compatibility with Renewable Energy	Less compatible	Compatible	Less compatible
System Complexity	Low	Moderate	High

Future outlook

- Electrolyser technologies are projected to improve significantly, with SOECs expected to achieve the largest advancements in efficiency, stack lifetime, and CAPEX, making them especially promising for renewable hydrogen production.

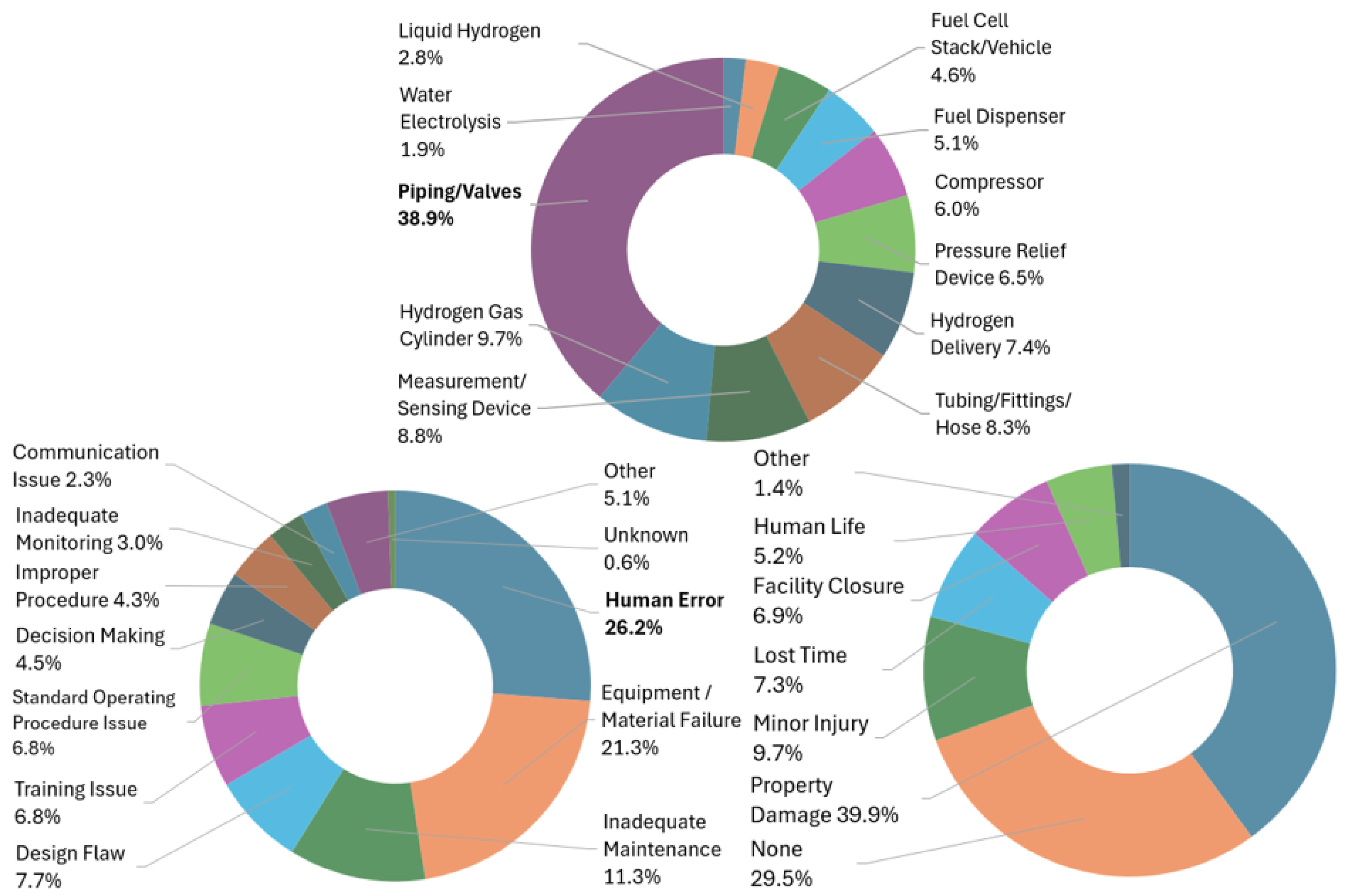
Hazard Analysis for Hydrogen Production

Three graphs illustrate hydrogen leakage related hazards in offshore hydrogen production. Graphs are adapted from El-Kady et al., 2024 [2] . These include:

- Hydrogen leakage contributing equipment (Figure a).
- contributing cause factors of hydrogen leakage (Figure b).
- consequences of incidents (damage and injuries) (Figure c).

Key takeaways:

- Equipment failures (especially in piping and valves due to leakage risk) and human factors are major contributors to hydrogen-related incidents.
- Hydrogen's wide flammability range, high flame speed, and low ignition energy make it inherently more hazardous than methane



Conclusion

Technological advancements

- **PEMEL** is identified as the most suitable technology for offshore hydrogen production due to its compact design and flexibility.
- **Modular design** approaches, integrating electrolysis systems with Balance of Plant , offer scalability and operational efficiency.

Safety and Design Challenges

- **Hydrogen's high flammability, risk of leakage, and explosiveness** present significant safety hazards, requiring robust mitigation.
- **Existing offshore platform design standards lack hydrogen-specific considerations**, emphasizing the need for tailored design frameworks.

Future research

My master thesis focuses on addressing the structural challenges of integrating electrolysis systems in offshore green hydrogen production platforms, with a particular emphasis on mitigating explosion risks. The central research question is:

How can structural design and platform layout be optimized to ensure safety and structural integrity against explosion hazards in offshore green hydrogen production?

References

[1] IEA (2023). Global hydrogen review 2023. Technical report, International Energy Agency.
[2] El-Kady, A. H., Amin, M. T., Khan, F., and El-Halwagi, M. M. (2024). Identification and assessment of risk factors in offshore wind-integrated hydrogen production system. International Journal of Hydrogen Energy, 52:1312–1332.

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