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The Emerging Green Hydrogen Market in Iberia: Exploring Opportunities and Challenges from the Perspective of Copenhagen Infrastructure Partners

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Abstract

Green hydrogen is a critical solution for decarbonizing hard-to-abate sectors and meeting global climate targets. Iberia's abundant renewable energy resources make it a strategic hub for green hydrogen, advanced by Copenhagen Infrastructure Partners (CIP) through two projects: Catalina and Madoqua Power2X. This study integrates engineering and management perspectives examining macro-environmental factors, stakeholder engagement, and CIP's capabilities. Findings reveal that despite favorable political interest and abundant renewables, challenges like limited local offtake agreements, infrastructure gaps, and regulatory uncertainty remain. Future efforts should prioritize demand-side incentives, enhanced integration of stakeholders, and clarifying regulations to advance CIP's expansion in Iberia's green hydrogen sector.

Key Words: Green Hydrogen, Just Transition, Market Entry, Renewable Energy, Stakeholder Engagement

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Introduction

The global commitment to mitigating climate change, reinforced by the Paris Agreement, necessitates substantial reductions in greenhouse gas (GHG) emissions to limit global temperature rise to below 1.5°C compared to the pre-industrial level (IPCC 2023). Green hydrogen has emerged as a key solution for decarbonizing hard-to-abate sectors such as steel, fertilizer, and long-distance heavy transport, aligning with Sustainable Development Goals (SDGs) for clean energy, industrial innovation, and climate action (IEA 2023). Produced through water electrolysis utilizing renewable energy, green hydrogen is emission-free in contrast to grey and blue hydrogen derived from fossil fuels (IEA 2023). Yet, as of 2023, less than 1% of the 97 million tons of hydrogen produced globally was low emission, highlighting the urgent need to scale up green hydrogen (IRENA 2023). Portugal and Spain, with their abundant solar and wind resources, are strategically positioned to become leaders in the European green hydrogen market, supporting the European Union's (EU) Green Deal goal of carbon neutrality by 2050 (Luaces 2024). Existing research highlights the importance of supportive policy frameworks in accelerating green hydrogen adoption. The EU has established ambitious targets to drive green hydrogen development, including the European Hydrogen Strategy (targeting 40 GW of electrolysis capacity by 2030), RePower EU's 20-million-ton of green hydrogen target, and binding renewable fuel standards and quotas set by the Renewable Energy Directive (RED III) (European Commission 2023). However, despite policy support, only 4% of projected global green hydrogen capacity for 2030 has reached Final Investment Decision (FID). Despite the favorable environmental conditions in Iberia, challenges like the additionality requirement persist. To qualify as green, hydrogen must fulfil a series of criteria (Delegate Act): first, hydrogen production must utilize additional renewable electricity capacity (the "additionality" requirement); second, hydrogen generation must align with the timing

of renewable energy generation (the "simultaneity" criterion); and third, the electrolyzer and renewable energy source must be in close geographic proximity (Ruhnau and Schiele 2022). These criteria aim to prevent the diversion of renewable electricity that could otherwise be used more efficiently elsewhere, potentially raising emissions indirectly. However, they also add complexity, have been criticized for prolonged timelines, and may raise investment costs for hydrogen projects within the EU (Collins 2024a). Additionally, the absence of committed offtakers - companies that provide financial certainty through long-term purchase agreements - introduces financial risks, thereby hindering project implementation (CIP 2024).

This study explores the key constraints and enablers of Copenhagen Infrastructure Partners' (CIP) market entry from a developer's perspective, integrating engineering and management approaches. By comparing two projects in Iberia - Catalina and Madoqua Power2X (M2PX) - that face both shared and distinct challenges and opportunities, it provides novel insights into regional dynamics, and political, economic and technical considerations. The research also employs a comparative, interdisciplinary methodology, combining stakeholder perspectives with quantitative modeling which presents a gap in existing literature. Furthermore, it evaluates the interplay between policy frameworks, market conditions, and project-specific technical and environmental factors, offering a comprehensive perspective that has not been addressed by previous research.

Copenhagen Infrastructure Partners (CIP) and Project Overview: Catalina and MP2X

CIP, a Copenhagen-based global leader in renewable energy investment, is advancing green hydrogen development in Iberia. Founded in 2012, CIP manages 12 funds with more than 110 GW renewable energy, and the world's largest clean hydrogen fund with 6.5 GW_E of electrolyzers and over 20GW_E under development (CIP 2024b). CIP recently secured winning bids in the Hydrogen Bank's first auction for two flagship projects: Project Catalina in Spain, and MP2X in Portugal

(VEYT 2024). These projects serve as valuable case studies to explore underlying drivers of the Iberian market. Table 1 summarizes their key characteristics, with further details provided in Appendix B (Catalina 2024; MP2X 2024).

Table 1: Case Projects Overview. Key Information. Project Catalina with a dedicated offtaker and MP2X without offtaker to date.

Project	**Catalina**	**Madoqua Power2X (MP2X)**
Location	Teruel, Spain[1]	Sines, Portugal[2]
COD	2029[3]	2029[3]
Project Partners	Copenhagen Infrastructure Partners, Fertiberia, Enagas renovable, Vestas Wind[1]	Madoqua, Power2X, Copenhagen Infrastructure Partners[2]
Electrolyzer Capacity & Technology	500 MW[1] PEM[4]	500 MW[2] PEM[4]
Energy Source	Onshore Wind & Solar PV Combined[1]	Onshore Wind & Solar PV Combined[2]
Annual Production Target	84,000 tons of green hydrogen[1]	Phase 1 (chosen for this research) 51,000 tons of green hydrogen & 300,000 tons of green ammonia[2]
Water Source	River basin[3]	Desalinated Water[3]
EU grant per kg of H_2 produced	0.48€[4]	0.48€[4]
Offtake segment	Fertilizer Industry & local gas grid[1]	Green ammonia for shipping and fertilizer industry[2]
Offtake agreement	Offtake-Agreement with Fertiberia, remainder to be injected in local Spanish gas grid[1]	No dedicated offtaker to date: Conversion to green ammonia to be exported through the port of Sines, injection in the local Portuguese gas grid[2]
Other Green Hydrogen projects at project site	Not to date[2]	Green H2Atlantic: Galp & EDP[3]

Research Objectives & Analytical Approach

Building on this background, this study aims to address the research question:

How do facilitating and constraining factors influence CIP's expansion into the emerging green hydrogen industry in Iberia?

1. *How do macro-environmental factors and key stakeholders facilitate or constrain CIP?*
2. *How do the availability of local offtake agreements and the water management strategy impact production costs?*
3. *What internal organizational capabilities and strategic factors are enabling or limiting CIP?*

[1] Catalina (2024) Phase 1 is chosen for this research.
[2] Madoqua Power2X (2024)
[3] CIP (2024)
[4] European Commission (2024)

A PESTEL analysis is performed to identify key macro-environmental dynamics shaping the Iberian green hydrogen market. Building on this, the Stakeholder Salience Framework by Mitchell, Agle, and Wood (1997) evaluates the roles and influences of key stakeholders in CIP's projects, providing insights into power dynamics and stakeholder management. The analysis then compares Catalina and MP2X to explore how differences in offtake agreements and water sourcing strategies influence competitiveness. Finally, an internal analysis grounded in the Resource-Based-View (RBV) examines CIP's organizational resources and capabilities to identify strategic opportunities and constraints of its expansion in Iberia (Appendix C).

2. Literature Review

The green hydrogen industry in Iberia is increasingly viewed as a critical element in the EU decarbonization agenda, given its renewable energy potential and strategic location. Existing literature primarily focuses on technoeconomic assessments, production efficiencies, and environmental impacts. Borges et al. (2024) demonstrated that hybrid solar PV and wind systems are optimal for green hydrogen production in Iberia. Their study achieved a Levelized Cost of Hydrogen (LCOH) between €3.13 and €3.48 per kg with renewable-to-electrolyzer power ratios of 2:1 to 3:1. While these findings highlight significant technological advancements, the study does not address how a company's internal capabilities influence project viability, nor does it incorporate perspectives from industry stakeholders due to its limited scope to technical considerations.

A critical challenge lies in the high cost of transporting hydrogen to industrial centers in Germany and the Netherlands, where demand and willingness to pay are higher (Eckl et al. 2022). Although Iberia's abundant solar and wind resources reduce production costs, this reduction is often offset by high expenses associated with transport, conversion processes and technical challenges (Eckl et

al. 2022). Hydrogen's low energy density requires costly compression or liquefaction processes for transport via road or sea, while its small molecular size increases the risks of leakage and material embrittlement, including in existing natural gas pipelines, requiring retrofitting operations (Collins 2024b). To address these barriers, hydrogen is usually converted into derivatives such as ammonia, serving as an interim solution until the Hydrogen Backbone pipeline becomes operational (IEA 2023).

Water management is another critical consideration, particularly in the water-scare context of Iberia. Producing 1 kilogram of hydrogen requires up to 18 liters of water, including transport losses. Simões et al. (2021) analyzed the techno-economic feasibility of treated wastewater and seawater desalination for hydrogen production, identifying treated wastewater as a viable option in urban areas and seawater desalination as an option in Sines. Building on their foundation, this study examines the strategic implications of water management at the project level, while also considering cost advantages from leveraging a firm’s renewable energy capacity.

Existing research on green hydrogen in Iberia primarily focuses on technical, economic, or environmental aspects, often overlooking the complex interplay between external drivers, stakeholder management, and internal organizational resources. Most studies emphasize production efficiencies and cost reductions, neglecting the multifaceted challenges arising at the intersection of operational, strategic, and stakeholder-related factors. This study addresses this gap by adopting an integrated approach, combining engineering and management perspectives to provide a nuanced understanding of the factors influencing the viability of green hydrogen projects in the Iberian Peninsula.

3. Methodology

3.1 Scientific Approach

This study explores the facilitating and constraining factors in the emerging green hydrogen industry using CIP as a paradigmatic case, offering project-specific insights while illustrating broader dynamics of the Iberian green hydrogen industry. Drawing on a mixed-method approach combining primary and secondary data, this research employs an inductive, critical realist methodology to uncover the causal mechanisms shaping the industry. By identifying causal tendencies, critical realism enables cautious predictions and supports actionable recommendations for project and industry development (Elder-Vass 2010). Furthermore, the triangulation employed addresses limited generalizability of two case studies and variability in cost and market estimates by cross-referencing academic and industry perspectives, enhancing validity and reducing bias (Saunders et al. 2023). Further details on the Ontology and Epistemology are in Appendix D.

3.2 Data

The primary data of this study consists of one-on-one, semi-structured interviews and own cost and water projections for the two chosen projects. Interviews were tailored to each participant's role and expertise, ensuring focused and relevant insights (Saunders et al. 2023). An inductive coding method was used to identify patterns and uncover industry dynamics beyond initial expectations, addressing factors that prior research has not fully explored. To capture diverse perspectives, interviewees (Appendix E & I) with various roles from different organizations participated as follows:

1. *Developer:* Morten Kielsen Kopenhagen - Vice President, Global Competence Center, Copenhagen Infrastructure Partners (CIP)
2. *Industry Association:* Osama Fawzy Georgy Henein - Founder, H2lligence Platform & Member of the Board of Advisors, Mediterranean Hydrogen Alliance
3. *Consultant:* Ahmed Abbas - Senior Hydrogen Consultant at Enerdata
4. *Regulator:* Johanna Schiele - Policy Officer Innovation Fund – European Commission
5. *Developer:* Ana Quelhas - Managing Director for Hydrogen at EDP Renewables
6. *Offtaker:* André Fonseca - Production and Operations Innovation Project Manager at Galp
7. *NGO:* Hasler Iglesias - Environmental R&D Researcher at CETENMA

Furthermore, this study draws on diverse secondary sources, including peer-reviewed articles, government roadmaps, and industry analyses. These provide insights into operating efficiencies, cost estimates, and policy and legal developments.

4. Analysis & Results

4.1 Macro-Environmental Drivers and Stakeholder Dynamics in the Iberian Green Hydrogen Industry

4.1.1 Policy Context & Legal Aspects

Building on the EU directives outlined in the introduction, this section examines the national hydrogen strategies of Portugal and Spain.

The Portuguese Hydrogen Strategy (2020) established the foundational targets for hydrogen development in Portugal. The 2024 update of the National Energy and Climate Plan 2030 (PNEC 2030) set more ambitious objectives, including the deployment of 3 GW of electrolyzer capacity and 8.6 GW of additional renewable energy by 2030 to comply with EU additionality requirements. These enhanced targets necessitate a revision of the Hydrogen Strategy to ensure alignment with the updated PNEC 2030 framework (DGEG 2024). Sines is a strategic hub for green hydrogen due

to its deep-water port infrastructure and location for supplying heavy industry. Nationally, the strategy aims to blend 10% (in volume) green hydrogen into the natural gas grid up to 2030 (DGEG 2024). However, a lack of detailed funding and limited local offtake development pose challenges for CIP's MP2X project in securing stable demand.

Spain's Hydrogen Strategy (2020) initially set an electrolyzer target of 4 GW for 2030. The 2024 update of the National Integrated Energy and Climate Plan (PNIEC) raised this target to 12 GW, requiring a revision of the Hydrogen Strategy to incorporate the updated targets (Collins 2024b). Spain's 2021 PERTE ERHA allocated €1.55 billion to green hydrogen, while 2022 legislation exempted electrolyzers from grid charges, reducing costs and improving project feasibility (MITECO 2023).

Despite political support, stakeholders highlight inefficiencies from misaligned hydrogen strategies between Portugal and Spain, such as simultaneous exports, underscoring the need for harmonized frameworks (Developer 2024). At the XXXIV Luso-Spanish Summit (2023), both nations endorsed the H2MED project, including the CelZa infrastructure linking Celorico da Beira and Zamora, projected to export up to 0.75 million ton of hydrogen annually. Both countries also committed to strengthening electrical interconnections to enhance collaboration (H2MED 2024).

Legal barriers significantly hinder green hydrogen development in Iberia, with complex permitting processes, stringent environmental standards, and overlapping agency responsibilities causing delays. The EU's additionality requirement further complicates matters by mandating new renewable power capacity, which is slowed by lengthy permitting in both countries (CIP 2024). The countries could benefit from greater regulatory alignment to streamline procedures, reduce inefficiencies, and enhance Iberia's competitiveness in the hydrogen market. Stakeholders noted a knowledge gap among local authorities regarding green hydrogen projects, leading to

unpredictable regulatory processes (Developer; Offtaker 2024). In response, Portugal plans to introduce a “one-stop-shop” system to simplify procedures, though stakeholders remain cautious due to existing administrative barriers (Developer 2024; Offtaker 2024).

4.1.2 Economic drivers

In 2023, Portugal and Spain ranked 7th and 5th, respectively, in the EU for Foreign Direct Investments (FDI), supported by stable interest rates, benefitting capital-intensive green hydrogen projects (Allianz 2024). Despite this stability, achieving financial viability remains challenging, as Spain and Portugal currently account for only 6.5% and 3.5% of total EU green hydrogen demand, respectively (European Hydrogen Observatory 2024; Enagás 2023). To mitigate risks, developers aim to secure fixed-price, long-term offtake agreements to stabilize demand and reduce price uncertainty before reaching final investment decisions (FID) (CIP 2024). However, stakeholders highlight that limited local demand and the lack of commitment to offtake agreements are primary barriers to reach FID in Iberia (Developer 2024). A Boston Consulting Group (BCG) study revealed that only 3% of potential industry offtakers are willing to commit to green hydrogen contracts beyond five years, leaving early hydrogen developers at financial risk (BCG 2023). While Portugal and Spain have set ambitious hydrogen consumption targets, the exact penalties for each industry are not always clear, discouraging long-term commitments of consumers (Developer 2024). Stakeholders note that direct use of hydrogen is the most cost-effective approach in Iberia, thereby avoiding costly conversion into derivatives like ammonia, reducing reliance on underdeveloped transport infrastructure, and keeping production close to consumers with offtake agreements (Offtaker 2024).

On the supply side, the landscape has transformed significantly. Historically, limited global electrolyzer capacity constrained green hydrogen projects (Developer 2024), but by 2023,

manufacturing capacity reached 31.7 GW globally, including 10.8 GW in Europe, thereby exceeding 2024 delivery projections by over sevenfold (IEA 2024a). However, this rapid expansion has created challenges due to overcapacity and large investments, with only one manufacturer achieving profitability in 2023, highlighting structural issues, that threaten the industry in the long-term (Martin 2024). Additionally, the EU has introduced measures to limit reliance on Chinese electrolyzer suppliers, capping their contribution to 25% of stacks in Hydrogen Bank-funded projects (Regulator 2024). This regulation aims to prevent financial disadvantages associated with prioritizing local sourcing. CIP (2024) highlights the complexity of this balance, noting, “It is challenging to justify to our investors the decision not to purchase from Chinese suppliers when doing so would significantly impact project returns. We therefore expect EU regulation to address this”. Moreover, underperforming technologies pose risks, as demonstrated by this study's sensitivity analysis on the economic impacts of reduced electrolyzer efficiency (Martin 2024). Given the limited current demand and developing supply chain, stakeholders underscore the necessity for collaboration over competition. Shared knowledge, infrastructure, and resources are viewed as critical for establishing a sustainable green hydrogen market in Iberia (Developer 2024).

4.1.3 Social aspects

Green hydrogen holds significant potential to advance just transition efforts in Iberia by promoting economic revitalization and job creation. Both projects, Catalina and MP2X, are situated in former coal power regions, providing opportunities to reskill workers from traditional energy sectors for roles in the hydrogen industry. CIP estimates that MP2X will generate 265 permanent roles, while Catalina highlights 8,000 construction-phase jobs, though long-term employment details remain unspecified (MP2X 2024; Catalina 2024). Beyond immediate job creation, the projects could stimulate the development of local supply chains thereby create indirect jobs, and reduce reliance on imported technologies by establishing a local technology cluster. In addition to socioeconomic

benefits, the projects contribute to decarbonization objectives. Catalina directly supports Spain's decarbonization efforts, whereas MP2X focuses on exporting green ammonia, thereby primarily supporting the decarbonization of other countries (NGO 2024). Green hydrogen also strengthens Iberia's energy security by reducing reliance on imported energy, lowering price exposure to volatile oil and natural gas prices and EU carbon taxes in the long term (Consultant 2024). The EU Just Transition Fund, with a budget of €19.32 billion for 2021 - 2027, supports economic diversification, innovation, workforce upskilling, clean energy, and environmental rehabilitation, offering additional aid for such transformations (European Commission 2023). Achieving a just transition requires equitable policy measures. Stakeholders' express concerns against cross-subsidization that could unfairly burden electricity consumers or non-beneficiaries of the hydrogen sector that could impact local support (Developer 2024).

