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Catalyzing the Clean Hydrogen Economy Using Business Model Innovation

Introduction

The low carbon intensity—or 'clean'—hydrogen market is far from where it needs to be to meet 2050 global decarbonization objectives with 2020 global hydrogen demand roughly equaling 90 million tons, mainly produced from fossil fuels.[1] To achieve net-zero greenhouse gas emissions by the same year, the clean hydrogen market will need to reach 600 MtH2eq by 2050, roughly six times current global hydrogen supply … and according to Deloitte analysis, that is achievable under the right conditions.[2] Those conditions cannot exist without decisive policy support to help create the foundation for market development via the underpinning of attractive business cases, clear standards and certification processes, supply chain diversification to ensure long-term resilience, etc.

Our focus in this paper turns to players in the private sector who struggle with how to mitigate perceived risk in the early stages of market development, even in regions with relatively attractive policy conditions (such as we see right now in the U.S. with certain tax provisions of the Inflation Reduction Act), on account of a simple reality: while we know how to produce clean hydrogen, it remains prohibitively expensive relative to alternatives for many businesses. While there is belief that costs will likely come down as the industry scales, progress toward the development of a robust global hydrogen economy has been slowed by uncertainty about where to begin among the various market participants operating across the value chain.[4] Many would-be hydrogen suppliers may fear that demand is inadequate, and many would-be hydrogen buyers may fear that cost-competitive supply is uncertain, contributing to market stagnation. Furthermore, for potential investors in enabling infrastructure that could catalyze future growth, that uncertainty is palpable.

Many have come to refer to this as the "chicken-or-egg" problem in hydrogen: what comes first—the supply or the demand signals … or even the enabling infrastructure? That likely understates the complexity of the issue we are facing, however. It might more aptly be described as the "systemic first mover dilemma" in clean hydrogen, with multiple different counterparties worried that if they move first, they may get stranded whereas if they don't move soon enough, they may get left behind. Deloitte and Princeton University's Andlinger Center have recently teamed up to explore the issue.[3] Working with industry participants at every stage of the hydrogen value chain, at least a dozen points were identified in the development, production and distribution of hydrogen where the first mover problem exists—in which one side in a bilateral relationship is waiting to see what the other does before committing resources—and it goes beyond suppliers and off-takers of the clean hydrogen itself. With funding, what might be the interplay between capital availability from private sources versus government incentives? Could electrolysis production start to scale before a clear path to solving supply chain challenges is sorted out? Could distribution infrastructure be developed without strong demand signals and price stability? The list goes on.

[1] IEA 'Net-Zero Emissions by 2050' scenario
[2] https://www2.deloitte.com/content/dam/Deloitte/at/Documents/presse/at-deloitte-wasserstoffstudie-2023.pdf
[3] https://acee.princeton.edu/wp-content/uploads/2023/07/Princeton_H2_study_final_report_June_2023.pdf
[4] Deloitte, Green hydrogen: Energizing the path to net zero

The challenges constraining the expansion of the clean hydrogen market, hinging on a short-term cost gap between clean hydrogen and alternatives, are typically ascribed to insufficient public policy, immature technology, or outdated business models.[5] Clean hydrogen policy and technology have made strides forward in the past several years, but innovative business model solutions have yet to reach widespread adoption. While government subsidies are catalyzing activity, they are limited: insufficient to cover the cost gap versus existing fuels, and some feel they are uncertain and hard to access. Simply put, organizations – whether in the private sector or public sector – have longstanding and deeply-held orthodoxies about 'the ways things are done' in energy project development. These norms in how to contract, in how to manage risk and in how to think about asset lifecycles should be challenged if the clean hydrogen market is to scale.

The investment dilemma, grounded in lagging business model solutions, is rooted in five key uncertainties present in today's clean hydrogen market:

I. **Demand uncertainty:** what if demand sectors don't contract for clean hydrogen at scale because of perceptions about price curves? Can companies access the needed financing mechanisms?

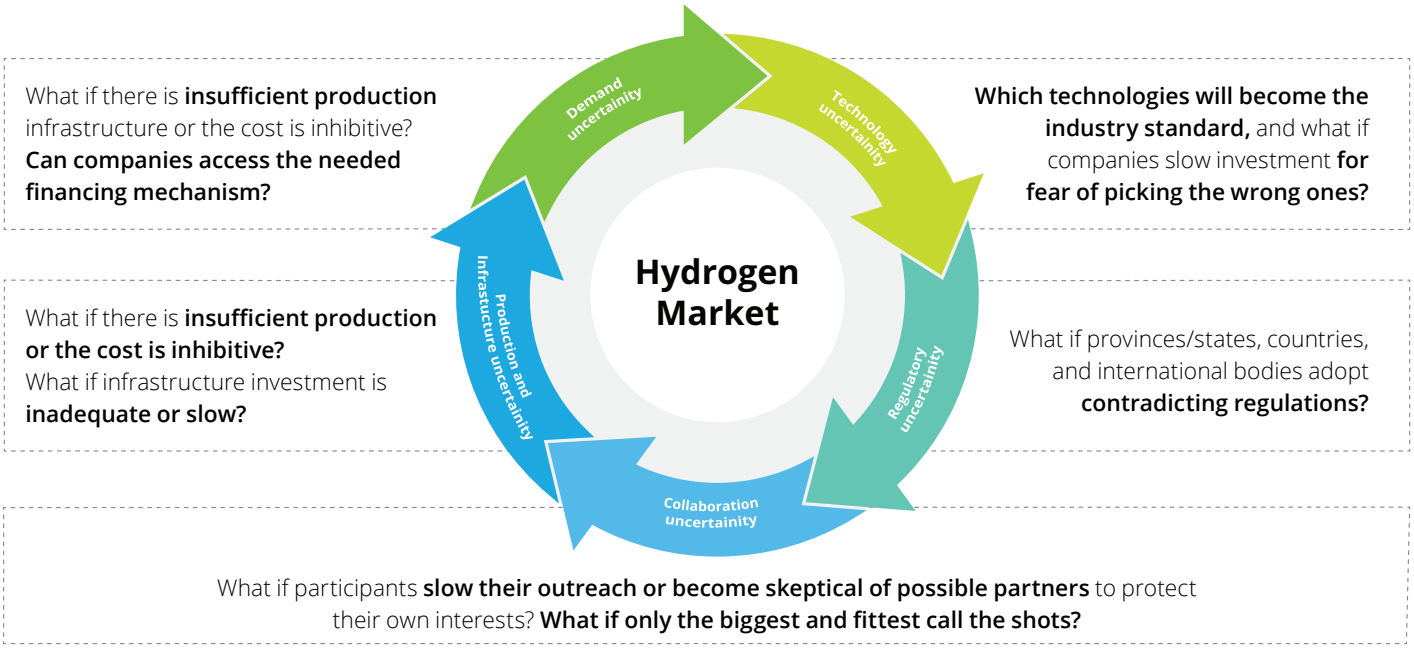
II. **Regulatory uncertainty:** what if provinces/states, countries, and international bodies adopt insufficient and/or contradictory regulations?

III. **Technology uncertainty:** which technologies will become the industry standard, and what if companies slow investment for fear of picking the wrong ones or lagging on the learning curve?

IV. **Production and infrastructure uncertainty:** what if there is insufficient production and infrastructure investment, or the cost is inhibitive? What if perceptions about ecological impact or public acceptance slow investment?

V. **Collaboration uncertainty:** what if participants slow their outreach or become skeptical of possible partners to protect their own interests? What if only the biggest and fittest call the shots?

Five key uncertainties in today's clean hydrogen market



[5] Deloitte Energy Transition Monitor

All of these align with the factor conditions needed to accelerate the hydrogen economy. For more information on the factor conditions, consult Deloitte's "Hydrogen: Making it Happen" report.[6]

These five uncertainties create risks that many companies are unable to individually manage and address. To help address the risks, Deloitte's research finds a number of innovative, real-life business model solutions that can help address these uncertainties. Some are present in the hydrogen industry today; others come from more mature energy industries that may have relied on business model innovation when they were in nascent stages of their own. By applying these solutions, businesses may finally crack the first mover dilemma in clean hydrogen at scale. Note that in the balance of this paper, we explore each of the uncertainties except for technological uncertainty, as that warrants a separate and more technical treatment, though business model solutions such as robust systems of standards and measures can likely help on the technology front as well.

The solutions aim to mitigate uncertainties by decreasing risk. While the solutions alone will not be able to make projects economical, they have a fundamental role to play in conjunction with policies, technological advancements, and fundamental market dynamics.

The solutions identified generally contribute to risk reduction through the following mechanisms:

- **Risk share:** distribute the burden and risk across a number of players
- **Risk transfer:** transfer some or all the risk to players that can absorb it
- **Risk alignment:** adopt mechanisms that ensure risks align with the diverse business models or parties involved

We highlight in the next section business model solutions that could help address uncertainties through risk reduction mechanisms. There are many that exist in the market today … but not many at scale. Here, we highlight thirteen models to illustrate the value they can bring. If implemented, these solutions could provide an added benefit to address the first mover dilemma and move one step closer to a scaled clean hydrogen economy.

6. https://www2.deloitte.com/nl/nl/pages/energy-resources-industrials/articles/hydrogen-report.html

1. Take or Pay [Risk Share → Demand Uncertainty]

In a Take or Pay agreement, the buyer and seller enter a contract to share risks between both parties. In the take scenario, the buyer purchases a pre-determined amount of goods and accepts shipment of them. In the pay scenario, the buyer still pays the seller a pre-determined amount but does not take shipment of the goods. In this model the buyer benefits from a consistent and predictable payment schedule, but avoids an obligation to take shipment of, process, and store goods that it does not need. The seller benefits from predictable revenue flow, but risks having to hold onto and store product. Take or Pay agreements can allow both buyers and sellers to avoid the cash flow unpredictability that commonly challenges businesses in nascent industries: the buyer makes guaranteed payments, and the seller receives guaranteed payments. By enabling buyers and sellers alike to demonstrate predictable cashflows, Take or Pay agreements can help market participants attract investment that can help them contribute to the development of the clean hydrogen economy.

The liquefied natural gas (LNG) industry, which faces many of the same shipping and storage challenges that today confront the hydrogen industry, often uses Take or Pay clauses for supply contracts.[7] LNG producers and consumers alike often find that these clauses help attract investment by eliminating the risk associated with unpredictable cash flows.