4.1.4 Electricity Grids, Hydrogen Pipelines and Environmental Factors of Iberia

Iberia's high penetration of solar and wind energy is a key advantage for grid-connected electrolyzers, supporting low carbon intensity and compliance with the Delegate Act for Renewable H_2 standards (AFRY 2024). However, infrastructure remains a primary barrier, particularly due to the absence of a dedicated hydrogen pipeline network, which limits inter-regional trade and connectivity. The H2Med initiative seeks to resolve this barrier by constructing a 703 km hydrogen pipeline connecting Portugal and Spain, forming part of a larger 2,750 km network linking Iberia to central Europe (H2Med 2024). Despite its potential, stakeholders are skeptical of meeting the 2030 completion target, citing regulatory, technical, and financial barriers (Industry Association 2024). Delays in critical infrastructure could constrain CIP's expansion within Iberia and its integration into the European hydrogen market (CIP 2024).

Iberia's abundant renewable energy resources establish it as a strategically advantageous region for hydrogen production. Solar generation peaks during the day and summer, while wind resources complement it at night and in winter, with capacity factors of 19-22% for solar PV, and 25-28% for onshore wind (AFRY 2024). A capacity factor quantifies a power plant's efficiency by comparing its actual energy output to its maximum theoretical potential, determined by resource availability and system performance, with location being critical.

4.1.5 Stakeholders of the Iberian Green Hydrogen Industry

The previously analyzed macro-environmental factors shape the roles, salience, and interactions of key stakeholders in Iberia's green hydrogen sector. Using the Stakeholder Salience Model, stakeholders are identified and categorized based on power, legitimacy, and urgency, which helps prioritize engagement and resource allocation (Mitchell, Agle, and Wood 1997). The stakeholder analysis for CIP identifies three main groups: definitive, dominant, and dependent stakeholders.

Table 2: Stakeholder Typology of CIP in Iberia. Own analysis adapted from "Towards a Theory of Stakeholder Identification and Salience: Defining Principle of Who and What Really Counts" by Mitchell, Agel and Wood, 1997

Stakeholder	Power	Legitimacy	Urgency	Classification
Regulators: EU, National,	High - Regulators control policies, funding, and permitting processes, which are essential for green hydrogen projects.	High - Their formal role aligns with EU climate mandates and national strategies for decarbonization.	High - Delays in policy harmonization and local offtake development present immediate barriers to progress.	Definitive Stakeholder
Offtakers	High - Offtakers' willingness to commit to long-term hydrogen contracts directly impacts financial viability and investment decisions.	High - Their industrial needs for decarbonization align with EU and national climate goals.	High - Early offtake agreements are crucial to achieve project feasibility. Regulatory uncertainty limits offtakers incentives to commit early.	Definitive Stakeholder
Owners & Investors	High - Require financial returns and seek a positive impact that aligns with their values.	High - Investors are formal stakeholders with contractual and fiduciary relationships.	Moderate - CIP's investors are primarily pension funds and insurance companies that expect long-term returns.	Definitive Stakeholder
Suppliers and O&M	Moderate - Stakeholder power varies significantly. Developers have a large dependiency on the few O&M providers, but electrolyzer manufacturers have less power due to overcapacity.	High - Their role is directly tied to the success of hydrogen production.	Moderate - Supply chain delays can hinder project timelines and lead to additional costs, but they do not directly prevent project implementation.	Dominant Stakeholder
Grid Operators	Moderate - They influence access to electricity grids and pipelines, shaping project feasibility and offtaker connectivity. Co-locating production near offtakers or export ports can mitigate this reliance.	High - Their role is critical for operational success and scalability of new projects.	Moderate / High - The timely deployment of transmission infrastructure is crucial for connecting supply and demand, ensuring hydrogen becomes a tradable commodity.	Dominant Stakeholder
Society and Local Communities	High - Communities can support or oppose projects based on job creation, economic development, and perceived environmental impacts.	High - They are directly impacted by project outcomes, particularly in terms of economic opportunities and environmental effects.	High - Addressing community concerns about sustainability and economic equity is essential to ensure local support.	Dominant Stakeholder
NGOs and Environment	Moderate - Environmental groups influence public opinion and regulatory decisions. Their influence is strong when issues such as emissions reductions or water usage become focal concerns.	High - NGOs represent public and moral interests, advocating for sustainability and environmental protection.	High - Reputational risks require immediate action to prevent long-term damage to CIP's brand or project feasibility.	Dependent Stakeholder

Definitive stakeholders are central to CIP's expansion due to their power, legitimacy, and urgency. Among them, regulators hold the highest salience, as their decisions directly influence CIP's ability

to secure permits, access funding, and advance projects. Permitting delays can disrupt hydrogen supply agreements and erode investor confidence by increasing costs and delaying timelines. To address these risks, CIP engages with authorities and participates in policy discussions. Regulatory clarity is critical for attracting offtakers, whose long-term commitments are essential for ensuring demand security, directly impacting project viability (Consultant 2024). However, regulatory uncertainty continues to deter offtakers, highlighting the importance of involving them in workshops or other participatory methods to foster trust and engagement (European Commission 2024). Investors are another definitive stakeholder group, providing the financial resources for large-scale projects. CIP collaborates primarily with institutional investors, including ESG-focused pension funds, who demand long-term returns (CIP 2024). Conflicts can arise between investor priorities, such as cost effectiveness, and local community interests like local sourcing. Regulators are key to mediating such conflicts, ensuring both project viability and sustainability goals.

Dominant stakeholders are critical for project feasibility, influencing location decisions, costs, and offtake opportunities. Local communities can significantly impact the feasibility of projects, either through support or opposition. Their stance often depends on factors such as the project's economic, social, and environmental benefits and negative effects, as well as their perspective on climate change. “Building trust with local communities requires long-term partnerships with organizations, transparent communication, and equitable benefit-sharing. By aligning project goals with community needs, green hydrogen developers can ensure meaningful impact, reduce resistance, and support sustainable development” (NGO 2024). For instance, CIP encountered mixed reactions to the 763 MW Maestrazgo Cluster project in Valencia, where concerns about visual impacts contrasted with expectations of economic benefits and local tax revenue (Cerrillo 2024). Suppliers and O&M providers are critical to ensure operational reliability, but the limited

number of full-service O&M providers in Iberia poses challenges, increasing costs and risks. Additionally, diversifying supply chains and integrating suppliers for key components, such as electrolyzers and hydrogen storage systems, could mitigate risks and enhance efficiency. Grid operators are vital for providing electricity grid access, enabling CIP to sell excess power (CIP 2024). Similarly, pipeline operators, Enagás in Spain and REN Gasodutos in Portugal, are critical for linking production sites to demand centers and facilitating inter-regional trade. Early engagement with these stakeholders is important to align infrastructure development with project requirements, ensuring efficient transmission and minimizing delays.

Dependent stakeholders, though less powerful, hold significant legitimacy and influence public perception. NGOs and environmental groups influence public opinions and regulatory developments. Proactively addressing environmental concerns through collaborations can mitigate reputational risks and protect relationships with key stakeholders. Appendix F provides a stakeholder map visualizing the industry's main drivers and forces.

4.2 Strategic Implications and Sensitivity Analysis for Project Catalina and MP2X: Water Sourcing and Impact of Local Offtake Availability

4.2.1 Catalina

Due to optimal solar and wind conditions, Catalina's location in Teruel offers strategic advantages for green hydrogen (H_2) production. My model estimates capacity factors of 21% for solar PV and 28% for onshore wind, resulting in a levelized cost of electricity (LCOE) of 45.64€/MWh (Appendix G). This value is significantly lower than average Spanish wholesale electricity prices which are around 60-70€/MWh on average, driven by taxes and the need for companies to include profit margins in their pricing structure (BBVA, 2024). Based on these and other inputs (Table 3), the projected LCOH is 4.16€/kg H_2 without subsidies and 3.97€/kg H_2 with the Hydrogen Bank

subsidy. The annual offset of 23 million euros for the first 10 years from the European Hydrogen Bank reduces hydrogen production costs by more than 4%.

Table 3: Project Catalina. LCOH Assumptions. Detailed Sensitivities of the Model can be found in Appendix H.

Category	Parameter	Value	Unit	Description
Financial	WACC	7%	%	Weighted Average Cost of Capital
	Lifetime	20[5]	Years	Expected lifetime of the project
	Hydrogen Bank Subsidy	23,046,381.9[5]	€/yr	Annual support from European Hydrogen Bank for the first 10 years
Operational	Hydrogen Production	84,000,000.0[6]	kg/yr	Annual green hydrogen production
	Electrolyzer Capacity	500[3]	MW	Installed electrolyzer capacity
	Electrolyzer Efficiency	63%[7]	%	Efficiency of the electrolyzer
Cost	CAPEX PEM (without Ammonia unit)	1,800[8]	€/kW	Capital expenditure per kW
	Stack Replacement Cost & Duration	25%[9] | 10 Years[10]	% of CAPEX | Years	Cost for stack replacement as % of CAPEX / Duration in years
	O&M (Operations & Maintenance) | Insurance	5% | 0.5%[10]	% of CAPEX | % of CAPEX	Annual O&M and insurance cost as % of CAPEX
	Electricity Cost	45.64[11]	€/MWh	Levelized cost of electricity
Water	Water cost	0.81€[12]	€/m³	Cost of water per cubic meter
	Water Conversion Factor	14.95[13]	L/kg H_2	Liters of water needed per kg of hydrogen including losses
LCOH	**Levelized Cost of Green Hydrogen**	**3.97**	**€/kg**	**The LCOH is the total cost to produce one kilogram of green hydrogen over a facility's lifetime.**

Catalina's costs align with broader LCOH projections in academia and industry. Maestre, Ortiz V.M., and Ortiz A. (2022) projected the LCOH in Spain between 3.88 – 4.2€/kg H_2 by 2030, depending on the system configuration. McKinsey (2024) estimates an LCOH of 4-5.5€/kg H_2 for Spain by 2030, while the IEA (2023) projects a lower range of 2-3€/kg H_2, driven by more optimistic CAPEX assumptions. However, the results of the model highlight a gap relative to gray hydrogen, which trades between 0.98-2.92€/kg H_2 in Spain (Bloomberg NEF 2023). Electricity cost is the primary driver of LCOH, accounting for 58% of the total, followed by CAPEX at 27%, O&M at 13%, insurance at 1%, and water costs less than 1%. Electricity costs, typically 60-75%

[5] European Commission (2024)
[6] Project Catalina (2024)
[7] Kumar & Himabindu (2019)
[8] IRENA (2020)
[9] US Department of Energy (2020)
[10] Deloitte (2021): Fueling the Future of mobility: Hydrogen Electrolyzers
[11] Based on own LCOE Model (As shown in Appendix)
[12] MITECO (2024)
[13] Simões et al. (2021)

of LCOH in academic estimates (Ruhnau and Schiele 2022), are slightly lower for project Catalina due to its strategic location, offering high load factors. A sensitivity analysis reveals that a 10% increase in LCOE would increase LCOH by 6.3%. Moreover, increasing electrolyzer efficiency from 63% to 90% reduces LCOH by 18.14%. The feasibility of achieving 90% electrolyzer efficiency has been demonstrated in recent studies, such as (Martin 2023), which highlights technological advancements that start making such high efficiencies attainable. Similarly, Zun and McLellan (2023) found that a 30% efficiency gain lowers LCOH by 21.8%, reinforcing this cost-saving potential (Appendix H). While the final offtake price for the project remains undisclosed, the projected gross margin per kilogram of hydrogen is estimated at 15.53%. This projection is based on Aurora Energy Research's forecasted hydrogen price of 4.70 €/kg H_2 by 2030 (Luaces 2024). It suggests a competitive position with further potential cost improvements, especially in electrolyzer efficiency and energy sourcing.

Catalina is set to source water from the Ebro River basin, a 320 km² wetland area and an economically viable choice due to the affordability of surface water in Spain (CIP 2024). Water consumption in hydrogen production can be attributed to three main factors: breaking down water molecules, reject water from demineralization, and losses from vapor and cooling systems (Fundación Nueva Cultura del Agua 2023). The project's electrolyzers will require approximately 1,255,800m³ of water annually to produce 84,000 tons of green hydrogen. While this amount represents only 0.017% of the 7,310 million m³ used annually by agriculture in the region (MITECO 2023; Instituto Nacional de Estadística 2024), this demand could further increase due to the uncertainty of water losses (EU Knowledge Hub for Water 2021). Moreover, relying on the Ebro basin for water brings inherent challenges, particularly in the context of competing demands from other sectors, such as agriculture, which heavily relies on the basin for irrigation. Seasonal changes and climate-induced reductions in water flow, as projected over the project's 20-year

lifespan (IPCC 2023), are expected to intensify challenges related to water scarcity. These pressures could be further exacerbated by the development of additional hydrogen projects in the region, leading to increased competition for limited water resources and potential cumulative effects. While industrial water costs in Aragón are currently around 0.81 €/m³, this rate only covers 91% of direct financial costs and 63.3% of environmental costs in the region, indicating that externalities are not fully reflected in the pricing and are therefore paid by society (MITECO 2023). Addressing these challenges requires a forward-looking water management strategy that emphasizes sustainability and inclusivity. Utilizing alternative water sources can reduce conflicts with local sectors, improve resource efficiency, and mitigate cost fluctuations.

4.2.2 MP2X

In contrast to Project Catalina, MP2X faces additional costs for converting a share of hydrogen into 300,000 tons of green ammonia (NH_3) for export due to limited local offtake. The project also incurs additional expenses for water desalination, which is being explored as a strategic opportunity due to the project's proximity to the Atlantic Ocean. While desalination is not explicitly mandated by the Portuguese government, projects that incorporate sustainable water sourcing are prioritized, particularly in strategically important locations (DGEG 2024). The higher annual production target of MP2X contributes to offsetting a share of these incremental costs. MP2X benefits from a slightly higher wind power load factor of 29%, in contrast to the 28% observed at Catalina, while the PV load factor at Sines is relatively lower, at 18%, compared to Catalina's 21%.

Table 4: Project MP2X. LCOH Assumptions. Detailed Sensitivities of the Model can be found in the Appendix H.

Category	Parameter	Value	Unit	Description
Financial	WACC	7%	%	Weighted Average Cost of Capital
	Lifetime	20[15]	Years	Expected lifetime of the project
	Hydrogen Bank Subsidy	24,520,000[14]	€/yr	Annual support from European Hydrogen Bank for the first 10 years
Operational	Hydrogen Production	104,400,000[15]	kg/yr	Annual green hydrogen production
	Electrolyzer Capacity	500[16]	MW	Installed electrolyzer capacity
	Electrolyzer Efficiency	63%[17]	%	Efficiency of the electrolyzer

[14] European Commission (2024)
[15] Own calculation based on MP2X Website & The Oxford Institute for Energy Studies (2024)
[16] Madoqua Power2X (2024)
[17] Kumar & Himabindu (2019)

Cost	CAPEX Hydrogen Electrolyzer	1,800[18]	€/kW	Capital expenditure per kW
	Stack Replacement Cost & Duration	25% | 10 Years[19]	% of CAPEX | Years	Cost for stack replacement as % of CAPEX / Duration in years
	O&M (Operations & Maintenance) | Insurance	5% | 0.5%[20]	% of CAPEX | % of CAPEX	Annual O&M and insurance cost as % of CAPEX
	Electricity Cost	47.83[21]	€/MWh	Levelized cost of electricity
Water	Water cost[22]	1.70[23]	€/m³	Cost of water per cubic meter
	Water Conversion Factor	14.95[24]	L/kg H_2	Liters of water needed per kg of hydrogen including losses
LCOH	**Levelized Cost of Green Hydrogen**	**3.79**	**€/kg H_2**	**The LCOH is the total cost to produce one kilogram of green hydrogen over a facility's lifetime.**

My model estimates an LCOH of 3.94€/kg H_2 for MP2X without subsidies and 3.79€/kg H_2 with subsidies, driven by an annual hydrogen production volume of 104,400t H_2. This estimate aligns with projections from academia and industry but adopts a slightly more conservative approach. For example, Agora Industry projects an LCOH of 3.20€/kg H_2 in Sines by 2030, while the IEA estimates a range of 2–3€/kg H_2, driven by more optimistic CAPEX assumptions (Agora 2024; IEA 2024). MP2X supplies both 51,000t H_2 for direct use and 300,000t NH_3, optimizing cost efficiencies through economies of scale. The projected levelized cost of green ammonia (LCOA) in my model is 829.50 €/t NH_3 for foreign demand centers before transport, increasing to 954.47€/t NH_3 when accounting for shipping to Rotterdam. Although no specific offtaker is confirmed to date, CIP's memorandum of understanding with the Port of Rotterdam and the Portuguese government to establish a "green corridor" makes Rotterdam a logical target market for my study (Ullyett 2024). Based on an assumed offtake price of 1,030€/t[25], my model forecasts a gross margin of 7.55% (Gupta 2024). This margin is sensitive to additional costs depending on the offtaker location. Sensitivity analysis reveals that hydrogen costs and transport distance significantly impacts the LCOA at final user. A 10% increase in the LCOH, from the current 3.79€/kg H_2 to 4.17€/kg H_2, raises the LCOA from 829.50€/t NH_3 to 897.52€/t NH_3 (+8.2%) at an ammonia-specific CAPEX of 680€/t. Similarly, a 10% increase in the ammonia-specific CAPEX, from 680€

[18] IRENA (2020)
[19] US Department of Energy (2020)
[20] Deloitte (2021)
[21] Based on own LCOE Model (As shown in Appendix G)
[22] Desalination Assumptions are provided in Appendix G.
[23] Own calculation based on desalination model (Table 6)
[24] Simões et al. (2021)
[25] Aurora Energy Research current offtake price in NL (2023)

to 748€, increases the LCOA from 829.50 €/t NH_3 to 842.68€/t NH_3, less than 2%. This indicates that the LCOH is the primary cost driver of green ammonia production, far outweighing the impact of CAPEX. Lowering hydrogen production costs is therefore crucial to reducing ammonia production costs and improve competitiveness. Furthermore, at a freight rate of 0.06€/km, based on Galimova et al. (2023), costs increase from 859.50 €/t NH_3 for a 500 km journey to 1,039.50 €/t NH_3 for 3,500 km. Benchmarking the results of my model suggests that the projected cost is on the higher end of academic estimates but remains competitive when compared to actual offtake agreements: Nosherwani and Neto (2021) estimated green ammonia production costs in coastal Germany between 635 - 819€/t NH_3 for 2030; Moritz, Schönfisch, and Schulte (2023) modeled costs ranging from 624 - 874€/t NH_3 for Germany; and Hydrogen Europe estimates the LCOA of 891€/t NH_3 at a LCOH of 5€/kg H_2 (Bonnet-Cantalloube et al. 2023). However, recent market data suggests that offtake agreements may exceed academic estimates: Germany's tender awarded to Fertiglobe for the supply of 259,000t NH_3 from Egypt from 2027 set a price of 1,000 €/t NH_3, including transport costs (Enerdata 2024).