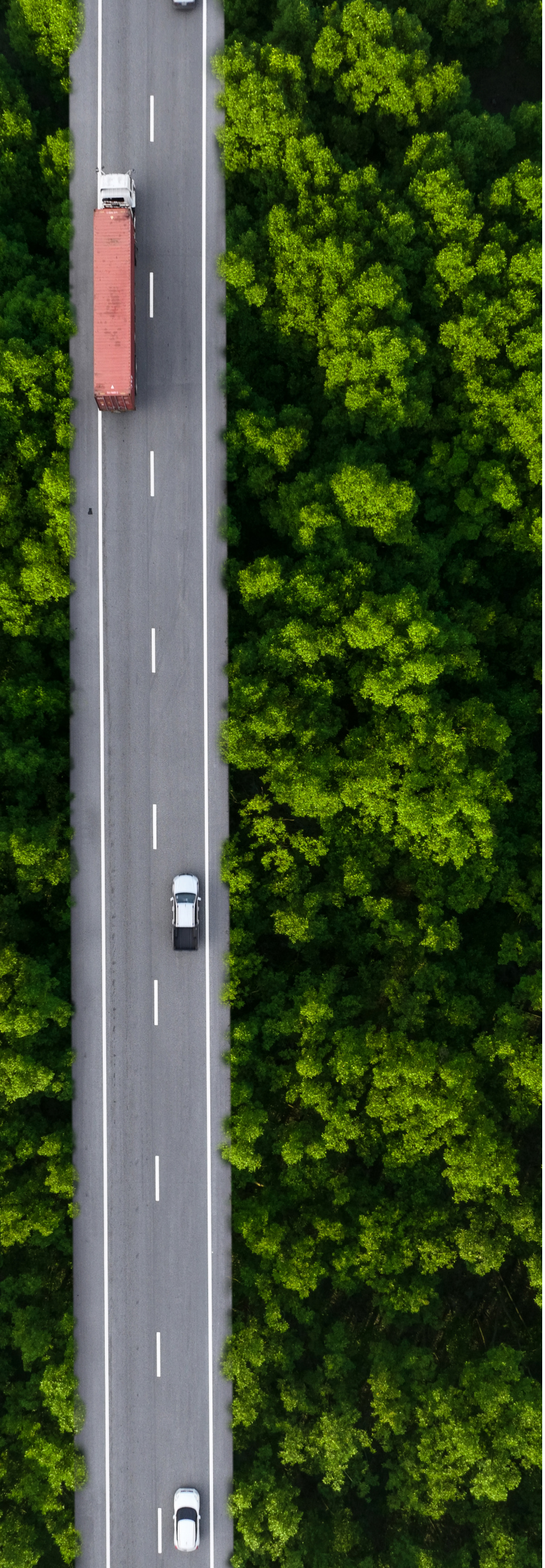
7. The Oxford Institute for Energy Studies: International Gas Contracts

2. Take and Pay [Risk Transfer → Demand Uncertainty]

Whereas in a Take or Pay agreement the buyer can choose not to accept delivery of the minimum contracted quantity of hydrogen, in a Take and Pay agreement the buyer is in breach of the contract and must pay damages when it does not accept delivery of the minimum contracted quantity. The contractual guarantee of delivery and payment reduces sellers' risk and provides them with a more predictable revenue stream. This can improve their ability to attract financing to develop or expand projects. Many early clean hydrogen projects will often operate under PPAs in which power is purchased up-front, with no option to receive a rebate for purchased power that is not used. This will contribute to making their input costs inflexible and will make it important to have a reliable purchaser for their output. Take and Pay can address this need for risk mitigation.

Kenya and Ghana are currently undergoing transition from Take or Pay to Take and Pay in power purchase agreements. While the two nations seek to reduce any financial burden purchasers experience from paying for energy that goes unutilized, the contractual transition will also reduce risk for investors and thus improve access to financing for energy infrastructure projects. Leaders in both Ghana and Kenya hope the shift to Take and Pay agreements will encourage power producers in their countries – who may currently tend to overproduce - to reduce waste by implementing due diligence processes that help them more accurately forecast energy demand.[8]

[8] Power purchase: Africa's shift to take-and-pay clauses (pinsentmasons.com)



3. Insurance [Risk Transfer → Demand Uncertainty]

Catalyzing hydrogen market investment will likely require mitigation of both perceived and actual risk associated with renewable energy investments. This is where insurance and re-insurance can come in. Given the nascent, rapidly evolving, and capital-intensive nature of the clean hydrogen industry, investments by both buyers and sellers come with risk that can make it difficult to attract needed capital. To bridge and transfer part of this investment risk, developers can purchase insurance, and insurers can purchase re-insurance to protect them in the event that a project fails.

In Sub-Saharan Africa, the African Energy Guarantee Facility (AEGF) is working to create a favorable investing environment by de-risking renewable energy investments through a risk-transfer facility shared by several insurance underwriters and banks.[9] This process currently functions through primary insurers, such as the African Trade Insurance Agency, who take on part of the risk associated with clean energy projects. AEGF then connects primary insurers with a much larger insurer to be reinsured, which allows primary insurers to take on more risk and optimize how they address risks and efficiently develop clean energy projects. Two financial institutions, the European Investment Bank and KfW, issue guarantees to the reinsurer as to address risk of various scenarios such as political as well as sovereign and sub-sovereign financial obligation risks. These guarantees can increase the operating capacity of the reinsurer. This process helps attract investment to a region that typically struggles to draw foreign funding and[10] facilitates market acceleration by lowering the risk burden for any one entity.[11]

9. De-risking Climate-smart Investments | World Resources Institute
10. United Nations
11. African Energy Guarantee Facility (AEGF)

4. Accessing Financing and Lowering Costs [Risk Transfer → Demand Uncertainty]

Accessing affordable financing can be a challenge for some projects and countries. To help create a thriving hydrogen global economy, it is important that countries with the right conditions – for example, the right natural resources – can participate. There are numerous existing and emerging mechanisms that can help decrease the borrowing cost of nations. Two notable ones are development banks which can provide attractive borrowing rates, or bi-lateral agreements between countries where countries with higher ratings can provide loans to lower rating countries.

A recent example is the creation of the Hydrogen for Development Partnership (H4D) by the World Bank, a new global initiative to boost the deployment of low-carbon hydrogen in developing countries. Through H4D, developing countries can gain further access to concessional financing and technical assistance to scale up hydrogen projects.[12]

[12] https://www.worldbank.org/en/news/press-release/2022/11/15/hydrogen-for-development-partnership-h4d-launch

5. Expression of Interest [Risk Alignment → Production & Infrastructure Uncertainty]

In an Expression of Interest (EoI), the potential leader of a new project requests responses from prospective investment partners to evaluate the viability of the new opportunity. An EoI can be used to allow hydrogen market participants to provide more transparency in the market and to align investments between companies and ensure synchronization. The EoI acts as a non-binding declaration of interest in collaborating, and it typically covers topics including project scope, the parties' qualifications, project timeline, and confidentiality provisions. EoIs facilitate information sharing and ensure flexibility – both of which can be essential to businesses that are exploring investment in the rapidly-changing, capital-intensive clean hydrogen energy.

The Northern Netherlands is leveraging Expressions of Interest to bridge investment gaps and ensure timely progress in several phases of its work to become the leading European hydrogen ecosystem. Leaders in the region say they see EoIs as "an effective way… to support investment gaps"[13] while the hydrogen market matures and scales and as an interim step to longer-term, more binding agreements.

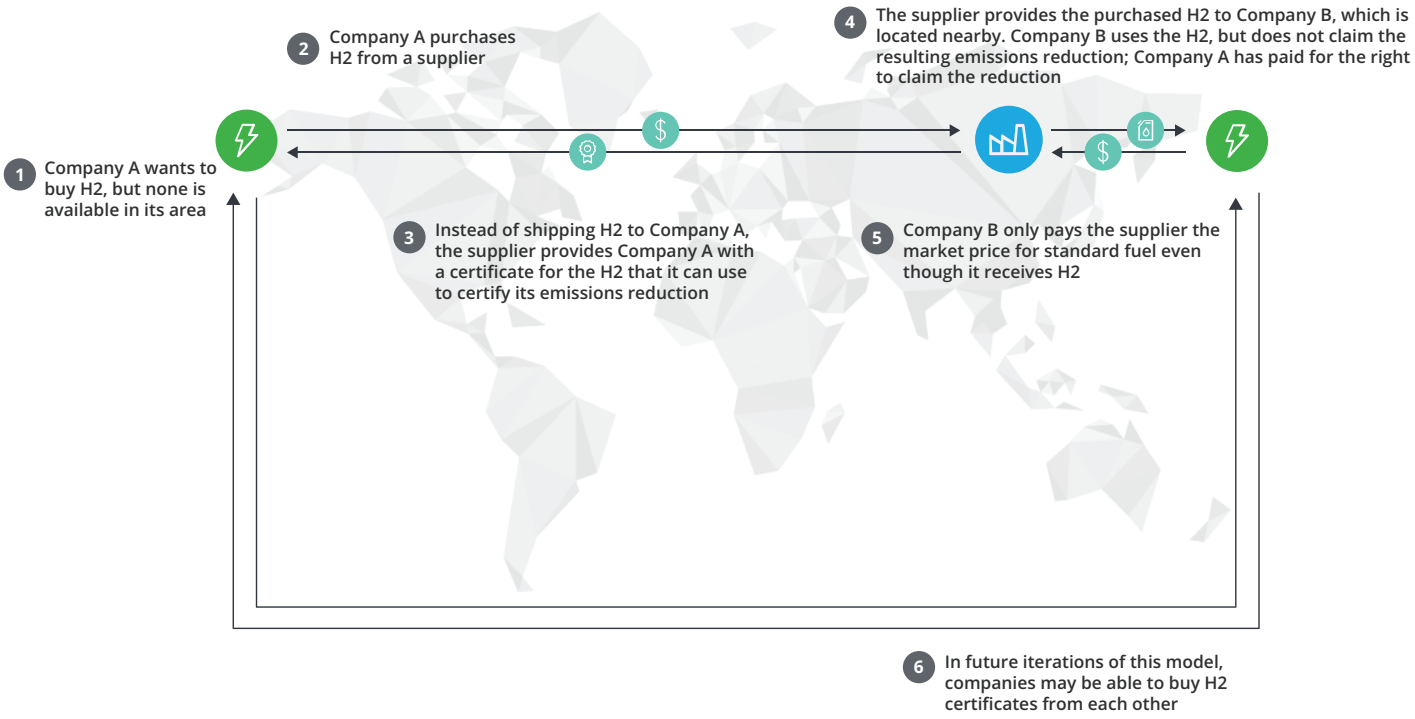
13. Investment_plan_Hydrogen_Northern_Netherlands_2020.pdf (provinciegroningen.nl)