Table 5: Project MP2X. Main LCOA & Transport Assumptions. Detailed Sensitivities of the Model can be found in Appendix H.

Category	Parameter	Value	Unit	Description
Financial	WACC	7%	%	Weighted Average Cost of Capital
	Ammonia CAPEX | OPEX	600€[26] | 5%[28]	€/ton | %	CAPEX per ton; OPEX as % of CAPEX
	Storage CAPEX | OPEX	10%[26] | 5%[28]	%	Cost of storage based on CAPEX in %, Storage OPEX as % of Capex
Operations & Cost	Annual Ammonia Output	300,000[27]	tons	Annual green ammonia production
	Electricity Demand	640[26]	kWh/ton	Energy per ton
	Hydrogen Demand | Cost	179[28]| 3.80€[29]	kg H2/ t | NH3/€	H2 required per NH3 ton; H2 cost per kg
	Nitrogen Demand | Cost	830.7 | 0,14[31]	kg N2/t NH3 | €/kg N2	N2 required per NH3 ton; N2 cost per kg
Transport	Transport Cost | Sea distance	0.06€[30] | 2,048.65[31]	€/ton/km | km	Cost per ton per km; distance Sines-Rotterdam
LCOA	**Levelized cost of Ammonia**	**954.47**	**€/t**	**Levelized cost of green ammonia including transport from Sines to the Port of Rotterdam**

[26] Souissi (2024) The Oxford Institute for Energy Studies.
[27] Madoqua Power2X (2024)
[28] Ahmed et al. (2024)
[29] Own calculation based on LCOH Model
[30] Galimova et al. (2023)
[31] Sea distance Sines-Rotterdam based on Sea Rates by DP

MP2X requires approximately 1,560,780 m³ of water annually to produce 104,400 tons of green hydrogen. Unlike Catalina, which relies on local river sources, MP2X is expected to use desalinated water from the port of Sines (CIP 2024). In my model, which considers transport losses and other operational factors, the levelized cost of water (LCOW) for MP2X is projected at 2.09€/m^3 of desalinated water (Appendix G). This cost is over twice that of Catalina's water supply despite MP2X's larger hydrogen output. However, the overall financial impact on project costs remains modest due to water's minimal contribution to total expenses. Given the proximity of MP2X to other green hydrogen projects, potential partnerships could reduce infrastructure expenses through shared resources. Stakeholders have expressed the opportunity to share infrastructure, provided that shared use does not introduce additional risks (Developer 2024; Offtaker 2024).

4.3 Resources and Competitive Advantages of CIP in Iberia through a Resource-Based View (RBV)

This section evaluates CIP's internal capabilities and sustainable competitive advantages from a Resource-Based-View, illustrating how these assets enable CIP to overcome industry-specific obstacles and effectively leverage opportunities in the Iberian market.

Key Tangible & Intangible resources: CIP's renewable energy portfolio is a cornerstone of its tangible assets, with a global pipeline of 120 GW of of renewable power capacity. This includes the 487 MW Monegros project under operation in Aragón, comprising 12 onshore wind farms strategically located near Catalina. The close geographical proximity between the Monegros wind farms and Project Catalina offers the opportunity to utilize surplus energy, which can be used for hydrogen production, preventing curtailment of wind energy during periods of grid bottlenecks (CIP 2024). CIP also benefits from access to critical infrastructure, such as the port of Sines in Portugal, facilitating hydrogen export and distribution; however, this access is not unique to CIP, as other developers share similar advantages. CIP has built a strong brand underpinned by financial

strength, innovation, and an exclusive focus on renewable energy investments. This alignment between sustainability and brand value is well-documented in research. Rasche (2017) found that prioritizing sustainability enhances brand value, as it mitigates reputational risks and appeals to environmentally conscious investors. This relationship is evident in CIP's strategy, which not only attracts ESG-focused investors but also enables the company to develop large-scale renewable energy projects. "Addressing environmental concerns is crucial for attracting investors who are increasingly focused on environmental impact. In fact, it is often the investors who are driving this agenda" (CIP 2024). By leveraging its scale advantage, including the largest green hydrogen pipeline globally and one of the largest installed wind capacities in Iberia, CIP strengthens its competitive position. This scale enhances bargaining power with stakeholders, enabling greater operational efficiencies and cost reductions, reinforcing its position as a market leader.

Key Capabilities: CIP's technical expertise in developing and managing renewable energy projects, supported by a skilled in-house team of engineers and project managers, ensures efficient execution and fosters innovation. However, in Iberia, these capabilities are considered a competitive parity, as established players like EDP in Portugal and Iberdrola in Spain have long cultivated similar expertise (Developer 2024). A strong understanding of local regulatory frameworks in Spain and Portugal and the EU mandates further enhances CIP's ability to navigate legal complexities. CIP's success in the Hydrogen Bank auctions and the permits for Catalina and MP2X demonstrate a competitive advantage, because few companies have a similar understanding of the requirements and the necessary resources to develop these capabilities. CIP's ability to build and leverage strategic partnerships with developers and offtakers, alongside its inclusion of local stakeholders, represents two additional key competitive advantages. Its experience in Iberia's onshore wind sector has facilitated partnerships like the one with Fertiberia and strengthened its

ability to engage stakeholders, such as farmers and environmental advocacy groups, to mitigate project opposition. These capabilities, which require significant time and effort to develop, enable CIP to effectively collaborate with local communities, foster trust, and ensure projects align with regional needs, reducing risks and enhancing project acceptability. Table 6 provides a summary of the identified sustainable competitive advantages and competitive parities.

Table 6: VRIO of CIP: Own construction based on (Barney 1991)

Resource and capability	Valuable	Rare	Imitable	Organizational	
Renewable Energy Portfolio	Yes	No			**Competitive parity**
Access to critical infrastructure	Yes	No			**Competitive parity**
Brand value	Yes	yes	yes	yes	**Sustainable competitive advantage**
Ability to attract investors	Yes	Yes	Yes	Yes	**Sustainable competitive advantage**
Scale advantage	Yes	Yes	Yes	Yes	**Sustainable competitive advantage**
Highly skilled employees	Yes	No			**Competitive parity**
Technological expertise & Innovation	Yes	No			**Competitive parity**
Talent to manage tender/auction systems	Yes	Yes	Yes	Yes	**Sustainable competitive advantage**
High level of partnership	Yes	Yes	Yes	Yes	**Sustainable competitive advantage**
Inclusion of local stakeholders	Yes	Yes	Yes	Yes	**Sustainable competitive advantage**

Addressing Weaknesses: Despite its experience in Spain's onshore wind sector, CIP lacks the deep local knowledge and long-standing relationships of established players like EDP in Portugal and Iberdrola in Spain. As CIP (2024) acknowledges, "We are highly dependent on local resources, advisors, and partners to successfully complete projects." In Portugal, Galp has leveraged its decades-long presence in Sines to repurpose existing infrastructure and maintain strong community ties, supporting the energy transition while preserving jobs and fostering local acceptance. For CIP, replicating this level of engagement remains a challenge due to its relatively recent entry into the Portuguese market. Developing long-term relationships and building local trust will be critical for CIP's success in overcoming this constraining factor.

5. Final Remarks

This study concludes that CIP's expansion into the Iberian green hydrogen market is facilitated by the region's abundant renewable energy resources, a supportive, yet moderately ambiguous, policy framework, and CIP's internal resources and capabilities, such as expertise in large-scale renewable energy projects and strong partnership capabilities. However, significant challenges persist, including limited infrastructure, high production costs, regulatory uncertainties and obstacles such as permits for new renewable energy projects, as well as the absence of local offtake agreements. Collaboration with key stakeholders is essential for CIP to address regulatory uncertainties, secure demand-side commitments, aligning with community and operational priorities, and embedding sustainability into projects.

The model of the study revealed that MP2X's larger production volume minimizes the additional costs from the lack of a local offtaker and reliance on desalination, achieving an LCOH of 3.79€/kg compared to 3.97€/kg for Catalina. While sustainable water sourcing has minimal impact on overall costs, the absence of a local offtaker significantly increases risks, as the LCOA is sensitive to transport distance and expenses. To overcome this barrier, CIP should continue to explore opportunities for local offtake opportunities in Portugal to mitigate risks. Notably, the annual ammonia production of MP2X accounts for 25.89% of Portugal's annual marine bunker fuel demand[32], underscoring the potential for local demand as the shipping industry increasingly adopts renewable fuels such as green ammonia (DGEG 2024).

[32] DGEG (2024) Based on a Tons Equivalent of 702,510 of International Marine Bunkers in Portugal (2022) and an assumed Lower Heating Value of Ammonia of 21.48 MJ/kg

This study also identifies that CIP has several competitive advantages that facilitate its expansion in Iberia, particularly its brand value, capability to develop large-scale renewable energy projects, and partnership capabilities. The early-stage nature of the green hydrogen industry allows CIP to shape foundational aspects of the market collaboratively with stakeholders. By engaging proactively with stakeholders, CIP can address uncertainties, influence market development, and embed strategic priorities into the industry's foundation. This could include prioritizing local supply chain development to reduce dependency on imported technologies and implementing sustainable water sourcing practices to address potential resource conflicts in water-scarce regions. As the industry matures, addressing these challenges proactively strengthens CIP's position in Iberia's emerging green hydrogen market while advancing broader decarbonization objectives.

Limitations & Further Research

This study examines two projects that provide insights into the Iberian green hydrogen market but may have limited applicability to other regions due to their unique characteristics. Projections of costs and infrastructure timelines depend on assumptions that could change with evolving market and regulatory conditions. Additionally, the reliance on stakeholder perspectives introduces subjectivity, as insights reflect specific interests of interviewees. Moreover, the industry is in its early stages, with limited long-term data on operational performance, cost trends, and market dynamics, constraining accurate forecasts of long-term viability and scalability.

Future research should focus on de-risking the demand side of green hydrogen projects through demand-side support mechanisms. Research into sustainable water sourcing and local supply chain development is also critical for addressing environmental constraints, mitigating resource competition, including renewable resources for national decarbonization, and fostering community acceptance as integral components of a just energy transition.

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7. Appendix

Appendix A: Abbreviations

BCG	Boston Consulting Group
CAPEX	Capital Expenditure
CIP	Copenhagen Infrastructure Partners
DGEG	Direção-Geral de Energia e Geologia (Directorate-General for Energy and Geology, Portugal)
EHB	European Hydrogen Bank
ESG	European Hydrogen Bank
EU	European Union
FDI	Foreign Direct Investment
FID	Final Investment Decision
GHG	Greenhouse Gas
H2	Hydrogen
H2Med	Hydrogen Pipeline Network Connecting Iberia to France
IEA	International Energy Agency
IRENA	International Renewable Energy Agency
LCOA	Levelized Cost of Ammonia
LCOE	Levelized Cost of Electricity
LCOH	Levelized Cost of Hydrogen
MITECO	Ministerio para la Transición Ecológica y el Reto Demográfico (Ministry for Ecological Transition, Spain)
MP2X	Madoqua Power-to-X
NGOs	Non-Governmental Organizations
O&M	Operations and Maintenance

OPEX	Operational Expenditure
PEM	A PEM (Proton Exchange Membrane) electrolyzer is a device that utilizes a proton-conducting polymer membrane to split water into hydrogen and oxygen using electricity, serving as a critical technology for green hydrogen production when powered by renewable energy.
PERTE ERHA	Proyecto Estratégico para la Recuperación y Transformación Económica – Energías Renovables, Hidrógeno Renovable y Almacenamiento (Strategic Project for Economic Recovery and Transformation – Renewable Energies, Green Hydrogen, and Storage)
PNIEC	Plan Nacional Integrado de Energía y Clima (National Integrated Energy and Climate Plan, Spain)
PNEC	Plano Nacional de Energia e Clima (National Energy and Climate Plan, Portugal)
PV	Photovoltaic
RBV	Resource-Based-View
RED II	Renewable Energy Directive II
RED III	Renewable Energy Directive III
REPowerEU	European Commission's Plan to Make Europe Independent from Russian Fossil Fuels Before 2030
RFNBO	Renewable Fuel of Non-Biological Origin
SAF	Sustainable Aviation Fuel
SDGs	Sustainable Development Goals
WACC	Weighted Average Cost of Capital

Appendix B: Background of Copenhagen Infrastructure Partners, Project Catalina & MP2X

i. Copenhagen Infrastructure Partners

Copenhagen Infrastructure Partners (CIP) is a leading global fund manager specializing in renewable energy infrastructure investments (CIP 2024a). “Established in 2012, CIP focuses on developing and managing large-scale renewable energy projects, including offshore wind, onshore wind, solar photovoltaic (PV), energy storage, and emerging technologies such as green hydrogen and Power-to-X (PtX) solutions” (CIP 2024a). The company’s mission is to advance the global energy transition while delivering strong financial returns to its institutional investors, which include pension funds and insurance companies.

CIP operates an innovative investment model through its Copenhagen Infrastructure Funds (CIFs), enabling long-term commitments to renewable energy projects with significant upfront costs. With a global presence spanning Europe, North America, Asia-Pacific, and Latin America, CIP has established itself as a key player in the renewable energy sector, contributing to the international effort to decarbonize energy systems and reduce greenhouse gas emissions (CIP 2024).

Technological leadership is a hallmark of CIP’s strategy. The company is at the forefront of developing next-generation renewable energy technologies, particularly in green hydrogen and PtX, which are critical to decarbonizing hard-to-abate sectors such as heavy industry and transportation (IEA 2023). Project Catalina in Spain and Project MP2X in Portugal exemplify CIP’s approach to integrating green hydrogen production with renewable energy assets. These projects aim to reduce reliance on fossil fuels, align with EU climate goals, and establish CIP as a leader in sustainable energy solutions (European Commission 2024).

CIP's success is underpinned by its deep expertise in renewable energy. With over 7 GW of wind capacity in its portfolio and a track record of developing and operating large-scale renewable energy assets, CIP has a strong competitive advantage in managing the cost structures and complexities of such projects. Its first-mover advantage in green hydrogen, particularly in strategic locations like Aragon and Sines, provides access to prime sites, critical infrastructure, and valuable partnerships, positioning CIP ahead in a rapidly growing market.

Sustainability is a core element of CIP's operations. The company integrates Environmental, Social, and Governance (ESG) principles into its investment strategy, ensuring that its projects contribute to climate goals while supporting local economies. CIP emphasizes stakeholder collaboration, workforce reskilling, and regional economic development, particularly in areas transitioning from fossil fuels to renewable energy. This commitment enhances its appeal to ESG-conscious investors and strengthens its alignment with global sustainability priorities. (CIP 2024)

Despite its strengths, CIP faces challenges, including balancing cost efficiency with sustainability commitments, particularly when regional sourcing increases costs compared to international suppliers like those in China. Additionally, the evolving regulatory landscape for green hydrogen presents risks that require proactive management. However, CIP has significant opportunities to leverage EU subsidies and incentives for green hydrogen and PtX projects and to collaborate with stakeholders on shared infrastructure, enhancing cost efficiency and reducing emissions. (CIP 2024)

Copenhagen Infrastructure Partners exemplifies leadership in renewable energy infrastructure, combining innovation, sustainability, and strategic foresight. Its investments in green hydrogen and PtX projects demonstrate a commitment to decarbonizing critical sectors and driving the energy

transition. With its expertise, scale, and forward-thinking approach, CIP is well-positioned to shape the future of renewable energy infrastructure globally. (CIP 2024)

ii. Background of Project Catalina

Project Catalina is a pioneering green hydrogen project that is currently under development in Teruel, Spain. Catalina is developed by a consortium consisting of developers (Copenhagen Infrastructure Partners, Renato Ptx Holdco), offtakers (Fertiberia, Enagas), and suppliers (Vestas Wind), thereby de-risking it for the developers (Catalina 2024). The project will feature a total capacity of 1.1 GW, consisting of 504 MW of onshore wind and 571 MW of solar photovoltaic generation (Catalina 2024). It recently won in the first European Hydrogen Bank auction, receiving a total of 230,463,819€ during the first ten years of its operation (European Commission 2024). This energy is directed to a 500 MW electrolyzer, which is aimed to produce over 84,000 tons of green hydrogen annually. Catalina's infrastructure includes a 221-km pipeline, facilitating the efficient transport of hydrogen. The project promises significant environmental and socioeconomic benefits for the region. The project aims to mitigate more than 3.1 million tons of CO_2 emissions within the first decade of its operation (Catalina 2024). This positions Catalina as a critical contributor to Spain's decarbonization objectives, particularly in addressing emissions from hard-to-abate sectors. The use of green hydrogen also underpins sustainable agricultural practices, offering a pathway to produce CO_2-free fertilizers. With operations scheduled to commence by 2029 and a total capital investment exceeding €2.35 billion, the project exemplifies the alignment of environmental goals with economic growth. The anticipated local benefits include the creation an anticipated number of 8000 jobs during the construction phase. The project's design reflects a strategic approach to meeting regional and national hydrogen demands; it is capable of supplying

over 100% of Aragón's projected hydrogen consumption while addressing approximately 15% of Spain's overall hydrogen requirements (Project Catalina 2024).

iii. Background of Project MP2X

Project Madoqua Power to X is 500MW green hydrogen project that is currently under development in the industrial zone of the port of Sines with a planned COD in 2029. The project is being developed by three developers, the Portuguese Madoqua, Dutch Power to X and the Danish company Copenhagen Infrastructure Partners (MP2X 2024). Unlike Project Catalina, this project lacks a dedicated offtaker, requiring a significant portion of the hydrogen to be converted into green ammonia at the developers' expense (MP2X 2024). The ammonia is then expected to be shipped to industrial offtakers via the Port of Rotterdam. MP2X is the second project of Copenhagen Infrastructure Partners that won in the first European Hydrogen Bank Auction. MP2X will receive a total subsidy of 245,178,772 during the first 10 years of the project's operations. MP2X is a green hydrogen and renewable ammonia project based in Portugal's Sines Industrial and Logistics Zone (ZILS). A collaboration between Madoqua Renewables, Power2X, and Copenhagen Infrastructure Partners (CIP), the project aims to harness Portugal's renewable energy resources for large-scale production (MP2X 2024). MP2X is projected to create 265 direct jobs and over 6,000 indirect jobs, contributing to sustainable economic growth in the Alentejo region. MadoquaPower2X is strategically positioned to support the decarbonization of various sectors, including maritime fuels, by establishing a green corridor between the Port of Sines and Northern Europe. This initiative is expected to facilitate reliable, large-scale supply chains for green ammonia and hydrogen, meeting the growing demand for sustainable fuels in the shipping industry and beyond (MP2X 2024).