6. Book and Claim [Risk Alignment → Production & Infrastructure Uncertainty]

The book and claim method allows companies to receive carbon credits for using fuels that may not be readily available. Under book and claim, a company that cannot access hydrogen supply infrastructure – Company A – purchases hydrogen from a supplier. Rather than shipping the hydrogen to Company A, the supplier provides Company A with a certificate for the clean hydrogen purchase and instead provides the hydrogen to Company B. Company B then uses the hydrogen to power its operations, but does not receive any carbon credit for the emissions its hydrogen offsets because this credit has instead been applied to Company A. This arrangement can reduce hydrogen producers' production and investment risk by giving them access to a vast pool of prospective buyers across the globe. The mechanism can be useful to activate industries and prevents companies moving clean fuels around the world, thus creating more emissions.

The book and claim model is already being used by airlines to claim credits for decarbonizing fuels. RSB is piloting a book and claim system for large airlines to manage their credits.[14] Companies such as Singapore Airlines, Jet Blue, and United are all piloting programs for decarbonizing their operations through book and claim.

Example 6: Book and Claim



14. RSB Book and Claim

7. Redeploy Existing Assets [Risk Alignment → Production & Infrastructure Uncertainty]

The utilization and redeployment of existing energy assets and networks can offer a lower-cost, sustainable pathway to entering the hydrogen market.[15] The reuse of existing networks in a clean energy context can leverage the sunk costs already incurred by energy producers and helps existing operators and stakeholders smoothly transition from a legacy focus to a future focus.

Redeployment and repurposing are solutions with proven success. Replicability, modularity, volume, and experience were key drivers to achieving cost reductions in wind, solar, batteries and EVs.[16] Given the challenges associated with funding new technology development on a scale with capability and capacity to address core decarbonization objectives, near-term investment should be proportionally allocated toward established physical and business technologies in conjunction with developing H2 technologies.

The International Journal of Hydrogen Energy is currently exploring the European natural gas network's repurposing potential into a hydrogen backbone. The journal examined data (operating years, network pressure levels, duration of projects, blending rates, sizes) from the National Transmission System Operators and found that existing 80bar natural gas pipelines could be converted to 45-55bar hydrogen pipelines.[17]

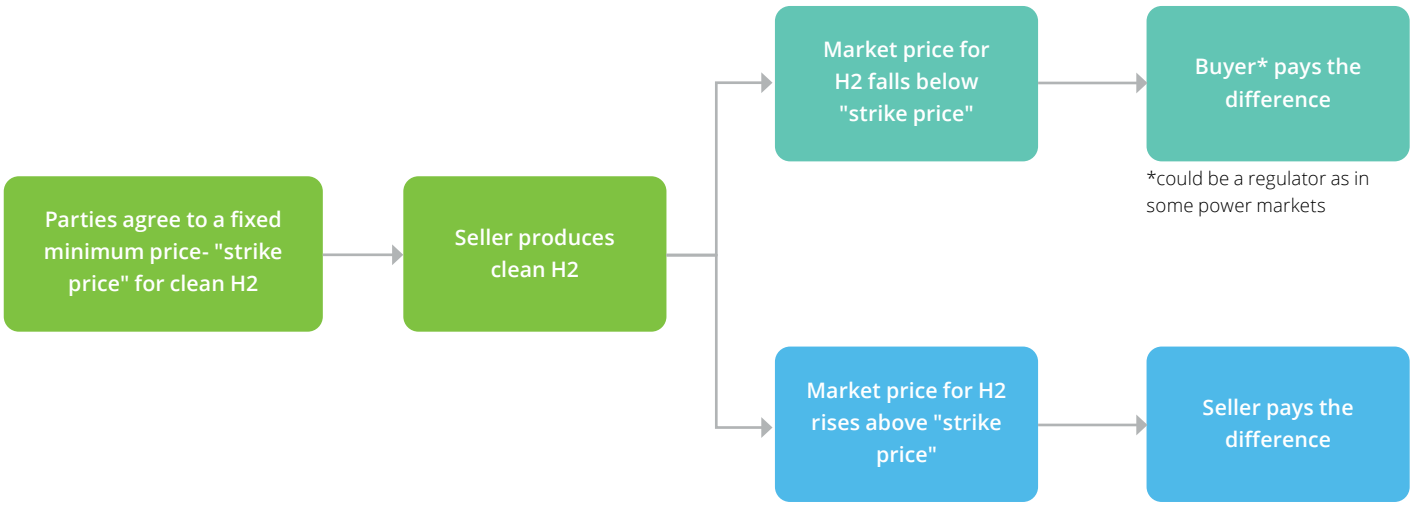
15. Legacy Asset Redeployment: How to Lower Costs, Avoid Stranded Assets, and Accelerate the Clean Energy Transition | Deloitte
16. ibid. n. pag.
17. International Journal of Hydrogen Energy

8. Contract for Difference [Risk Sharing → Regulatory Uncertainty]

In a Contract for Difference (CfD), a seller of clean hydrogen or renewable electricity collaborates with a buyer to set an agreed-upon minimum price – known as a strike price – for their output. If the market price for the seller's output moves above or below the strike price in the time between the contract signing and the sale, the party who would be injured by this price movement is paid the difference between the strike price and the market price. Power generators who sign Contracts for Difference are insulated from the risk associated with market price fluctuations; they are guaranteed a specific cash flow for the duration of the contract. CfDs can also reduce investment risk for power purchasers by limiting the price they pay for hydrogen or electricity. By acting simultaneously as a subsidy for producers and as a defense against price gouging, Contracts for Difference can be a good way to share risk and can incentivize both power producers and power consumers to invest in hydrogen.

The United Kingdom's Contracts for Difference program was implemented in 2015 with a goal of driving further investment in renewable energy. It awards CfDs to power generators through a competitive process that currently relies on bid prices but may soon also consider how much a renewable energy project contributes to the health of the wider renewable energy industry. The program helped reduce the per-MWh price of offshore wind by almost 70% between 2015 and 2022.[18]

Example 8: Contract for Difference CD)

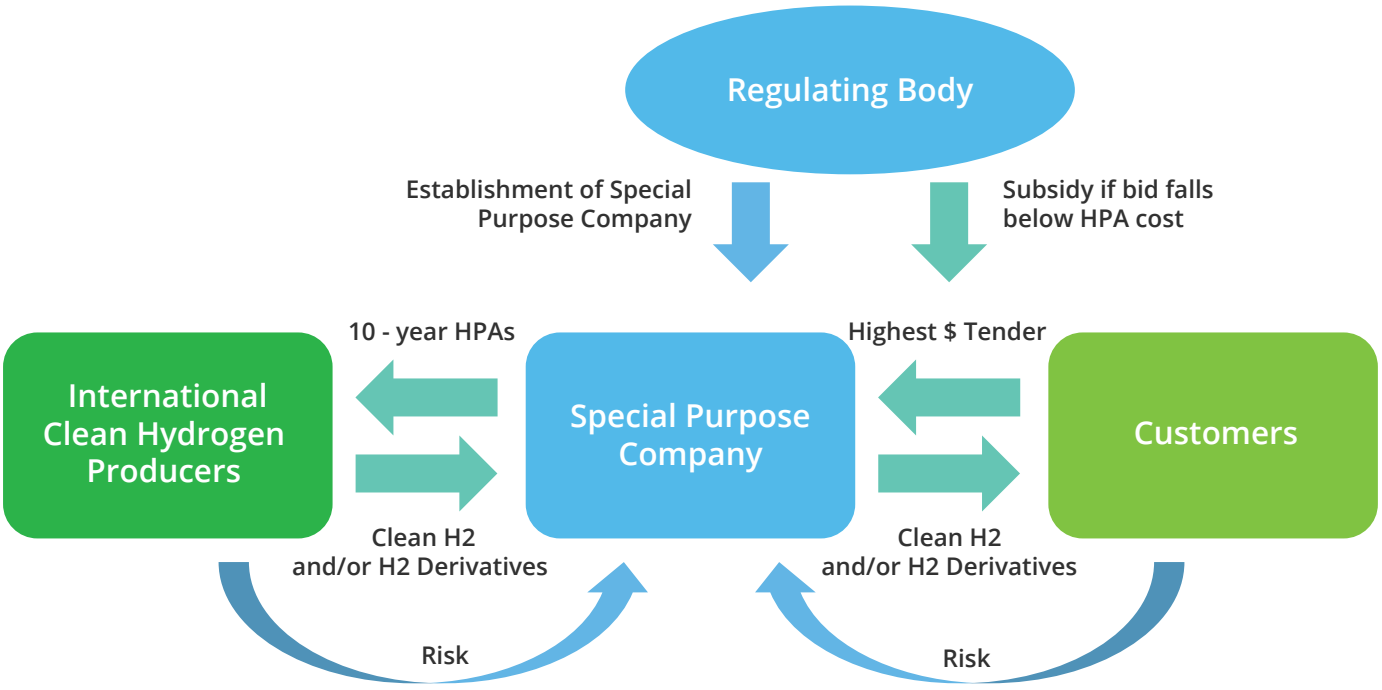


[18] Government explores major reform to flagship renewables scheme to improve energy security and drive investment - GOV.UK (www.gov.uk)

9. Auctions [Risk Alignment → Regulatory & Collaboration Uncertainty]

Adopting an auction or 'double auction' approach involves buying clean hydrogen at the lowest price possible and selling it to the highest bidders. It also likely involves policy intervention as a subsidy would need to be provided by the regulator to cover the gap between today's production costs for clean hydrogen and/or power-to-X products and the market price for fossil-based products.[19] An intermediary is created to manage the auction process, buying clean hydrogen via ten-year Hydrogen Purchase Agreements (HPA) and selling them to possible customers who will bid for short term supply contracts using separate tenders. This approach helps allow risk alignment between suppliers and buyers in the market.