Appendix C: Brief Explanation of Applied Theories

i. Stakeholder Salience Theory

Mitchell, Agle, and Wood (1997) developed the Stakeholder Salience Theory, offering a framework to identify and prioritize stakeholders by evaluating three key attributes:

1. **Power:** The extent to which a stakeholder can influence the organization, either by providing or withholding resources or imposing their will (Mitchell, Agle, and Wood 1997).

2. **Legitimacy:** The degree to which the stakeholder's claims or involvement with the organization are perceived as appropriate, proper, or valid (Mitchell, Agle, and Wood 1997).

3. **Urgency:** The urgency of a stakeholder's claim, determined by its time-sensitivity and critical importance (Mitchell, Agle, and Wood 1997).

The theory suggests that stakeholders who possess one, two, or all three of these attributes will demand different levels of attention from managers. Those with all three attributes are deemed the most salient and require the highest priority (Mitchell, Agle, and Wood 1997). This helps organizations prioritize stakeholders and allocate resources effectively in response to their influence and needs (Mitchell, Agle, and Wood 1997).

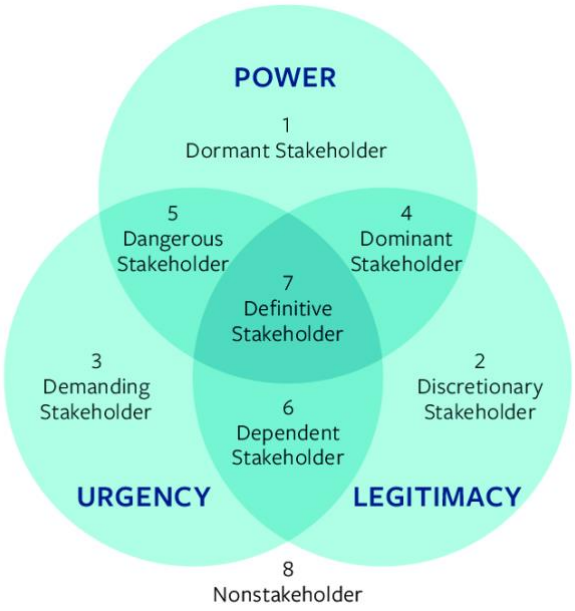

Figure A 1. The Stakeholder Salience Model by Mitchell, Agle, and Wood (1997)

ii. PESTEL

The PESTEL analysis is a comprehensive strategic framework employed to systematically evaluate the macro-environmental factors that shape and influence the operations and strategic direction of an organization, project, or industry. It analyzes six key dimensions: Political (policies, stability, regulations), Economic (market conditions, growth, trade), Social (cultural trends, demographics, behavior), Technological (innovation, R&D, advancements), Environmental (sustainability, climate change, resources), and Legal (laws, compliance, constraints). By assessing these factors, PESTEL helps identify opportunities and risks, ensuring informed decision-making and long-term strategic planning (Corporate Finance Institute 2023). While a PESTEL analysis has been widely used to assess developments in the energy industry, its use in to explore the Iberian green hydrogen industry is novel. First studies have started to employ the framework to other markets, such as the green hydrogen sector in China (Ren et al. 2023)

iii. Resource-Based-View (RBV)

The Resource-Based View (RBV) of the firm is a strategic framework that emphasizes the importance of internal resources in achieving and sustaining competitive advantage (Madhani 2010). According to RBV, a firm's success is determined by how well it utilizes its unique resources and capabilities, rather than external factors like industry structure or market conditions (Miller 2019). These resources include physical assets, human skills, organizational processes, and intangible elements like brand reputation and knowledge (Miller 2019).

To evaluate whether a resource contributes to competitive advantage, the VRIO framework is used, which examines four key criteria:

1. **Value:** Does the resource add value by enabling the firm to exploit opportunities or neutralize threats?
2. **Rarity:** Is the resource rare and not widely possessed by competitors?
3. **Imitability**: Is the resource difficult or costly for competitors to imitate or replicate?
4. **Organization:** Is the firm organized to capture the value of the resource, with appropriate structures, processes, and culture?

Resources meeting all four criteria provide a sustainable competitive advantage, while those failing one or more criteria may lead to only temporary or no advantage at all (Miller 2019). The application of the RBV to explore the Iberian green hydrogen industry from a company-specific perspective is, to the best of my knowledge, a novel approach. Academic research in this area often emphasizes external dynamics, such as policy frameworks, market trends, and technological advancements, while overlooking the critical role that a firm's internal resources and capabilities play in leveraging opportunities and addressing challenges. By focusing on RBV, this study

highlights how unique organizational assets - such as technical expertise, strategic partnerships, financial resources, and operational efficiencies - can enable companies to navigate the complexities of the green hydrogen industry. This perspective underscores the importance of aligning internal strengths with external opportunities to drive sustainable competitive advantage.

Appendix D: About the chosen Ontology and Epistemology of this Study - Methodology

Critical realism uses a tendential prediction model, which allows for cautious predictions based on identification of causal tendencies once sufficient data has been gathered. By identifying causal tendencies, critical realism enables cautious predictions and supports actionable recommendations for project and industry development. This aligns with critical realism's focus on uncovering hidden structures and provides the flexibility to adapt findings as new insights emerge, ensuring a deeper understanding of the underlying mechanisms at play. This study follows an inductive approach to explore and understand the underlying causal mechanisms shaping the emerging Iberian green hydrogen industry. An inductive approach allows patterns and insights to emerge from stakeholder interviews and secondary data, aligning with critical realism's goal of identifying hidden structures and mechanisms. (Saunders et al. 2023) This approach supports flexibility, adapting to new findings to provide a nuanced view of the external influences, economic constraints, and policy impacts that drive the industry.

Appendix E: Background of Interviewees and Reason for Inclusion in this Study

1. *Morten Kielsen Kopenhagen – Vice President, Global Competence Center, Copenhagen Infrastructure Partners (CIP):* Morten Kielsen Kopenhagen's role at CIP brings an invaluable perspective on large-scale infrastructure investments in renewable energy projects. His expertise in developing and financing sustainable energy infrastructure ensures a pragmatic understanding of how hydrogen initiatives can be integrated into global energy systems, overcoming financial and logistical challenges. Morten is directly involved in the development of Catalina and MP2X and could therefore share insights beyond the available information of public reports.

2. Osama Fawzy Georgy Henein – Founder, H2lligence Platform & Member of the Board of Advisors, Mediterranean Hydrogen Alliance: Osama Fawzy Georgy Henein's leadership in the H2lligence Platform and his advisory role within the Mediterranean Hydrogen Alliance provide crucial insights into hydrogen's strategic and technological development in the Mediterranean region. His experience bridges technical innovation with regional policy, fostering collaboration across diverse markets. Osama brings a unique perspective to this study, because he works together with very diverse stakeholders daily. Also, he is predominantly involved in the hydrogen projects in North Africa, and therefore has an outside perspective on the EU-market. Besides his engagement in the hydrogen sector, he teaches energy courses at a number of universities, including Technische Universität Berlin, and can therefore contribute to both predominantly business and academic issues.

3. Ahmed Abbas – Senior Hydrogen Consultant at Enerdata:

Ahmed Abbas's consultancy expertise at Enerdata positions him as a critical stakeholder in analyzing market dynamics and energy transitions. His deep knowledge of hydrogen economics, energy forecasting, and policy frameworks enhances the study's understanding of the global hydrogen market's future trends. Ahmed Abbas recently published an extensive study *"Unlocking the potential of green hydrogen: Insights for climate philanthropy"* and therefore has extensive knowledge of the European Hydrogen Market.

4. Johanna Schiele - Policy Officer Innovation Fund – European Commission:

Johanna Schiele's role with the European Commission's Innovation Fund is vital for understanding the regulatory and financial support mechanisms driving hydrogen innovation. Her insights into the EU's climate goals and funding strategies offer a comprehensive view of how policy shapes industry development and research priorities. Johanna is directly involved in the auction of the Hydrogen Bank and was one of the main designers of the auction system. She is regularly organizing and attending stakeholder workshops and has extensive knowledge of the leading hydrogen projects in Europe. Previously, she was an MPP Candidate and McCloy Fellow at the Harvard Kennedy School, where she focused on energy and climate regulation, and worked as an Associate for European Power Markets at Aurora Energy Research Ltd, analyzing European power markets. Earlier in her career, she contributed to climate and energy models as a Research Assistant at the Oxford Martin School.

5. Ana Quelhas – Managing Director for Hydrogen at EDP Renewables:

Ana Quelhas's leadership at EDP Renewables highlights the practical integration of hydrogen into renewable energy projects. Her expertise contributes to the study by demonstrating how hydrogen technologies can scale alongside renewables to achieve decarbonization goals, particularly in

utility-scale applications. As the Managing Director of Hydrogen at EDP Renewables, Ana is involved in several green hydrogen projects in Iberia. She has extensive knowledge of the opportunities and roadblocks that developers are currently facing.

5. *André Fonseca – Production and Operations Innovation Project Manager at Galp:*

André Fonseca's role at Galp focuses on operational innovation, making him a key stakeholder in understanding the challenges of implementing hydrogen technologies within existing energy production systems. His practical knowledge aids in addressing technical barriers and improving operational efficiencies in hydrogen production and utilization. As a Production and Operations Innovation Project Manager at Galp, André is involved in Galp's green hydrogen project H2Atlantic in Sines and has extensive knowledge about the offtaker perspective.

6. *Hasler Iglesias* – Environmental R&D Researcher at Centro Tecnológico de la Energía y del Medio Ambiente (CETENMA):

Hasler Iglesias, an Environmental R&D Researcher at CETENMA, offers valuable insights for this research due to the organization's strong expertise in water technologies, particularly wastewater treatment and reuse. CETENMA, an NGO based in Spain, is also deeply involved in energy efficiency, renewable energies, and water recovery, making them a key player in advancing sustainable solutions. Their experience in stakeholder collaboration and implementing innovative water technologies provides a different angle to the study, which might not always receive sufficient attention from common business stakeholders.

Appendix F: Stakeholder Map

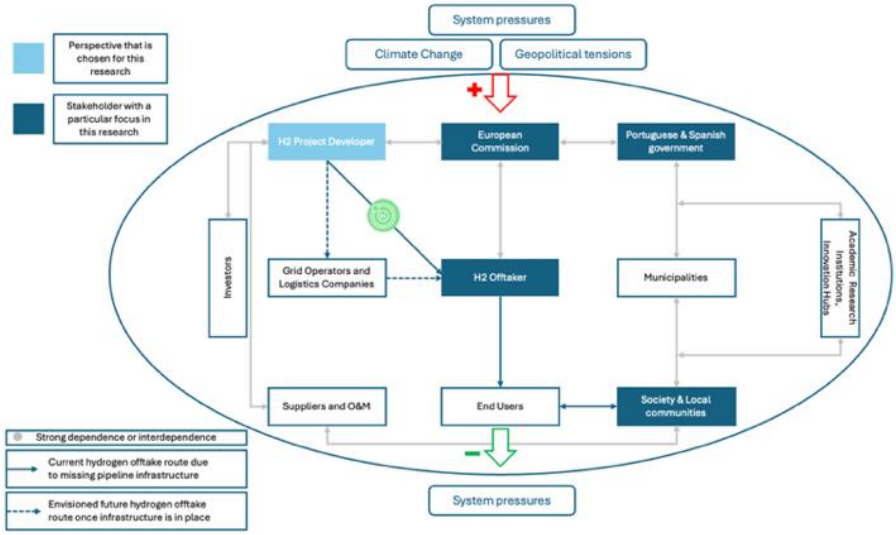

Figure A2: Stakeholder Map: Perspective of the Iberian green hydrogen industry. The displayed interdependencies are not exhaustive and focus on illustrating the key industry drivers.

Appendix G: Model Assumptions

The assumptions of this study are based on a variety of academic articles, industry report and roadmaps. All assumptions are based on sources that were published within the last three years and aim to consider the regional focus on Iberia. Finally, the sensitivity analysis aims to show how each driver impacts the final costs in a dynamic emerging industry.

i. Catalina

Table A1: Project Catalina. LCOE Assumptions.

Category	Parameter	Solar PV	Onshore Wind	Unit	Description
Financial	WACC	7%	7%	%	Weighted Average Cost of Capital
	Lifetime	20[33]	20[33]	Years	Expected lifetime of the project
Operational	Load Factor	21%[34]	28%[35]	%	Average operational capacity factor
	Availability Factor	99%[36]	94.3%[36]	%	Availability factor, baseline is 8760h per year; onshore wind turbines need 500h of maintenance
	Capacity (Output Power)	571[37]	504[37]	MW	Installed capacity of the power source
	Degradation	1%[33]	-	%	Annual degradation rate
Cost	CAPEX	560[33]	1,120[33]	€/kW	Capital expenditure per kW
	Fixed O&M	9[33]	14[33]	€/kW	Fixed Operations and Maintenance in € per kw installed
	Annualized fixed cost	2[33]	2[33]	€/kW	Annualized fixed cost in € per kw installed

ii. MP2X

Table A2: Project MP2X. LCOE Assumptions.

Category	Parameter	Solar PV	Onshore Wind	Unit	Description
Financial	WACC	7%	7%	%	Weighted Average Cost of Capital
	Lifetime	20[33]	20[33]	Years	Expected lifetime of the project
Operational	Load Factor	18%[38]	29%[39]		Average operational capacity factor
	Availability Factor	99%[40]	94.3%[41]		Annual hours of operation; onshore wind turbines need 500h of maintenance
	Capacity (Output Power)	571[41]	504[42]	MW	Installed capacity of the power source
	Degradation	1%[42]	-	%	Annual degradation rate
Cost	CAPEX	560[30]	1,120[30]	€/kW	Capital expenditure per kW

[33] Ruhnau, Schiele (2022)
[34] Global Solar Atlas (2024)
[35] Global Wind Atlas (2024)
[36] AFRY (2024)
[37] Project Catalina Website (2024)
[38] Global Solar Atlas (2024)
[39] Global Wind Atlas (2024)
[40] AFRY (2024)
[41] Project MP2X Website (2024)
[42] Ruhnau Schiele (2024)

Fixed O&M	9[43]	14[43]	€/kW	Fixed Operations and Maintenance in € per kw installed
Annualized fixed cost	2[43]	2[43]	€/kW	Annualized fixed cost in € per kw installed

Table A3: Project MP2X. Desalination Assumptions

Category	Parameter	Value	Unit	Description
Financial	CAPEX per unit capacity	8,600,000[43]	€/m³	Based on mid-sized desalination plants in the region studied by Ocean Energy Systems and the IEA.
	Annual OPEX	25%[44]	%	Operational expenditure as a percentage of CAPEX
Operational	Daily Production Requirement	4,276[44]	m³/day	Required daily water production to meet annual demand
	Electricity consumption	4[44]	kWh/m³	Energy required per cubic meter in reverse osmosis systems
	Electricity cost	48[45]	€/MWh	Electricity cost based on CIP's dedicated Renewable Energy Assets as found by my LCOE model
LCOW	**€ per cubic meter**	**2.09**	**€/m³**	**Levelized cost of desalinated water per cubic meter**

Appendix H: Sensitivity Analysis of Project Catalina & Project MP2X

The following figures illustrate the results of the sensitivity analysis conducted on my model, offering a detailed examination of the primary cost drivers influencing the two selected projects. These analyses identify and quantify the impact of key variables, such as CAPEX, OPEX, electrolyzer efficiency, renewable energy costs, capacity utilization rates, and potential financial incentives or subsidies. The sensitivity analysis highlights the extent to which variations in these factors affect the overall LCOH and project economics. By visualizing the relative influence of these drivers, the figures provide valuable insights into areas where optimization or intervention could yield significant cost reductions. For example, they demonstrate how incremental improvements in electrolyzer efficiency or reductions in renewable energy prices can lead to substantial cost savings. Additionally, the analysis accounts for external uncertainties, such as

[43] IEA Ocean Energy Systems (2024)
[44] Own calculation based on daily production target
[45] Own assumption based on own LCOE modeling for Project MP2X

fluctuations in energy markets and regulatory changes, to evaluate their potential impact on project viability.

i. Sensitivity Analysis Catalina

All sensitivity analyses account for the LCOH after integrating the confirmed subsidy from the European Hydrogen Bank, which CIP has officially secured.