Example 9: Auctions



In 2022, the German government kicked off its first-of-a-kind clean hydrogen subsidy scheme, H2Global, with the launch of a tender to import clean H2-derived ammonia from international producers.[20] While the first tranche of H2Global is for USD $900MM, the plan is to increase this amount significantly in the next years.

19. https://www.h2-global.de/post/neue-bundesregierung-gibt-startschuss-fuer-h2global-initiative#:~:text=The%20H2Global%2program%20was%20developed%20in%20recent%20months,Germany%20and%20in%20Europe%20to%20the%20highest%20bidders.
20. https://www.hydrogeninsight.com/policy/germanys-h2global-kicks-off-world-s-first-green-hydrogen-subsidy-scheme-with-ammonia-import-tender/2-1-1369442?zephr_sso_ott=iCylrZ

10. Demand Aggregation [Risk Alignment + Risk Transfer → Collaboration Uncertainty]

Demand Aggregation is a practice wherein companies enter an alliance to purchase a product with the goal of centralizing demand to help accelerate the development of that product. Sellers are often involved in such alliances; establishing a relationship with a demand aggregation project can provide sellers with a large market for their product. In some demand aggregation projects, such as the Sustainable Aviation Buyers Alliance (SABA), members of the alliance also work together to advocate for regulatory and technological changes that are intended to speed adoption of the product they purchase. Demand aggregation can help alleviate the first mover problem in clean hydrogen by giving producers a strong, centralized market for their product, by connecting buyers with sellers, and by leveraging the combined resources of many market participants to lobby for hydrogen-friendly regulations. By creating increased certainty around demand, and ensuring demand spans beyond a single year, the risk of investments can be decreased significantly. Such risk reduction can allow other participants like banks to participate.

SABA is a corporate alliance working in collaboration with the Rocky Mountain Institute (RMI) and Environmental Defense Fund (EDF) to spur the growth of the market for Sustainable Aviation Fuel (SAF). It was created by a group of founding member organizations, which includes Deloitte, to help aggregate their demand for SAF certificates and engage with regulatory authorities on policy planning and development. In addition to building a SAF certificate system, the alliance is intended to help members navigate the technical aspects of SAF and the SAF market, aviation emissions accounting, and the SAF policy landscape.[21]

Another type of demand aggregation, for example, is when gas processors or traders end up contracting clean hydrogen from a number of players, allowing suppliers to focus on production risks and transfer commercial and retail risk to others. This is being used in the Middle East already and has supported some projects in passing Final Investment Decision (FID) when the aggregator is well established and credible. A recent project that adopted this approach is the NEOM green hydrogen project, where Air Products became the exclusive off-taker of the green ammonia to transport it around the world.[22]

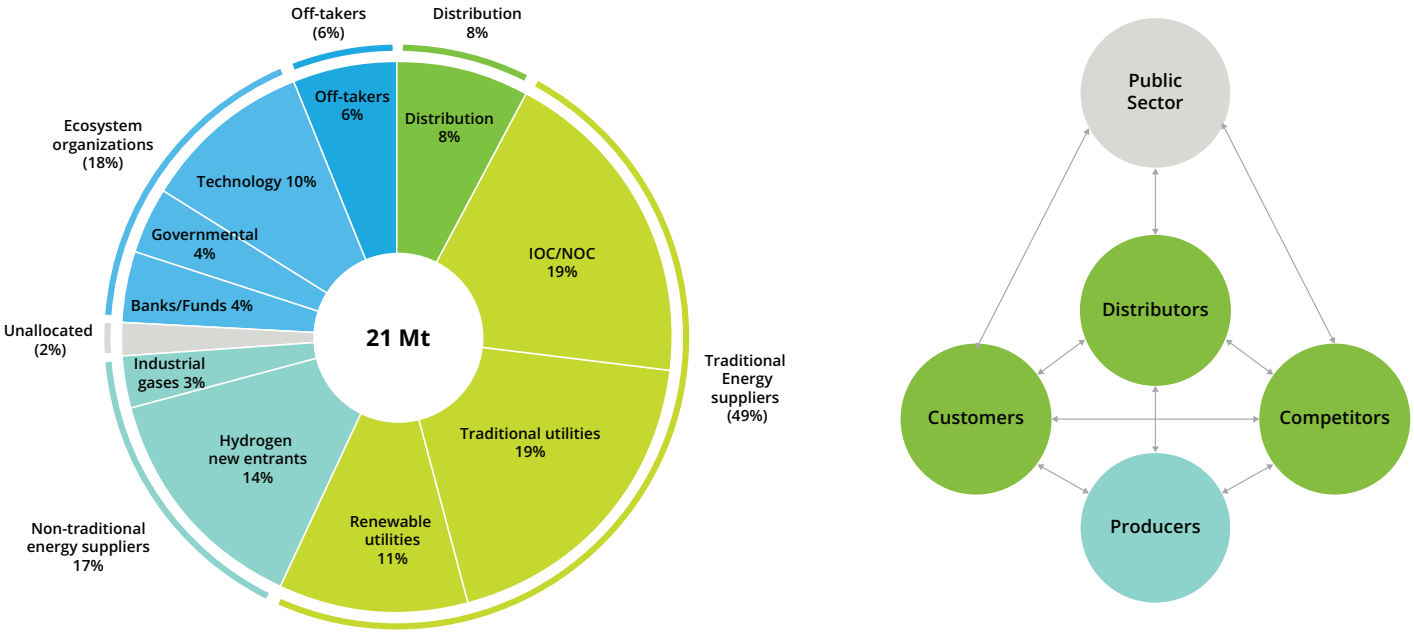
21. About SABA - Accelerating the transition to net zero aviation (flysaba.org)
22. Air Products