WACC X LCOE

3,97 €	15,00 €	20,00 €	25,00 €	30,00 €	35,00 €	40,00 €	45,00 €	50,00 €	55,00 €
3%	2,09 €	2,36 €	2,62 €	2,89 €	3,15 €	3,41 €	3,68 €	3,94 €	4,21 €
4%	2,15 €	2,42 €	2,68 €	2,95 €	3,21 €	3,48 €	3,74 €	4,00 €	4,27 €
5%	2,22 €	2,48 €	2,75 €	3,01 €	3,27 €	3,54 €	3,80 €	4,07 €	4,33 €
6%	2,28 €	2,55 €	2,81 €	3,08 €	3,34 €	3,61 €	3,87 €	4,14 €	4,40 €
7%	2,35 €	2,62 €	2,88 €	3,15 €	3,41 €	3,68 €	3,94 €	4,20 €	4,47 €
8%	2,43 €	2,69 €	2,95 €	3,22 €	3,48 €	3,75 €	4,01 €	4,28 €	4,54 €
9%	2,50 €	2,76 €	3,03 €	3,29 €	3,56 €	3,82 €	4,09 €	4,35 €	4,62 €
10%	2,58 €	2,84 €	3,11 €	3,37 €	3,63 €	3,90 €	4,16 €	4,43 €	4,69 €
11%	2,66 €	2,92 €	3,19 €	3,45 €	3,71 €	3,98 €	4,24 €	4,51 €	4,77 €

Figure A 3: Project Catalina. WACC (column) vs. LCOE (row)

WACC X CAPEX

3,97 €	1.000,00 €	1.200,00 €	1.400,00 €	1.600,00 €	1.800,00 €	2.000,00 €	2.200,00 €
3%	3,07 €	3,23 €	3,39 €	3,55 €	3,71 €	3,87 €	4,03 €
4%	3,10 €	3,27 €	3,44 €	3,61 €	3,77 €	3,94 €	4,11 €
5%	3,13 €	3,31 €	3,49 €	3,66 €	3,84 €	4,01 €	4,19 €
6%	3,17 €	3,35 €	3,54 €	3,72 €	3,90 €	4,09 €	4,27 €
7%	3,21 €	3,40 €	3,59 €	3,78 €	3,97 €	4,17 €	4,36 €
8%	3,24 €	3,44 €	3,64 €	3,85 €	4,05 €	4,25 €	4,45 €
9%	3,28 €	3,49 €	3,70 €	3,91 €	4,12 €	4,33 €	4,54 €
10%	3,32 €	3,54 €	3,76 €	3,98 €	4,20 €	4,42 €	4,64 €
11%	3,36 €	3,59 €	3,82 €	4,05 €	4,28 €	4,51 €	4,73 €
12%	3,41 €	3,65 €	3,88 €	4,12 €	4,36 €	4,60 €	4,83 €

Figure A 4: Project Catalina. WACC (column) vs. CAPEX (row)

Efficiency X Stack Replacement Cost

3,97 €	0%	5%	10%	15%	20%	25%	30%
90%	3,12 €	3,15 €	3,17 €	3,20 €	3,22 €	3,25 €	3,28 €
85%	3,22 €	3,25 €	3,27 €	3,30 €	3,32 €	3,35 €	3,37 €
80%	3,33 €	3,36 €	3,38 €	3,41 €	3,44 €	3,46 €	3,49 €
75%	3,46 €	3,48 €	3,51 €	3,54 €	3,56 €	3,59 €	3,61 €
70%	3,60 €	3,63 €	3,66 €	3,68 €	3,71 €	3,73 €	3,76 €
63%	3,85 €	3,87 €	3,90 €	3,92 €	3,95 €	3,97 €	4,00 €
60%	3,97 €	3,99 €	4,02 €	4,04 €	4,07 €	4,09 €	4,12 €
55%	4,20 €	4,22 €	4,25 €	4,27 €	4,30 €	4,33 €	4,35 €

Figure A 5: Project Catalina. Electrolyzer Efficiency (column) vs. Stack Replacement Cost (row)

Efficiency X LCOE

3,97 €	15,00 €	20,00 €	25,00 €	30,00 €	35,00 €	40,00 €	45,00 €	50,00 €	55,00 €	60,00 €
90%	2,11 €	2,30 €	2,49 €	2,67 €	2,86 €	3,04 €	3,23 €	3,41 €	3,60 €	3,78 €
85%	2,15 €	2,34 €	2,54 €	2,74 €	2,93 €	3,13 €	3,32 €	3,52 €	3,72 €	3,91 €
80%	2,18 €	2,39 €	2,60 €	2,81 €	3,02 €	3,23 €	3,43 €	3,64 €	3,85 €	4,06 €
75%	2,23 €	2,45 €	2,67 €	2,89 €	3,11 €	3,34 €	3,56 €	3,78 €	4,00 €	4,23 €
70%	2,27 €	2,51 €	2,75 €	2,99 €	3,23 €	3,46 €	3,70 €	3,94 €	4,18 €	4,42 €
65%	2,33 €	2,58 €	2,84 €	3,10 €	3,35 €	3,61 €	3,87 €	4,12 €	4,38 €	4,64 €
60%	2,39 €	2,67 €	2,95 €	3,23 €	3,50 €	3,78 €	4,06 €	4,34 €	4,61 €	4,89 €
55%	2,47 €	2,77 €	3,07 €	3,38 €	3,68 €	3,98 €	4,29 €	4,59 €	4,89 €	5,20 €

Figure A 6: Project Catalina. Electrolyzer Efficiency (column) vs. LCOE (row)

Efficiency X CAPEX

3,97 €	1.000,00 €	1.200,00 €	1.400,00 €	1.600,00 €	1.800,00 €	2.000,00 €	2.200,00 €
90%	2,48 €	2,67 €	2,87 €	3,06 €	3,25 €	3,44 €	3,63 €
85%	2,58 €	2,77 €	2,96 €	3,16 €	3,35 €	3,54 €	3,73 €
80%	2,69 €	2,88 €	3,08 €	3,27 €	3,46 €	3,65 €	3,85 €
75%	2,82 €	3,01 €	3,20 €	3,40 €	3,59 €	3,78 €	3,97 €
70%	2,96 €	3,16 €	3,35 €	3,54 €	3,73 €	3,92 €	4,12 €
65%	3,13 €	3,32 €	3,52 €	3,71 €	3,90 €	4,09 €	4,28 €
60%	3,33 €	3,52 €	3,71 €	3,90 €	4,09 €	4,29 €	4,48 €
55%	3,56 €	3,75 €	3,94 €	4,13 €	4,33 €	4,52 €	4,71 €

Figure A 7: Project Catalina. Electrolyzer Efficiency (column) vs. CAPEX (row)

Subsidies X Electricity Costs

3,97 €	15,00 €	20,00 €	25,00 €	30,00 €	35,00 €	40,00 €	45,00 €	50,00 €	55,00 €	60,00 €
37.116.428,51 €	2,24 €	2,51 €	2,77 €	3,04 €	3,30 €	3,56 €	3,83 €	4,09 €	4,36 €	4,62 €
33.742.207,74 €	2,27 €	2,53 €	2,80 €	3,06 €	3,33 €	3,59 €	3,86 €	4,12 €	4,38 €	4,65 €
30.674.734,31 €	2,29 €	2,56 €	2,82 €	3,09 €	3,35 €	3,62 €	3,88 €	4,14 €	4,41 €	4,67 €
27.886.122,10 €	2,31 €	2,58 €	2,84 €	3,11 €	3,37 €	3,64 €	3,90 €	4,17 €	4,43 €	4,70 €
25.351.020,09 €	2,33 €	2,60 €	2,86 €	3,13 €	3,39 €	3,66 €	3,92 €	4,19 €	4,45 €	4,72 €
23.046.381,90 €	2,35 €	2,62 €	2,88 €	3,15 €	3,41 €	3,68 €	3,94 €	4,20 €	4,47 €	4,73 €
20.741.743,71 €	2,37 €	2,64 €	2,90 €	3,16 €	3,43 €	3,69 €	3,96 €	4,22 €	4,49 €	4,75 €
18.667.569,34 €	2,39 €	2,65 €	2,92 €	3,18 €	3,45 €	3,71 €	3,97 €	4,24 €	4,50 €	4,77 €
16.800.812,41 €	2,40 €	2,67 €	2,93 €	3,20 €	3,46 €	3,72 €	3,99 €	4,25 €	4,52 €	4,78 €

Figure A 8: Project Catalina. Hydrogen Bank Subsidy (column) vs. LCOE (row)

Hydrogen Production Volume X CAPEX

3,97 €	1.000,00 €	1.200,00 €	1.400,00 €	1.600,00 €	1.800,00 €	2.000,00 €	2.200,00 €
148811124,00	2,87 €	2,97 €	3,08 €	3,19 €	3,30 €	3,41 €	3,52 €
135282840,00	2,91 €	3,03 €	3,15 €	3,27 €	3,39 €	3,51 €	3,63 €
122984400,00	2,96 €	3,09 €	3,22 €	3,35 €	3,48 €	3,61 €	3,75 €
111804000,00	3,01 €	3,16 €	3,30 €	3,44 €	3,59 €	3,73 €	3,88 €
101640000,00	3,07 €	3,23 €	3,39 €	3,55 €	3,71 €	3,86 €	4,02 €
92400000,00	3,13 €	3,31 €	3,48 €	3,66 €	3,83 €	4,01 €	4,18 €
84000000,00	3,21 €	3,40 €	3,59 €	3,78 €	3,97 €	4,17 €	4,36 €
75600000,00	3,29 €	3,51 €	3,72 €	3,93 €	4,15 €	4,36 €	4,57 €
68040000,00	3,39 €	3,63 €	3,86 €	4,10 €	4,34 €	4,57 €	4,81 €
61236000,00	3,49 €	3,76 €	4,02 €	4,29 €	4,55 €	4,81 €	5,08 €
55112400,00	3,61 €	3,91 €	4,20 €	4,49 €	4,78 €	5,08 €	5,37 €
49601160,00	3,75 €	4,07 €	4,40 €	4,72 €	5,05 €	5,37 €	5,70 €
44641044,00	3,89 €	4,25 €	4,62 €	4,98 €	5,34 €	5,70 €	6,06 €

Figure A 9: Project Catalina. H_2 Production Volume (column) vs. CAPEX (row)

ii. Sensitivity Analysis MP2X

All sensitivity analyses account for the LCOH after integrating the confirmed subsidy from the European Hydrogen Bank, which CIP has officially secured.

WACC X LCOE

3,79 €	15,00 €	20,00 €	25,00 €	30,00 €	35,00 €	40,00 €	45,00 €	50,00 €	55,00 €
3%	1,84 €	2,11 €	2,37 €	2,63 €	2,90 €	3,16 €	3,43 €	3,69 €	3,96 €
4%	1,89 €	2,15 €	2,42 €	2,68 €	2,95 €	3,21 €	3,48 €	3,74 €	4,01 €
5%	1,94 €	2,21 €	2,47 €	2,73 €	3,00 €	3,26 €	3,53 €	3,79 €	4,06 €
6%	1,99 €	2,26 €	2,52 €	2,79 €	3,05 €	3,32 €	3,58 €	3,85 €	4,11 €
7%	2,05 €	2,31 €	2,58 €	2,84 €	3,11 €	3,37 €	3,64 €	3,90 €	4,17 €
8%	2,11 €	2,37 €	2,64 €	2,90 €	3,17 €	3,43 €	3,69 €	3,96 €	4,22 €
9%	2,17 €	2,43 €	2,70 €	2,96 €	3,23 €	3,49 €	3,75 €	4,02 €	4,28 €
10%	2,23 €	2,49 €	2,76 €	3,02 €	3,29 €	3,55 €	3,82 €	4,08 €	4,35 €
11%	2,29 €	2,56 €	2,82 €	3,09 €	3,35 €	3,62 €	3,88 €	4,14 €	4,41 €

Figure A 10: Project MP2X. WACC (column) vs. LCOE (row)

WACC X CAPEX

3,79 €	1.000,00 €	1.200,00 €	1.400,00 €	1.600,00 €	1.800,00 €	2.000,00 €	2.200,00 €
3%	3,06 €	3,19 €	3,32 €	3,45 €	3,58 €	3,71 €	3,84 €
4%	3,09 €	3,22 €	3,36 €	3,49 €	3,63 €	3,76 €	3,90 €
5%	3,11 €	3,25 €	3,39 €	3,54 €	3,68 €	3,82 €	3,96 €
6%	3,14 €	3,29 €	3,44 €	3,58 €	3,73 €	3,88 €	4,03 €
7%	3,17 €	3,32 €	3,48 €	3,63 €	3,79 €	3,94 €	4,10 €
8%	3,20 €	3,36 €	3,52 €	3,68 €	3,84 €	4,01 €	4,17 €
9%	3,23 €	3,40 €	3,57 €	3,74 €	3,90 €	4,07 €	4,24 €
10%	3,26 €	3,44 €	3,61 €	3,79 €	3,97 €	4,14 €	4,32 €
11%	3,30 €	3,48 €	3,66 €	3,85 €	4,03 €	4,21 €	4,40 €
12%	3,33 €	3,52 €	3,71 €	3,90 €	4,09 €	4,29 €	4,48 €

Figure A 11: Project MP2X. WACC (column) vs. CAPEX (row)

Efficiency X Stack Replacement Cost

3,79 €	0%	5%	10%	15%	20%	25%	30%
90%	2,92 €	2,94 €	2,97 €	2,99 €	3,01 €	3,03 €	3,05 €
85%	3,03 €	3,05 €	3,07 €	3,09 €	3,11 €	3,13 €	3,15 €
80%	3,15 €	3,17 €	3,19 €	3,21 €	3,23 €	3,25 €	3,27 €
75%	3,28 €	3,30 €	3,32 €	3,34 €	3,36 €	3,38 €	3,40 €
70%	3,43 €	3,45 €	3,47 €	3,49 €	3,51 €	3,53 €	3,55 €
63%	3,68 €	3,70 €	3,72 €	3,75 €	3,77 €	3,79 €	3,81 €
60%	3,81 €	3,83 €	3,85 €	3,87 €	3,89 €	3,91 €	3,93 €
55%	4,05 €	4,07 €	4,09 €	4,11 €	4,13 €	4,15 €	4,18 €

Figure A 12: Project MP2X. Electrolyzer Efficiency (column) vs. Stack Replacement Cost (row)

Efficiency X LCOE

3,79 €	15,00 €	20,00 €	25,00 €	30,00 €	35,00 €	40,00 €	45,00 €	50,00 €	55,00 €	60,00 €
90%	1,81 €	2,00 €	2,18 €	2,37 €	2,55 €	2,74 €	2,92 €	3,11 €	3,29 €	3,48 €
85%	1,84 €	2,04 €	2,24 €	2,43 €	2,63 €	2,82 €	3,02 €	3,22 €	3,41 €	3,61 €
80%	1,88 €	2,09 €	2,30 €	2,51 €	2,71 €	2,92 €	3,13 €	3,34 €	3,55 €	3,76 €
75%	1,92 €	2,14 €	2,37 €	2,59 €	2,81 €	3,03 €	3,26 €	3,48 €	3,70 €	3,92 €
70%	1,97 €	2,21 €	2,45 €	2,68 €	2,92 €	3,16 €	3,40 €	3,64 €	3,87 €	4,11 €
65%	2,03 €	2,28 €	2,54 €	2,79 €	3,05 €	3,31 €	3,56 €	3,82 €	4,08 €	4,33 €
60%	2,09 €	2,37 €	2,64 €	2,92 €	3,20 €	3,48 €	3,76 €	4,03 €	4,31 €	4,59 €
55%	2,17 €	2,47 €	2,77 €	3,07 €	3,38 €	3,68 €	3,98 €	4,29 €	4,59 €	4,89 €

Figure A 13: Project MP2X. Electrolyzer Efficiency (column) vs. LCOE (row)

Efficiency X CAPEX

3,79 €	1.000,00 €	1.200,00 €	1.400,00 €	1.600,00 €	1.800,00 €	2.000,00 €	2.200,00 €
90%	2,41 €	2,56 €	2,72 €	2,87 €	3,03 €	3,18 €	3,34 €
85%	2,51 €	2,67 €	2,82 €	2,98 €	3,13 €	3,29 €	3,44 €
80%	2,63 €	2,79 €	2,94 €	3,09 €	3,25 €	3,40 €	3,56 €
75%	2,76 €	2,92 €	3,07 €	3,23 €	3,38 €	3,54 €	3,69 €
70%	2,92 €	3,07 €	3,22 €	3,38 €	3,53 €	3,69 €	3,84 €
65%	3,09 €	3,24 €	3,40 €	3,55 €	3,71 €	3,86 €	4,02 €
60%	3,29 €	3,45 €	3,60 €	3,76 €	3,91 €	4,07 €	4,22 €
55%	3,54 €	3,69 €	3,85 €	4,00 €	4,15 €	4,31 €	4,46 €

Figure A 14: Project MP2X. Electrolyzer Efficiency (column) vs. CAPEX (row)

Subsidies X Electricity Costs										
3,79 €	15,00 €	20,00 €	25,00 €	30,00 €	35,00 €	40,00 €	45,00 €	50,00 €	55,00 €	60,00 €
37.116.428,51 €	1,97 €	2,23 €	2,50 €	2,76 €	3,03 €	3,29 €	3,56 €	3,82 €	4,09 €	4,35 €
33.742.207,74 €	1,99 €	2,26 €	2,52 €	2,78 €	3,05 €	3,31 €	3,58 €	3,84 €	4,11 €	4,37 €
30.674.734,31 €	2,01 €	2,28 €	2,54 €	2,80 €	3,07 €	3,33 €	3,60 €	3,86 €	4,13 €	4,39 €
27.886.122,10 €	2,03 €	2,29 €	2,56 €	2,82 €	3,09 €	3,35 €	3,62 €	3,88 €	4,14 €	4,41 €
25.351.020,09 €	2,04 €	2,31 €	2,57 €	2,84 €	3,10 €	3,37 €	3,63 €	3,90 €	4,16 €	4,43 €
23.046.381,90 €	2,06 €	2,32 €	2,59 €	2,85 €	3,12 €	3,38 €	3,65 €	3,91 €	4,18 €	4,44 €
20.741.743,71 €	2,07 €	2,34 €	2,60 €	2,87 €	3,13 €	3,40 €	3,66 €	3,93 €	4,19 €	4,45 €
18.667.569,34 €	2,09 €	2,35 €	2,62 €	2,88 €	3,15 €	3,41 €	3,67 €	3,94 €	4,20 €	4,47 €
16.800.812,41 €	2,10 €	2,36 €	2,63 €	2,89 €	3,16 €	3,42 €	3,69 €	3,95 €	4,21 €	4,48 €

Figure A 15: Project MP2X. Hydrogen Bank Subsidy (column) vs. LCOE (row)

Hydrogen Production Volume X CAPEX							
3,79 €	1.000,00 €	1.200,00 €	1.400,00 €	1.600,00 €	1.800,00 €	2.000,00 €	2.200,00 €
148811124,00	2,98 €	3,09 €	3,19 €	3,30 €	3,41 €	3,52 €	3,63 €
135282840,00	3,02 €	3,14 €	3,26 €	3,38 €	3,50 €	3,62 €	3,74 €
122984400,00	3,07 €	3,20 €	3,33 €	3,47 €	3,60 €	3,73 €	3,86 €
111804000,00	3,13 €	3,27 €	3,41 €	3,56 €	3,70 €	3,85 €	3,99 €
101640000,00	3,19 €	3,34 €	3,50 €	3,66 €	3,82 €	3,98 €	4,14 €
92400000,00	3,25 €	3,43 €	3,60 €	3,78 €	3,95 €	4,12 €	4,30 €
84000000,00	3,32 €	3,52 €	3,71 €	3,90 €	4,09 €	4,28 €	4,48 €
75600000,00	3,41 €	3,62 €	3,84 €	4,05 €	4,27 €	4,48 €	4,69 €
68040000,00	3,51 €	3,75 €	3,98 €	4,22 €	4,46 €	4,70 €	4,93 €
61236000,00	3,62 €	3,88 €	4,14 €	4,41 €	4,67 €	4,94 €	5,20 €
55112400,00	3,74 €	4,03 €	4,32 €	4,62 €	4,91 €	5,20 €	5,50 €
49601160,00	3,87 €	4,20 €	4,52 €	4,85 €	5,17 €	5,50 €	5,83 €
44641044,00	4,02 €	4,38 €	4,75 €	5,11 €	5,47 €	5,83 €	6,19 €

Figure A 16: Project MP2X. H_2 Production Volume (column) vs. CAPEX (row)

Sensitivity Analysis MP2X: Ammonia-specific sensitivities

Ammonia-specific sensitivity analyses that do not involve transport-related factors utilize the LCOA at the production site in Sines, ensuring a focused examination of production drivers without the influence of transport costs or associated assumptions. In contrast, sensitivity analyses that address transport factors apply the LCOH after transport to comprehensively account for the effects of logistics and distribution.

LCOH X CAPEX (Ammonia specific)						
829,50 €	480,00 €	580,00 €	680,00 €	780,00 €	880,00 €	980,00 €
2,00 €	470,32 €	489,71 €	509,09 €	528,47 €	547,86 €	567,24 €
2,50 €	559,82 €	579,21 €	598,59 €	617,97 €	637,36 €	656,74 €
3,00 €	649,32 €	668,71 €	688,09 €	707,47 €	726,86 €	746,24 €
3,50 €	738,82 €	758,21 €	777,59 €	796,97 €	816,36 €	835,74 €
3,79 €	790,73 €	810,12 €	829,50 €	848,88 €	868,27 €	887,65 €
4,50 €	917,82 €	937,21 €	956,59 €	975,97 €	995,36 €	1.014,74 €
5,00 €	1.007,32 €	1.026,71 €	1.046,09 €	1.065,47 €	1.084,86 €	1.104,24 €
5,50 €	1.096,82 €	1.116,21 €	1.135,59 €	1.154,97 €	1.174,36 €	1.193,74 €
6,00 €	1.186,32 €	1.205,71 €	1.225,09 €	1.244,47 €	1.263,86 €	1.283,24 €

Figure A 17: Project MP2X. LCOH (column) vs. CAPEX (Ammonia-specific) (row)

Hydrogen Feedstock cost X LCOE

829,50 €	15,00 €	20,00 €	25,00 €	30,00 €	35,00 €	40,00 €	45,00 €	50,00 €	55,00 €
2,00 €	499,49 €	502,69 €	505,89 €	509,09 €	512,29 €	515,49 €	518,69 €	521,89 €	525,09 €
2,50 €	588,99 €	592,19 €	595,39 €	598,59 €	601,79 €	604,99 €	608,19 €	611,39 €	614,59 €
3,00 €	678,49 €	681,69 €	684,89 €	688,09 €	691,29 €	694,49 €	697,69 €	700,89 €	704,09 €
3,50 €	767,99 €	771,19 €	774,39 €	777,59 €	780,79 €	783,99 €	787,19 €	790,39 €	793,59 €
4,00 €	857,49 €	860,69 €	863,89 €	867,09 €	870,29 €	873,49 €	876,69 €	879,89 €	883,09 €
4,50 €	946,99 €	950,19 €	953,39 €	956,59 €	959,79 €	962,99 €	966,19 €	969,39 €	972,59 €
5,00 €	1.036,49 €	1.039,69 €	1.042,89 €	1.046,09 €	1.049,29 €	1.052,49 €	1.055,69 €	1.058,89 €	1.062,09 €
5,50 €	1.125,99 €	1.129,19 €	1.132,39 €	1.135,59 €	1.138,79 €	1.141,99 €	1.145,19 €	1.148,39 €	1.151,59 €
6,00 €	1.215,49 €	1.218,69 €	1.221,89 €	1.225,09 €	1.228,29 €	1.231,49 €	1.234,69 €	1.237,89 €	1.241,09 €

Figure A 18: Project MP2X. LCOH (column) vs. LCOE (row)

Transport Cost X Sea distance

954,47 €	500	1000	1500	2048	2500	3000	3500
0,02 €	839,50 €	849,50 €	859,50 €	870,46 €	879,50 €	889,50 €	899,50 €
0,04 €	849,50 €	869,50 €	889,50 €	911,42 €	929,50 €	949,50 €	969,50 €
0,06 €	859,50 €	889,50 €	919,50 €	952,38 €	979,50 €	1.009,50 €	1.039,50 €
0,08 €	869,50 €	909,50 €	949,50 €	993,34 €	1.029,50 €	1.069,50 €	1.109,50 €
0,10 €	879,50 €	929,50 €	979,50 €	1.034,30 €	1.079,50 €	1.129,50 €	1.179,50 €
0,12 €	889,50 €	949,50 €	1.009,50 €	1.075,26 €	1.129,50 €	1.189,50 €	1.249,50 €

Figure A 19: Project MP2X. Transport Cost (€/t/km) (column) vs. Sea distance in km (row)

Hydrogen Feedstock cost X Transport cost per km

954,47 €	0,02 €	0,04 €	0,06 €	0,08 €	0,10 €	0,12 €
2,00 €	550,06 €	591,03 €	632,01 €	672,98 €	713,95 €	754,93 €
2,50 €	639,56 €	680,53 €	721,51 €	762,48 €	803,45 €	844,43 €
3,00 €	729,06 €	770,03 €	811,01 €	851,98 €	892,95 €	933,93 €
3,50 €	818,56 €	859,53 €	900,51 €	941,48 €	982,45 €	1.023,43 €
4,00 €	908,06 €	949,03 €	990,01 €	1.030,98 €	1.071,95 €	1.112,93 €
4,50 €	997,56 €	1.038,53 €	1.079,51 €	1.120,48 €	1.161,45 €	1.202,43 €
5,00 €	1.087,06 €	1.128,03 €	1.169,01 €	1.209,98 €	1.250,95 €	1.291,93 €
5,50 €	1.176,56 €	1.217,53 €	1.258,51 €	1.299,48 €	1.340,45 €	1.381,43 €
6,00 €	1.266,06 €	1.307,03 €	1.348,01 €	1.388,98 €	1.429,95 €	1.470,93 €

Figure A 20: Project MP2X. LCOH vs. Transport Cost (€/t/km) (row)

Appendix I: Interviews

Interview with Morten Kielsen Kopenhagen – Copenhagen Infrastructure Partners

1. *As the company with the largest green hydrogen fund globally, how does CIP manage the uncertainties surrounding hydrogen demand besides engaging in consortiums?*

"Demand for green hydrogen is what is most up in the air right now. Before we make an investment, we go into consortiums, or we have a fixed price with long-term offtake agreements. We will not

invest capital into a project where we don't have an offtake agreement. If we cannot obtain the price, contract length or quality, then we will not invest in the project, as we are not selling into a commodity market."

2. *How do you account for the fact that the European Hydrogen Bank is not indexed?*

"The European Hydrogen Bank is a flat fee, but we will reduce our risk exposure by indexing our offtake price either by a commodity index or the inflation rate."

3. *What makes Portugal and Spain attractive for Copenhagen Infrastructure Partners compared to other European countries and how do you perceive the current local hydrogen market?*

"Iberia is an attractive market for CIP due to abundant solar and wind sources, leading to high utilization rates."

4. *What are the main opportunities and barriers that you currently see for large-scale hydrogen deployment in Spain and Portugal, respectively?*

"One major issue we face in Iberia is the local demand, the offtake market. The pipeline infrastructure for hydrogen is not in place yet, meaning that we need to be close to the consumers of the hydrogen and need to have an offtake agreement with them. As soon as the pipelines are in place, the offtake will become much easier. In fact, for project MP2X in Sines, we are only converting green hydrogen into its derivatives because there is no local offtake, and ammonia will be much easier to ship than green hydrogen. Green Ammonia will then primarily be utilized in the

shipping and fertilizer industry. The lack of transmission build out is limiting flexibility and opportunities of our new projects. A major obstacle in Iberia is that there's some rigid environmental requirements that need to be met before developing new projects and the additionality from the EU regulation implies that we cannot just have power purchase agreements with existing assets, but we need to develop new renewable capacity before developing hydrogen projects and in Portugal and Spain it's very hard get the permit to build wind turbines and solar. The regulation forces us to add renewable assets max. 3 years before the COD of the hydrogen project, meaning that we would need to buy renewable projects at a late development stage, but that is very expensive. Therefore, we are developing our own renewable assets, we can do that very cost-effective, and we are very good at that."

5. *What are the main financial risks associated with CIP's green hydrogen projects in Iberia, and how do you plan to close a potential gap between the willingness to pay from off-takers and the LCOH of your projects?*

"One of the biggest levers you can get in these projects is a grid connection because it gives you the authority to sell electricity of your renewable assets when the price is high and use it for hydrogen when the prices are low. This optimizes your business case significantly, and can in fact, have an effect as big as a subsidy from the European Hydrogen Bank. Therefore, being able to get a grid connection is key for our projects. We are currently not targeting any other subsidies beyond the European Hydrogen Bank, but we are exploring all opportunities."

6. *How much of your green hydrogen and ammonia will go industrial demand centers in Spain and Portugal and how much will be exported abroad? Will the hydrogen primarily be transported by ship or through the pipeline?*

"There is not a lot of industry. There is some fertilizer industry in Iberia, but overall, there is not a vast amount of industry that will require our hydrogen – but things can of course change."

7. *Where will the water for the electrolyzers of Project Catalina and Project Madoqua Power2X be procured from?*

"For project Catalina, we have a water permit from the National Environment Agency to use water from a River reservoir close to the electrolyzer facility that is of course subject to a lot of regulations. So, there we are taking the fresh water source. However, it is important to state that the amount that we need is not substantial to cause negative environmental implications. There is an ESG perspective on the water source that forces us to either locate projects close to a place with abundant water resources or we can use alternative water sources. We are considering this issue for all our projects. It's a big topic. Most developers know that this is key to sell the projects because the investors here a looping for environmental impact. It is particularly the investors who are pushing this agenda. We are a green fund and are trying to be at the forefront of this."

8. *How does CIP plan to secure a stable and scalable supply of electrolysers and other key components for its green hydrogen projects? Do you plan to procure these components from the EU?*

"Ideally, we would like to buy European. But pragmatically, it might not be possible because the supply chains might not always be there as we speak, and you can say the supply chain is not scaled to a level where its competitive with the Chinese, which has the scale and supply already. What we will be doing for our Spanish and Portuguese projects is a tender process which will include some sort of local requirements. Our expectation is that there will be European regulation that will drive this agenda. It's hard to explain to our investors to not buy Chinese if this implicates a big hit on returns."

9. *What is your perspective on the European Hydrogen Bank Auction Regime, and do you feel certain elements are missing from the selection process?*

"From our perspective, the format of the European Hydrogen Bank works fine. However, I think an increased budget is needed to close the price gap between green hydrogen and its alternatives."

10. *How do you ensure that projects in Iberia will be cost-competitive against other H2-producing regions with favorable conditions and low costs of labor, such as Sub-Saharan Africa?*

"I don't think there is a doubt that it would be cheaper to actually produce most of our hydrogen in North Africa and then just pipeline through Europe, but I don't see a world where European regulators will do that because energy security has come so far up on the agenda."

11. *What is CIP's long-term vision for hydrogen in Iberia and Europe, and where do you see the market and CIP's role in 5 to 10 years?*

"We firmly believe that Iberia has the potential to become a key production and export hub for green hydrogen. Significant progress is being made by gas TSOs in developing the necessary infrastructure to support this vision. The success of flagship projects like Madoqua Power2X and Catalina will likely pave the way for further initiatives and drive intensified investment in the region."

12. *What key strengths does CIP bring to the Iberian market & what weaknesses do you might have that partners can help you overcome in the expansion process?*

"We excel in securing investor funding and delivering profitable projects, with no fund performing below target. This expertise is particularly crucial in the Power-to-X market, where demonstrating profitability encourages further investment into the sector. Additionally, we rely heavily on local resources, advisors, and partners to successfully advance projects, acknowledging that we are not experts in the Iberian market."

13. *One of these challenges is that there are currently very few full-service EPC contractors in Iberia, leading to high O&M costs for new projects. Some developers are breaking down EPC responsibilities into separate contracts to reduce costs, which can increase risk exposure and impact the bankability of projects. What is CIPs perspective on this challenge and how do you plan to overcome this issue? Will the projects be maintained by Copenhagen Infrastructure Service?*

"Ideally, we would like an O&M who takes the entire EPC guarantees and production guarantees for the lifecycle of the project. It is hard to find anyone to do this in a new market like this without putting large margins on top."

Participant 2

1. *Iberia aims to become a leading hub for green hydrogen exports to northern Europe and beyond. Given the competitive advantages of Egypt, Algeria, and Morocco - such as abundant solar resources and lower labor costs - how do you assess Iberia's global long-term competitiveness against other hydrogen-producing-regions? Do you expect these regions to be competitors or partners in the global green hydrogen market going forward?*

"Iberia has the potential to become a significant production and export hub for green hydrogen due to its abundant renewable energy resources. However, while some industries, such as the fertilizer sector, are developing in the region, the overall demand for green hydrogen is still emerging. The challenge lies in the infrastructure, such as grid connections and pipelines, which are crucial for scaling production and exports. In contrast, countries like the Netherlands are positioning themselves as key trading hubs for green hydrogen, particularly in Northern Europe. Although the possibility for Iberia to serve as a hub exists, energy security concerns and the broader geopolitical landscape could shift the focus elsewhere. While collaboration between regions, such as North Africa and Europe, holds potential, Iberia's role in the global green hydrogen market remains to be fully realized."

2. *How do you think the commissioning of the Iberian Corridor, also known as the H2Med project, will change the potential and industry dynamics in Portugal and Spain?*

"The commissioning of the Iberian Corridor will significantly positively impact the emerging hydrogen industry in Iberia"

3. *How can Europe and Iberia mitigate risks for offtakers, particularly those who will depend on the reliable and continuous supply of green hydrogen? What role does hydrogen storage play in in reducing these risks, and are there specific storage or other risk-reduction strategies in Iberia that could enhance confidence in long-term offtake agreements?*

"Portugal and Spain are positioned at the center of upcoming auctions led by the H2Global initiative, under the leadership of Germany and in collaboration with other European countries. While Portugal and Spain stand to benefit from these auctions, it remains uncertain whether they will directly capitalize on these opportunities. The cost of producing green hydrogen in North Africa is expected to be significantly lower than in Iberia, with estimates ranging between $2.5 to $3.5 per kilogram. In comparison, production costs in Iberia are projected to be higher, around $4.00 to $4.50 per kilogram. This price disparity may encourage Iberian stakeholders to consider offtake agreements with North African countries, particularly if cost competitiveness becomes a decisive factor for the region."

green hydrogen across Europe, leveraging its strategic location and pipeline infrastructure."

4. *What do you see as the primary roadblocks for deploying large-scale hydrogen projects in Portugal and Spain, respectively? Are there specific regulatory, infrastructural, or financial challenges unique to each country?*

"Europe, and specifically Portugal and Spain, face challenges in expanding green hydrogen and ammonia projects due to the limited availability of land for deployment. This constraint poses a significant obstacle to the development of large-scale projects in these countries."

5. *One of these challenges is that there are currently very few full-service EPC contractors in Iberia, leading to high O&M costs for new projects. However, breaking down EPC responsibilities into separate contracts can increase risk exposure and impact the bankability of projects. What is your perspective on this challenge and how can developers overcome it?*

"The decision on whether to decentralize the responsibility among several EPC contractors or assign it to a single entity is critical in the integration of green hydrogen projects. While dividing the project into tranches among multiple contractors may reduce certain risks, it also introduces significant complexities, particularly given the nascent nature of this technology. One potential strategy to mitigate costs is to collaborate with EPC contractors from developing countries, who offer both the expertise and lower labor costs in comparison to European contractors. A joint venture model, combining the technical know-how of contractors from countries such as Egypt or

India with European project management, could significantly reduce the overall project costs while maintaining technical competence."

6. *From your perspective, when do you foresee renewable hydrogen in Iberia becoming bankable without subsidies? Will this primarily be driven by declining costs of renewable electricity and technology, or by rising carbon prices under mechanisms like the EU Emissions Trading System?*

"Securing offtake agreements is essential for the bankability of green hydrogen projects, as financial institutions require these to provide funding. Additionally, creating demand through carbon taxes on hard-to-abate industries and subsidies for green hydrogen producers will be critical to fostering a sustainable market for green hydrogen."

7. *The European Hydrogen Bank is focusing its auctions on lowering the LCOH, recognizing that CAPEX is not the only significant factor. In your view, how effective will this strategy be in driving competitive green hydrogen production in Iberia, and what other measures could further support cost reductions across the hydrogen value chain?*

"The European Hydrogen Bank's focus on lowering the Levelized Cost of Hydrogen (LCOH) through targeted auctions is a promising strategy to drive competitive green hydrogen production in Iberia. By emphasizing LCOH rather than solely focusing on CAPEX, the approach takes a more holistic view of hydrogen production costs, accounting for operational efficiency, energy input costs, and infrastructure utilization. This strategy is particularly effective in a region like Iberia, where abundant renewable resources - especially solar and wind - provide a strong foundation for

low-cost hydrogen production. However, for the strategy to achieve its full potential, additional measures must be implemented across the hydrogen value chain."

8. *As Iberia's green hydrogen projects advance, do you anticipate that most offtakers will be co-located near the production sites, or will there be a growing reliance on transporting hydrogen over longer distances to industrial demand centers? What key factors will influence this decision?*

"As Iberia's green hydrogen projects evolve, it is likely that both co-located and long-distance offtaker strategies will coexist, depending on specific market dynamics and project circumstances. While co-location offers economic and logistical benefits, the growing demand in industrial centers across Europe will necessitate long-distance transport to meet broader market needs. The European Union is repurposing existing natural gas pipelines to transport and blend green hydrogen until dedicated green hydrogen infrastructure is developed. This transition is crucial for Iberia, which will benefit from the use of repurposed pipelines to transport hydrogen throughout Europe. However, liquid hydrogen storage remains unviable, making green ammonia the preferred carrier for hydrogen storage and transportation through these pipelines. This approach positions Iberia as a key player in transporting green hydrogen across Europe, leveraging its strategic location and pipeline infrastructure."

9. *What is your evaluation of Iberia's potential to develop into a leading green hydrogen cluster?*

"Iberia has the potential to become a leading green hydrogen cluster due to its renewable resources, strategic location, and policy support. However, achieving this requires significant investment in infrastructure, enhanced regional collaboration, and efforts to attract local industrial offtakers. A phased approach - focusing on domestic clusters initially while preparing for export readiness - will be critical to leveraging Iberia's competitive advantages in the global hydrogen economy."

10. *How do you assess the engagement of Hydrogen developers in Iberia with local communities? Do you believe this will be important for future success of projects?*

"From my point of view, developers should foster technical schools in rural areas near production sites to foster local engagement."

Participant 3

1. *The Spanish government recently approved a new target to install 12GW of electrolyzers producing green hydrogen by 2030 as part of its updated National Integrated Energy and Climate Plan 2023-2030. Do you believe this target is viable, and if not, what are the key roadblocks that need to be addressed to reach it?*

"Spain is strategically well-positioned due to its abundant solar resources, onshore wind capacity, and the development of offshore wind. It is one of the most advantageous locations in Europe for green hydrogen production, with strong connectivity and established gas infrastructure to support transportation needs."

2. *What do you see as the primary roadblocks for deploying large-scale hydrogen projects in Portugal and Spain, respectively? Are there specific regulatory, infrastructural, or financial challenges unique to each country?*

"The primary challenge in the hydrogen sector is not related to investment or equipment, but rather the availability of offtakers. While capacity and equipment, such as electrolyzers, are in place, the development of hydrogen projects is stalling due to the lack of sufficient offtake agreements. Spain is well positioned with its renewable energy resources to produce low-cost hydrogen, but without committed offtakers, large-scale projects face significant delays. This issue is not unique to Spain; globally, hydrogen projects are struggling to advance despite having the necessary capacity and investment. While both countries have the necessary infrastructure, such as gas networks that could be retrofitted for hydrogen transport, this has not been tested at scale. Additionally, while Spain and Portugal have vast renewable energy potential, there is not yet a surplus of renewables to fully support large-scale hydrogen production. This requires further development of renewable energy infrastructure, which adds significant cost to hydrogen projects. Developers are faced with two options: either invest heavily in developing both hydrogen production and renewable infrastructure from scratch or wait for available capacity and sign power purchase agreements. Both options involve substantial challenges - either higher initial costs or delays in accessing competitive electricity pricing."