11. Co-opetition [Risk Alignment → Collaboration Uncertainty]

Targeted partnership between competitors, known as 'co-opetition,' is one of the more visible business model solutions to the chicken-or-egg problem in clean hydrogen. The U.S. Department of Energy's Regional Clean Hydrogen Hubs model[23] is an example of co-opetition at work: producers, distributors and suppliers will cooperate to develop a centralized location where an end-to-end hydrogen market can develop. This cooperation can support risk alignment by connecting market competitors across the value chain. It also can create opportunities to explore new contracting strategies as the various cooperating parties look to secure their positions in the market while keeping pricing flexible.

The Consortium for Battery Innovation (CBI) is an example of co-opetition between lead battery manufacturers, industry suppliers, research institutes, commodity traders and end users who share expertise and pool resources to promote innovation and growth across the industry. In addition to fostering relationships between members, the Consortium connects members to government and stakeholder funding to accelerate innovations that can expand the global battery market.[24]

Example 11: "Co-opetition" through targeted partnerships



Source: Deloitte Energy Transition Monitor

[23] Regional Clean Hydrogen Hubs | Department of Energy
[24] Consortium for Battery Innovation

12. Hydrogen as a Service [Risk Transfer → Collaboration Uncertainty]

Under a Hydrogen-as-a-Service (HaaS) business model, the seller provides hydrogen storage and refueling infrastructure (and in some cases vehicle retrofits) at no cost to an end user in the hydrogen mobility space. In return, the end user signs an agreement to purchase hydrogen from the seller, usually for several years. HaaS directly addresses the 'chicken or egg' problem in hydrogen-powered fleet transportation. It grants fleet operators access to storage and fueling infrastructure and hydrogen-ready vehicles without up-front capital investment, and it contractually guarantees hydrogen producers a profitable relationship with an off-taker. With this mechanism, the largest and fittest players can manage higher risks and help the less capable to play a role in the hydrogen space.

British Columbia's Hydra Energy recently signed HaaS deals with the owners of eight commercial truck fleets. Once they have undergone Hydra's complimentary retrofitting process, the trucks will run on a mix of diesel and hydrogen fuels that produces 40% less carbon emissions than conventional diesel trucks, and they will refuel at Hydra's stations. The end users have agreed to purchase hydrogen from Hydra at a fixed price at parity with diesel for five years, thus guaranteeing affordable supply for the end user and reliable revenue for Hydra.[25]

[25] Hydra Energy - Real hydrogen now

13. Value Chain Collaboration [Risk Share + Risk Alignment → Collaboration Uncertainty]

There is interdependency across multiple players in any value chain. However, most of the attention for resolving the first mover dilemma tends to focus primarily on the direct supplier and off-taker, with strict commercial constructs to guide the interactions. One approach being investigated in some sectors, for example steel (with the production of 'green steel' widely seen to be an early, attractive use of clean hydrogen), is full value chain collaboration. In this, many more players both upstream and downstream are involved. In steel an expanded consideration of the integrated value chain would include mining companies, steel producers, automotive players (steel buyers), fuel suppliers, etc. Creating such value chain collaboration where each player is willing to give a little of its own margin to 'grow the pie' by focusing on lowering the price to end customers could very well lead to accelerated adoption and scale of clean hydrogen, also decreasing the need for subsidies to activate change.

Deloitte participates in a number of value chain collaborations, including one in the steel sector. More information can be found in the joint Shell-Deloitte report "Decarbonising Steel: Forging New Paths Together"[26]

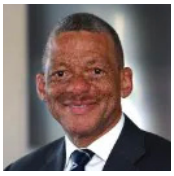
[26] https://www.shell.com/shellenergy/marketingandtrading/_jcr_content/root/main/section/simple/item/links/item0.stream/1669392117011/5b1f673472d02633f82125fef387d13c266a454d/shell-decarbonising-steel-digital.pdf

Conclusion

Clean hydrogen's potential to help enable a net-zero future is immense but achieving that potential will likely require thoughtful investment and fresh approaches from businesses across the value chain. With the help of innovative business models, business leaders can crack the systemic first mover dilemma and capitalize on the clean hydrogen boom that recent advances in technology and policy have enabled.

Contact Us

Geoff Tuff
U.S. Hydrogen Practice Leader
US Sustainability Leader for Energy, Resources and Industrials
gtuff@deloitte.com



Stanley Porter
Vice Chair, Deloitte LLP
Global Leader for Energy, Resources and Industrials
sporter@deloitte.com

Jennifer Steinmann
Global Sustainability Practice Leader
jsteinmann@deloitte.com

Tarek Helmi
Global Hydrogen Practice Leader
thelmi@deloitte.nl

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