3. *How likely do you evaluate a strong Portuguese-Spanish market integration, where Spain would be the destination of green hydrogen produced in Portugal? What would be the main roadblocks for this scenario?*

"Portugal and Spain have significant synergies in renewable energy, with Portugal's potential for floating offshore wind and solar complementing Spain's established renewable capacity. Their well-connected infrastructure to the rest of Europe makes it mutually beneficial for both countries to collaborate closely on green hydrogen development."

4. *How do you evaluate current first mover strategies in Iberia, such as pursued by Copenhagen Infrastructure Partners. Do you see first-mover advantages overweigh current roadblocks that we see due to high costs and regulatory boundaries?*

"Securing an offtake agreement effectively mitigates most of the risks associated with hydrogen project development. In addition, location is crucial for hydrogen production, as 70% of the cost is tied to electricity, with renewable electricity being the primary factor. Spain is particularly well-positioned due to its proximity to affordable renewable resources, like North Africa, while also benefiting from its integration into the European energy infrastructure."

5. *How do you assess the risk that European companies might expand to the U.S. to benefit from the Inflation Reduction Act and then export their hydrogen derivatives back to the EU from there?*

"The competition between Europe and the U.S. certainly revolves around more than just hydrogen production; it encompasses the broader manufacturing ecosystem, including equipment manufacturers. The Inflation Reduction Act has indeed incentivized many companies to consider relocating or expanding their facilities in the U.S., which poses challenges for Europe's industrial base. The European Commission is trying to adapt its strategies to ensure that local industries remain competitive, especially considering U.S. incentives and the evolving dynamics with Chinese commerce.

6. *How important is government policy in advancing the Technology Readiness Level of hydrogen technologies? Are there specific policies that have significantly accelerated certain technologies to higher TRLs in Iberia?*

"Europe offers multiple layers of support mechanisms for innovation and development. At the European level, initiatives such as Important Projects of Common European Interest (IPCEI), the Innovation Fund, and the Hydrogen Bank are designed to support a wide range of activities, including equipment manufacturing and advanced research. These programs promote cross-border collaboration and benefit various types of players, from startups to well-established companies. Additionally, individual nations implement their own support mechanisms, tailored to their specific economic and industrial needs, which provide further opportunities for organizations. Larger players often leverage both European and national programs to drive large-scale projects."

7. *How can Portugal incentivize local offtake to support their own decarbonization before exporting hydrogen abroad?*

"There needs to be a market that values the additional cost that is needed for green hydrogen"

8. *Do the opportunities for securing offtake agreements and establishing consortiums in Portugal and Spain differ from other hydrogen markets?*

"Portugal and Spain have offtake advantages due to their proximity and land connection with central Europe, especially Germany, The Netherlands, and Belgium."

9. *A lot of electrolyzers are currently being procured from China / Chinese suppliers, both due to a more competitive pricing and availability. How likely do you foresee a European electrolyzer industry establish around new hydrogen projects in Iberia? If this industry was to establish, how could the EU and Iberia secure access to critical raw materials, such as rare earths from China?*

"Currently, European manufacturers lead the technology, industry capacity, and sourcing for large-scale projects. European projects are predominantly dependent on European manufacturers, but there is a looming risk with the emerging wave of Chinese manufacturers, who have rapidly scaled up production seemingly overnight. These new players from China present a significant challenge, as they are offering prices that are approximately 25-30% lower than their European counterparts.

While this poses a critical threat to European manufacturers, questions remain regarding the credibility and operational reliability of these new Chinese systems, as they have yet to undergo extensive examination. The European Commission is aware of this risk and is actively discussing measures to control and manage the flow of subsidies and support to prevent funds from benefiting Chinese manufacturers. European projects that receive funding or grants from the European Union will likely be required to source equipment from European suppliers."

“This is an ongoing discussion, and while the exact timeline for enforcement is unclear, it is likely that regulations will come into effect soon, given the seriousness of the issue. From an economic and competitive standpoint, Chinese electrolyzers may appear very attractive to project developers due to their significantly lower costs. However, the forthcoming European legislation and regulations must also be considered. Adding another layer of complexity to this situation is the fact that Chinese manufacturers are now setting up facilities in Europe, further complicating the competitive landscape.”

12. How can Europe and Iberia mitigate risks for offtakers, particularly those who will depend on the reliable and continuous supply of green hydrogen? What role does hydrogen storage play in in reducing these risks?

“This would primarily require policy intervention, which can be divided into two key parts. On one side, policies should aim to stimulate the market by incentivizing producers, possibly through mechanisms such as offering premiums or contracts for difference to help bridge the cost gap between grey and green hydrogen. On the other side, there should be measures to penalize emitters and encourage a transition to green hydrogen, such as increasing carbon pricing and imposing stricter emission limits on industries. However, these interventions come with costs that must be

carefully managed and distributed among the parties involved, without disrupting the market or placing an excessive burden on end consumers."

13. *In your study, you looked into the future potential of hydrogen storage solutions. From your point of view, where will hydrogen storage solutions be primarily located in Iberia and what will be the impact on the green hydrogen industry?*

"Storage is an extremely important aspect of hydrogen infrastructure, and the type and medium of storage will depend on the final application and availability. For industries such as power generation and fertilizers, which require large quantities of hydrogen, cost-effective storage solutions are essential. Additionally, the role of storage becomes critical when considering intermittent renewable energy sources. Without sufficient storage capacity, it would be difficult to maintain a continuous supply of low-cost hydrogen. For such applications, it is crucial to explore the availability of geological storage options, such as depleted oil and gas fields, reservoirs, or aquifers. However, the availability of these options varies geographically."

14. *What role will the sustainability of water use play in Spain's hydrogen projects, particularly in regions facing water scarcity, and how are projects incorporating desalination or other water management technologies to ensure sustainability?*

"Spain faces challenges with the availability of freshwater and is one of the largest users of desalination, ranking first in Europe. While hydrogen production typically requires freshwater, there is ongoing research into the use of saltwater, with desalination being a viable option. Although desalination would increase investment costs, there are two important factors to consider.

First, the environmental impact of desalination, particularly the discharge of brine water and the associated electricity consumption, must be addressed. Second, when comparing the freshwater consumption required for hydrogen production, it is relatively negligible. Additionally, the cost of building a desalination plant would only add around 2% to the overall cost of hydrogen production, making it a minor consideration."

15. *What offtaking-industries will Iberia primarily be able to serve, and which sectors will be served by other, more cost competitive regions such as Chile or Morocco?*

"Iberia has the potential to produce hydrogen at highly competitive prices, which could offset a portion of the additional transport costs and meet a significant portion of Europe's demand. When compared to countries like Morocco, Chile, and Egypt, Iberia holds a comparative advantage, especially if we exclude the costs of transporting and converting hydrogen. However, the critical question remains: how much of Europe's total hydrogen demand can Iberia realistically supply? Another key consideration is the trend seen in Germany's energy policy, which focuses on diversifying supply sources rather than purely minimizing economic costs. Many European countries may prioritize diversity of supply over cost-efficiency. Germany, for instance, has established communication and shown interest in importing hydrogen from regions as distant as Chile and Australia, as well as closer countries like Morocco and, to a lesser extent, Egypt."

16. *What do you foresee as the major obstacles in the Iberian Green Hydrogen Industry over the next 10 years?*

"I do not have specific details about Iberia, but it's important to understand the development process for renewable energy projects, including how long it takes to secure approvals, finalize social and environmental permits, and begin construction. Another key factor is the availability of the local electricity network, as grid connection bottlenecks can often delay or block progress. This process is likely to apply to hydrogen projects as well, as they follow similar steps across most European countries. If any issues arise in these stages, they could significantly hinder hydrogen project development. Additionally, since renewable energy sources are not always located near hydrogen production sites, grid connections are crucial for transporting electricity, making the grid an essential part of the infrastructure."

Participant 4

1. *Given the results of the first auction, do you anticipate that projects in Iberia will remain competitive in future auction rounds despite limited local demand and delays in the deployment of pipelines?*

"A major competitive advantage for Iberia is its low renewable power prices, which are crucial for hydrogen projects, especially since electricity costs account for 60-70% of total costs. Iberia's strength in this area is expected to continue, making it a key factor in future competition."

2. *While industry players appreciate the Hydrogen Bank's production subsidies, they have raised concerns about the absence of demand-side support, particularly given the limited demand in Iberia. Potential offtakers are reluctant to commit due to uncertainty surrounding the*

implementation of binding RED III targets and associated penalties. Do you plan to further involve offtakers in your work, or consider introducing a mechanism similar to Germany's H2 Global to address the cost gap for off-takers?

"Beyond OPEX, capital costs like lending rates, CAPEX for electrolyzers, labor costs, and operational costs also play important roles. Electrolyzers are traded freely across Europe, so differences may arise in OEM pricing and maintenance. On the revenue side, the willingness and ability to pay a green premium for hydrogen will be driven by both market demand and regulatory frameworks. We won't have different and uncoordinated support schemes for the supply and demand side because that would risk over subsidizing and create a lot of bureaucratic complexity in managing contracts between companies."

3. *Are there any specific policy frameworks that Portugal and Spain need to adapt or implement to better align with the European Hydrogen Bank's objectives?*

"On the regulatory side, the EU's RED III directive mandates a 42% industry quota for hydrogen, but it needs to be transposed into national law by countries like Spain and Portugal. The deadline is May next year, and there could be repercussions if it's delayed, as seen with other EU targets in the past. Europe's support environment, with instruments like the CO2 price and the quota system, is already much more comprehensive than anywhere else, including the U.S. with the IRA. At some point, the market needs to work without subsidies at every level."

4. *Are you concerned that the low clearing price in the first auction could lead to challenges for project developers, like what we've seen in other sectors like offshore wind in the US, where developers have pulled out due to unfavorable economic conditions? How does the Hydrogen Bank plan to address speculative bidding and ensure that selected projects have a clear business case and long-term viability?*

"Six out of the seven selected projects have signed, and with that, the competition bond comes into effect. If they fail to build, they won't just lose out on payment, they'll also face penalties, creating a strong economic incentive to complete the projects as promised. For the second auction round, we've raised the penalty from 4% to 8%. This decision isn't a reflection on the quality of the projects selected but rather the high level of competition we've seen, allowing us to implement stricter rules going forward. We've introduced an intermediary deadline of two and a half years for projects to reach FID. If they fail to meet that milestone, we'll pull the completion guarantee early, ensuring that funds aren't blocked for five years, and can be quickly reallocated for new bids in future auction rounds. Projects now need to submit a pre-FID study to bid, ensuring they are well-prepared. Although many were already doing this, we've formalized the requirement to guarantee project maturity, as bidders must be in a position to build within the five-year timeline. We don't micromanage how companies choose to bid. If utilities decide to bid aggressively, aiming for visibility or strategic reasons, even taking a small loss, that's their choice. Our role is to set penalties and incentives while letting them determine their best approach. Finally, it will be interesting to see if the aggressive bidding strategies seen in the first round will adjust in the second round. Ultimately, each company's board must make that decision, and it's important that we don't interfere with it."

5. *With the second auction's focus on reducing supply chain dependency, particularly on Chinese electrolyzers, do you foresee challenges for Iberian developers in sourcing affordable electrolyzers, potentially driving up project costs?*

"Our rule focuses on the stacks, which make up 50-60% of CAPEX, and CAPEX itself is only 30% of the total project cost. So, even if there's a price increase, we're talking about a few percentage points on 50% of 30% of the overall cost. This likely won't drive project costs through the roof, but it's something everyone will need to assess individually."

6. *Could you explain why projects with existing funding are often excluded from auctions, even when they are among the most advanced and promising? Might the European Hydrogen Bank reconsider its policy on subsidy accumulation or explore ways to account for different stages of development in future auctions?*

"Our philosophy is that we live in a free market economy, and demand and supply elasticities distribute the effect of a subsidy. We try to avoid excessive bureaucratic effort and stick to principles because we believe they're the right approach. The reason we don't allow for accumulation is that we want competition based on the best project economics, not on which country offers the most generous national funding. If that were the case, countries like Germany, Denmark, and the Netherlands would always have an advantage, and that's not what we want to drive. There are many projects that have received previous funding but are stuck because it wasn't enough or because their economics have changed. We understand that, and while those projects have other funding opportunities, such as through the Innovation Fund general call, they can't participate in the auction. The auction is designed to create a level playing field, based solely on

project economics. Therefore, our auction deliberately excludes national state aid availability to ensure that the competition remains fair. For projects needing further support, other instruments - like the Innovation Fund - are still available to help them reach completion, but the auction isn't the tool for that."

7. *Can you explain the role industry participation has played in shaping the auction design, particularly in terms of rewarding early movers in the hydrogen industry?*

"We always involve offtakers in our stakeholder consultation workshops because they're an important part of the equation. We listen to their feedback on the auction design, and we incorporate it. We aimed for maximum transparency when summarizing the feedback we received. Our design choices reflect a balance between the various - and sometimes conflicting - opinions from stakeholders, all grounded in solid economic principles. Consultation with industry is crucial. They provide valuable feedback on what's realistic and feasible, especially in terms of standards like ISO or cybersecurity requirements, which are directly shaped by conversations with manufacturers and common industry practices. We've heard a wide range of opinions from stakeholders, and we've tried to find a balanced middle ground in the auction design. It's been a thorough process, ensuring that it reflects both the industry's needs and the principles we believe in."

8. *How might Spain and Portugal leverage the "auctions-as-a-service" model, as seen in Germany's participation in the first auction? What are the main roadblocks for countries using*

this model? Will the European Commission offer incentives to encourage member states' participation?

“H2Global has a double-sided auction, meaning they take the whole counterparty risk. That's a very different model. We're not changing our auction model this year, but we’ll consult again next year after we’ve seen more progress from the first round of projects.”

9. *One major challenge for developers is the differing standards and regulatory frameworks across countries, even between Portugal and Spain, despite their shared electricity market. In your opinion, can the European Hydrogen Bank help align national standards to address this issue?*

   “When it comes to electricity tariffs and grid connection requirements, these are regulated by national laws, and member states have the authority to make their own decisions. Our instrument is too small, both financially and in terms of the hydrogen sector’s overall importance, to have any real impact on aligning those national regulations." "We don’t have the capacity to enforce or influence national standards like electricity tariffs or grid connection rules. This is governed by national parliaments, and hydrogen’s role within their broader regulatory frameworks isn’t significant enough for our instrument to impose any change.”

Participant 5

1. *How does your company navigate the current regulatory landscape for hydrogen production and distribution in Portugal, and what changes would you propose to accelerate the hydrogen economy around Sines and in Portugal?*

"Currently, renewable hydrogen is not being traded because it is not yet competitive. We are producing gray hydrogen, but replacing it with green hydrogen remains very expensive, and there's a significant funding gap. Without substantial financial support, it's impossible to build a viable business case for green hydrogen projects - this challenge exists across all geographies. Green hydrogen today mirrors the early days of wind and solar energy - expensive and reliant on funding support. However, as costs decrease and the technology matures, it will become competitive, just as renewables did. Investors will shift focus away from fossil fuels, as green alternatives become more attractive from a business perspective. Currently, even if you support 100% of the CAPEX, you're still not in the money, and so without support on the OPEX, it's very difficult to make the business case a reality. So, another way to combine this and to complement this is to support the demand and the demand can be supported by supporting OPEX as well."

2. *Do you believe a mechanism to support direct use of hydrogen in Portuguese industries could help to stimulate project implementation, and if yes, how would this look like?*

"We know how to produce renewable hydrogen, but it's many times more expensive than traditional fuels like diesel, gasoline, or gray hydrogen. To build a competitive hydrogen economy, we need not only vision but the right policy tools and incentives to make production financially

sustainable. Supporting demand is what's missing. Investments are needed to help pay the premium and make modifications in processes or equipment for applications like buses or trucks. This is a gap not just in Portugal and Spain, but across Europe and the US as well. The issue with the European Hydrogen bank is that: Projects with existing funding, which are often the most advanced, are excluded from auctions. This creates a situation where smaller, less developed projects struggle to meet cost requirements, leaving larger, more capable projects sidelined. In addition, I anticipate speculative behavior in these auctions, leading to mixed signals for policymakers. While the short-term outcome may seem favorable, in the long run, it could lead to dissatisfaction when projects fail to materialize as expected. A demand-side mechanism could work similarly to H2 Global in Germany, which is a two-sided mechanism supporting both production and demand. A system like this could be adapted for the demand side, providing balanced support in both directions. When designing public policies, it's important to ensure they are fair and socially just. Renewable hydrogen will be a heavy consumer of electricity, and poorly designed policies could penalize electricity consumers or create cross-subsidization. This could unfairly make electricity users subsidize the decarbonization of the gas sector or other hydrogen consumers. Policies should avoid these inequities and ensure support goes to the right stakeholders."

3. *What are your expectations regarding how Portugal will implement the binding industry targets from RED III into national law, and how will this affect your hydrogen project plans in Sines?*

"Both Portugal and Spain are beginning to address hydrogen consumption targets, but the details are still unclear. Member States have flexibility in implementing European regulations, but critical information, such as sector-specific targets and penalties for non-compliance, remains unknown. Without knowing these penalties, industrial consumers are hesitant to commit to long-term hydrogen purchases, as the financial risks could be substantial. Furthermore, there is a need to harmonize the regulatory framework across markets and geographies. For instance, between Portugal and Spain, we participate in the same power market, yet their plans seem disconnected. Basic coordination issues, like two neighboring countries exporting simultaneously, show that there is plenty of room to improve when designing public policies."

3. *Portugal recently approved a one-stop-shop system for renewable energy projects. What role could this system play in accelerating the development of hydrogen projects in the country?*

"Local authorities' actions are often not aligned with the government's policy objectives or renewable energy targets. The painful, lengthy permitting process we've faced with renewables is now being repeated with hydrogen projects, despite the government's push for both. Even for a small R&D hydrogen pilot project in Portugal, navigating the public administration is a major headache. It's a first-of-its-kind project, and no one, including the authorities, seems to know who's responsible for what, which leads to delays and confusion. There's a clear lack of both knowledge and resources within public administration, along with a need for digitalization to make processes more efficient and agile."

4. *Which of the current early-stage projects do you see becoming integral part of the local hydrogen ecosystem in Sines? Do you foresee competition, or is there potential for further collaboration with new stakeholders and projects?*

"At this point in time, players need to be open to collaboration because there's no demand to compete over. There's a tremendous amount of knowledge and synergies to build, especially when it comes to shared infrastructure and working with nearby projects. From our perspective, we are well-positioned in the hydrogen market because our project, GreenH Atlantic, has a secured off-taker, Galp, who is also a shareholder. This involvement from the offtaker is key, as they have a deep understanding of the costs, market conditions, and the value of renewable hydrogen. Finally, our 100 MW project is more credible than others because it is less dependent on unknown demand or the development of non-existent infrastructure, such as port logistics. While still small compared to other large-scale projects, our project's foundation is solid and will be of interest to key players."

5. *How does your company view the potential for synergies between GreenH2 Atlantic and other hydrogen projects in Sines such as MadoquaPower2X? Are there specific areas where collaboration could enhance both projects, such as shared infrastructure, logistics, or technology integration?*

"Sharing O&M costs across businesses is rare because it's highly specific to individual operations and entails risks that most players are unwilling to take on. While we don't usually see companies collaborating on O&M, there are synergies in shared infrastructures like pipelines, storage, and logistics, where collaboration is more common and beneficial."

6. *With a limited number of Engineering, Procurement, and Construction (EPC) providers in the Iberian Peninsula, could H2 Atlantic and other emerging projects in Sines combine their resources to negotiate better terms with EPCs or even attract international firms for more cost-effective O&M execution? What is your strategy to ensure affordable and reliable O&M in Sines?*

"We have hundreds of workers at our transitioning sites, being retrained for the renewable hydrogen economy. Our long-standing presence in these communities, along with repurposing existing infrastructure, helps us contribute to the energy transition while preserving jobs and supporting the local economy. It's a compelling story of workforce development and its alignment with the energy transition."

7. *How does your company envision the integration of hydrogen production with existing renewable energy sources and what current technological challenges do you face in ensuring integration of hydrogen with the electrical and gas grids in Sines and across Portugal?*

"There is a global understanding that we need to fully decarbonize our economy, and while energy efficiency and electrification can go a long way, we still need fuels for high-temperature processes and certain transportation sectors. This is where renewable hydrogen becomes crucial, but it requires comprehensive policy frameworks and regulatory support to bridge the financial gap and make it viable. I believe the market will start in a decentralized form with production and consumption nearby, but long-term, we need to connect the dots and create a tradable commodity, both within the continent and overseas. While overseas trade may be easier with existing infrastructure, the carrier and seaborne trade options are still unclear. Within continents, pipeline

infrastructure is crucial but will take many years to develop, and we must not neglect this part of the value chain."

9. *One major risk for project developers is the obligation to deliver hydrogen when facing technical or environmental challenges. How do developers protect themselves from contractual obligations to deliver hydrogen if technical issues arise? Can hydrogen producers in Sines establish backup agreements with each other to ensure supply continuity in case of production shortfalls?*

"At the early stages of hydrogen projects, it's essential to have an offtaker with operational flexibility. Without this, the project would require nearly double the capacity to account for potential failures, which are inevitable. Downtime could last for months, and a flexible off-taker ensures that, if disruptions occur, they can seamlessly switch to alternative sources without impacting operations."

10. *According to a study by Boston Consulting Group, only 3% of offtakers want to commit to offtake agreements for longer than 5 years. What are the main barriers to securing long-term offtake agreements? How can offtake agreements be designed to be mutually beneficial for both parties? In your view, how can Portugal and Spain de-risk projects not only for project developers but also for offtakers who will become increasingly reliant on green hydrogen?*

"As an industrial consumer, I can't commit to paying a premium for hydrogen without understanding the future regulatory landscape. The market is on hold because consumers fear committing to costs that could become irrational in the long term and threaten their business

viability. As a hydrogen developer, we're securing public funding, land, environmental licenses, and grid connections, but we can't make a final investment decision. Without a long-term commitment from credible off-takers, it's impossible to proceed confidently. This is the situation not only in Portugal and Spain but also in other markets like the US."

12. *How does your company plan to ensure grid flexibility and stability while integrating large-scale hydrogen production into the energy system in Sines? Do you anticipate any issues in balancing the grid as renewable energy sources and hydrogen production facilities are deployed?*

"We're developing three projects in Iberia, each at 5 MW, spread across different locations, one in the North of Spain, another in the South, and a third in Portugal. This approach will, in enable one project to serve as a backup for another, thereby minimizing the need for costly spare components across all sites in the future once infrastructure in its place. In the absence of a reliable network connection, large-scale storage solutions become essential, though they are costly to implement."

13. *From your perspective, what set of instruments could address the funding gap most efficiently: direct subsidies and regulatory incentives like the Hydrogen Bank, or environmental charges and creation of demand through taxes & obligations?*

"The hydrogen bank offers a fixed premium on top of revenues from the offtaker. To participate, you need to estimate your own price hypothesis and define the gap. However, the offered premium is very small, which indicates that this move is likely more about securing an option rather than

closing the gap in costs. In fact, with such low bids, it's speculative, as participants are likely expecting someone else to cover the remaining costs, which is unlikely to happen. The hydrogen bank is designed to bridge the gap between costs and revenues, but some of the winning bids raise concerns as they may not fully reflect the actual financial needs. This could make it challenging for these projects to move forward successfully. At the same time, more advanced projects with existing funding are excluded from participation, which limits the involvement of well-prepared developers. This situation risks favoring less mature projects over more established ones, particularly in regions like Spain and Portugal."

14. *Based on your experience, what trends are you seeing in the willingness of off-takers in Portugal to pay a green premium for renewable energy? How do you foresee this evolving in the near and long term, considering factors like regulatory changes, corporate sustainability goals, and market competition?*

"Offtakers often have unrealistic price expectations, hoping that costs will be lower. However, the reality is that financial costs have surged dramatically, especially electricity prices, which now represent up to 75% of the cost of hydrogen production. Over the past three years, these prices have risen sharply due to global instability, and there's no relief in sight. Given these conditions, it's nearly impossible for smaller projects to achieve production costs of €5 per kilogram, making it especially challenging for them to succeed."

Participant 6

1. *Could you elaborate on the specific strategies and technologies GreenH2Atlantic will implement to optimize operating expenses, enhance load factor efficiency, and manage real-time hydrogen production at the Sines hydrogen hub?*

"We are developing a comprehensive hydrogen energy management system, which will serve as the backbone of our operation. This system will not only facilitate the interconnection between our green hydrogen and gray hydrogen production sites but also ensure compliance with regulations like RFNBO. The complexity of this project lies in managing multiple inputs and consumers across different sites, making the seamless integration of these hydrogen streams critical to optimizing the entire production process. In parallel to our software development efforts, we are creating a digital twin that simulates the optimal operational point of the electrolyzer. This digital model considers various factors like energy production, consumer demand, and electricity costs. By doing so, we can continuously adjust operations to achieve cost efficiency while optimizing production output, allowing us to adapt to changing energy market conditions and consumer needs."

2. *Your company aims to decarbonize the Sines refinery by replacing grey hydrogen with green hydrogen. What are the key challenges your company anticipates in scaling up green hydrogen production for the refinery, and how do you plan to address these challenges?*

"In line with our commitment to carbon neutrality, we are collaborating with a partner to develop a next-generation optimization tool specifically tailored to our hydrogen production processes. This tool aims to combine the best features of existing market solutions with innovations that address our unique operational challenges. Our goal is to build a more tailored, flexible solution that not

only complements our hydrogen management system but also pushes the boundaries of optimization, ensuring maximum load factor and operational efficiency. We have a roadmap to increase decarbonized hydrogen in our assets, but one of the biggest challenges we're currently facing is navigating the regulations and policies around this first-of-its-kind scale production. At 100 MW, it's a significant project, and since this is new territory for both us and the regulatory bodies, especially in Portugal and even in Europe, it's been a learning curve. The bureaucratic process is slower because we're essentially breaking new ground, and with that comes unforeseen complications that we must overcome. The complexity of this project is heightened by the fact that it's not a standalone initiative; it's connected to our existing refinery, which operates under a distinct set of standards and regulations. Traditionally, refineries have been designed around hydrocarbons, adhering to robust, over-engineered API (American Petroleum Institute) standards that ensure decades-long operational lifespans. In contrast, hydrogen production standards are less rigid, reflecting shorter project lifespans of 20 to 25 years. This disparity necessitates a careful restructuring of our internal processes to harmonize these two systems. We are tasked with balancing the well-established practices of the refinery with the more agile, rapidly evolving standards of hydrogen production. This requires us to rethink our internal processes and practices, restructure how we approach design, and find a balance between the two systems as we push forward with decarbonization."

3. *What motivated your company to take the risk as an early mover in Green Hydrogen Purchase Agreements, despite uncertainties around RED III implementation in Portugal? What specific first-mover advantages do you foresee for early off-takers in Sines and more broadly in Portugal?*

"I believe that the initial leaders in the decarbonization space will primarily focus on direct hydrogen use. A critical factor driving this shift will be carbon emissions taxation which will either incentivize or penalize companies depending on how regulations evolve. It will be mandatory to comply with the upcoming carbon emissions regulations, and licenses will become more stringent. The companies that survive will have to find ways to decarbonize, primarily through energy efficiency and smaller projects that provide gains in energy savings. As you go deeper into decarbonization efforts, the costs associated with reducing CO2 increase. However, if companies can manage to surpass the cost of carbon emissions, they will continue to invest in these projects to remain competitive. The licenses for carbon emissions will become a key factor for survival, and companies that want to stay in business will need to adapt to more stringent regulations. Decarbonization will not just be an option but a necessity."

4. *With the growing number of hydrogen and renewable energy projects in Sines, what synergies do you foresee from their co-location? Are there specific opportunities for collaboration on shared infrastructure, logistics, or technology that could enhance the efficiency and outcomes for your company?*

"We may have some minor generic reform stations and are doing some off taking for ourselves or others, but this will be at the beginning stage with lower values. From the point of view of offtakers, if you don't use hydrogen directly, it will be more difficult to close the economics at this time. There is some collocation synergy, and that's why they are creating this green energy project. We have a part with all the infrastructure in place, including logistics facilities for offtake. This infrastructure will be used by all, and various scenarios can be built upon this. We already have synergies because we are close to a petrochemical and chemical industry. The renewable infrastructure is already

complex, especially when trying to integrate with multiple electrolyzers. Adding more complexity to an already intricate project could create challenges. You need to ensure that you have your base load covered, which guarantees a higher load factor and stability. I don't see the need to share facilities when it comes to producing green electricity. Some facilities are better off being dedicated to specific projects rather than shared, to avoid further complications in managing the renewable infrastructure."

5. *What steps have enabled your company to reduce the LCOH in Sines and where do you see the biggest opportunities for further cost reductions?*

"The ones that will be closer to closing the economics in hydrogen production will be those that directly use hydrogen without converting it into other forms, avoiding additional capital expenditures. The idea is to use the hydrogen directly and efficiently. We are in a strong position because we also produce green energy through our own photovoltaic plants. This gives us access to green electricity, and with Portugal's energy mix becoming over 90% decarbonized by 2037, we are ahead of many others in this transition. We are not near a city center, but we have access to all the necessary logistics facilities to offtake the product. This is a key advantage as it allows us to centralize production and distribution efficiently."

6. *What role do you see for national or EU-level support mechanisms, such as subsidies, quotas, or initiatives like Germany's H2Global, in increasing demand for green hydrogen in refineries and other sectors in Sines?*

“There are a lot of announcements, but you don't see a lot of projects achieving FID at the moment. Without support, direct use and a strong balance sheet, it becomes challenging to push projects further.”

7. *What specific strategies is your company pursuing to monetize the oxygen and heat by-products from hydrogen production in Sines? How do you expect these efforts to impact the project’s profitability, and what role will by-product valorization play in strengthening the business case for green hydrogen?*

“We are doing several studies on how to use the oxygen byproduct in our refinery. There are many possibilities, such as increasing efficiency in the furnaces with oxygen or using it to improve catalyst performance. We’re exploring ways to monetize this product further. We also see opportunities in using waste heat from the refinery. There’s a possibility of integrating this waste heat into other systems or using it for desalination projects because we’re near the seawater. We believe this kind of desalination project will be a big part of the future.”

8. *What is the rationale for operating the electrolyzer at a constant 100% baseload using grid electricity, supported by two oversized green PPAs, instead of investing in hydrogen storage? How does this approach benefit your company in terms of cost, efficiency, and operational stability? Do you believe that the following projects will pursue a similar strategy?*

“It's a cost decision. The economics don't make sense to invest in hydrogen storage for more than a couple of hours. By 2035-2037, we expect to have a 90% green electricity mix, making it difficult

to justify storage projects like hydrogen or batteries for such a short time span, maybe just seven or eight years. The return on investment isn't there. We believe more in electricity and battery storage than in hydrogen storage. However, we still maintain some storage as a safety measure to keep operations running smoothly if something goes wrong. It's not about long-term use but more about providing flexibility in production and consumption when necessary. We have oversized PPAs, and any energy we don't use, we sell. Even though there's a cost involved, we do get a return from the energy we sell, making it a viable option."

9. *How do you see GreenH2Atlantic attracting hard-to-abate industries like steel and cement, and positioning Sines as a key hub for renewable shipping fuel for major shipping companies?*

"We are in a strong position because we also produce green energy through our own photovoltaic plants. This gives us access to renewable electricity, and with Portugal's energy mix becoming over 90% decarbonized by 2037, we are ahead of many others in this transition. What I believe is that the production of hydrogen will be more decentralized and closer to the offtakers. Industries like cement, steel, or ceramics will need hydrogen for decarbonization. A consortium can be formed to share an agreed amount of hydrogen, with each party investing towards the same goal. The backbone of this project involves connecting all the offtakers and producers in Sines to share hydrogen through the region. However, I don't foresee a significant amount of hydrogen being exported; it's more likely that products like ammonia and methanol, or biofuels incorporating green hydrogen, will be exported. The project's focus is on supporting industries like cement, steel, and ceramics with hydrogen for decarbonization. By forming a consortium, several offtakers can share the hydrogen supply, spreading the investment and risk. For existing facilities, the

hydrogen production will likely be arranged through clusters to diversify offtakers and reduce project risk. I see this as a better approach than relying solely on one offtaker. Companies moving to new locations like Sines will benefit from the established infrastructure and logistics, making it a green energy hub."

10. *To what extent do you see monetizing byproducts like oxygen and heat from hydrogen production as a significant part of the overall business case? Is it a core strategy, or more of a secondary opportunity for innovation? Additionally, given the emphasis on these byproducts in academic discussions, how do you perceive their actual role and attractiveness within real-world projects like this?*

"Oxygen is already a key component in our refinery operations, but we are actively conducting feasibility studies to explore how we can further monetize this byproduct. For example, we're assessing its use in increasing furnace efficiency through oxy-combustion and evaluating its impact on catalyst performance in specific units. These efforts aim to maximize the value of the oxygen we produce, ensuring it contributes to greater operational efficiency and sustainability within our refinery processes"

11. *What are the key opportunities and challenges associated with using seawater and wastewater for hydrogen production, and how is your company addressing potential cost increases or operational hurdles related to desalination and water processing?*

"We've already studied some integration with wastewater, looking at alternatives to reduce CO2 emissions. The aim is to use resources like seawater more efficiently, but current licensing is still a challenge."

Participant 7

1. *How can green hydrogen projects adapt to the impacts of climate change, such as increased drought frequency, to maintain water supply sustainability?*

"Balancing water use for agriculture, energy, and industry in arid regions requires regional solutions, equitable policies, and access to high-quality water for sustainable and fair resource management."

2. *What water sourcing methods (e.g., desalination, wastewater reuse) do you believe have the most potential to support green hydrogen production sustainably?*

"Efficient hydrogen production relies on the use of high-quality, contaminant-free water, reducing dependency on biologically mediated pathways and enhancing the performance and scalability of advanced technologies such as electrolyzers."

3. *To what degree is lifecycle assessment already integrated in project selection and development and what do you recommend to further consider lifecycle impacts as a regulator and developer?*

"Lifecycle assessments (LCAs) are increasingly utilized in sectors such as construction and green manufacturing to inform policy and guide sustainable practices. However, their application in energy systems and bio-based fuels remains limited, highlighting a disconnect between sustainability ambitions and comprehensive environmental evaluation. The incorporation of lifecycle assessments into green finance and industrial practices is essential for holistic sustainability. Yet, many sectors prioritize narrow metrics, such as carbon footprint and water usage, over the complex indicators required for a full understanding of environmental impacts."

4. *What strategies are most effective for fostering local community acceptance of large-scale green hydrogen projects?*

"Sustainable community engagement relies on long-term partnerships with trusted local organizations, aligning their goals with project objectives to build trust, foster collaboration, and ensure meaningful impact over time. Successful projects prioritize partnerships with local institutions that hold community trust, moving beyond fleeting strategies to establish enduring relationships that align local needs with project aspirations."

6. *How can green hydrogen developers balance investor demands for cost efficiency with community and environmental group expectations?*

"Sourcing locally or within Europe, even at a higher upfront cost, aligns with quality, sustainability, and compliance, mitigating future regulatory risks while supporting long-term cost-effectiveness. Investing in human rights and environmentally compliant local supply chains not only addresses ethical and regulatory demands but also serves as a strategic safeguard against future risks in an increasingly transparent market."

8. *What are common conflicts between developers and stakeholders in green hydrogen projects, and how can they be effectively resolved?*

"Transitioning to hydrogen-based solutions highlights the delicate balance between regulatory compliance, practical implementation, and community acceptance. Stakeholders demand assurance

of safety and adherence to standards, while value chains must address localized concerns, including the 'not in my backyard' effect, to ensure successful adoption and integration."

10. *What roles do environmental organizations and NGOs play in ensuring green hydrogen projects adopt responsible water usage practices?*

"Polarizing advocacy strategies that position companies as adversaries rather than collaborators can hinder opportunities for meaningful engagement and sustainable development. A more constructive approach emphasizes collaboration by recognizing companies as experts in their respective fields, fostering partnerships to co-develop sustainability initiatives and conduct joint assessments. This approach not only aligns corporate expertise with sustainability goals but also promotes shared accountability and long-term progress."

11. *Could community ownership models, like those used in onshore wind farms where residents hold a minority stake, be adapted for hydrogen projects despite their high costs and current lack of profitability? Or is this approach better suited to other technologies and industries at this stage of hydrogen's development?*

"In hydrogen projects, the social impact often lacks the tangible, immediate disruptions - such as noise, visual impact, or smells - found in other technologies, making community engagement more nuanced. While citizens primarily prioritize uninterrupted access to water, farmers and industries may express concerns over resource allocation and competition. Addressing these through strategies like industrial symbiosis - sharing energy, waste management, or supply materials - can foster collaboration and mutual benefit. For residential areas, where infrastructure like electrolyzers

resembles familiar utilities, the focus should remain on transparent communication to ensure acceptance without overcomplicating engagement strategies.”