Hydrogen Innovation Initiative

Debt financing low carbon hydrogen projects in the UK

For Energy Systems Catapult
On behalf of the Hydrogen Innovation Initiative

Final Report
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Study undertaken by:
EigenVentures

CATAPULT Energy Systems

About Hydrogen Innovation Initiative

This survey was funded by the Hydrogen Innovation Initiative, which was set-up with support from Innovate UK and the Industrial Advisory Board to drive forward a hydrogen supported economy for the UK. HII has a mission to support UK industry by accelerating the development of critical hydrogen technology and supply chains for the fast-growing hydrogen economy. With industry-wide input, we have published a Hydrogen Technology Strategy for UK industry and working with funding bodies and investors to secure funding for hydrogen innovation and supply chain programmes. HII's partners include the Catapult Network, the Advanced Propulsion Centre, the Aerospace Technology Institute, the Net Zero Technology Centre and the National Physical Laboratory.

About Energy Systems Catapult

The report was organised by Daniela Montaño, Mona Khalili, Frank Bridge, Paul Jordan, Liam Lidstone and Richard Halsey from the Energy Systems Catapult (ESC), an independent research and technology organisation launched by Innovate UK in 2015 with a mission to accelerate Net Zero energy innovation.

About Eigen Ventures

The survey, interpretation of findings and reporting were carried out by Eigen Ventures Ltd, which provides business support services to low-carbon and clean tech innovators and funding agencies. The survey interviewers and report authors were John Pexton, Giles Dixon and Mark Bornhoft.

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Executive Summary

There is significant interest and intent by banks and private funds globally to finance the commercial-scale production of low carbon hydrogen and hydrogen derivatives such as ammonia. However, to date only a few such projects have been funded by third party debt, and none in the UK. This will gradually change as the perceived technology risks diminish and government subsidy schemes are implemented. The world's first such scheme is the UK Government's Hydrogen Production Business Model (HPBM) under which the first production subsidies were agreed in late 2023; and other countries intend to finalise subsidy schemes in 2024. The HPBM structure was widely praised by industry stakeholders in our survey, not only for being the first to market, but also for its focus on revenue support and project due diligence.

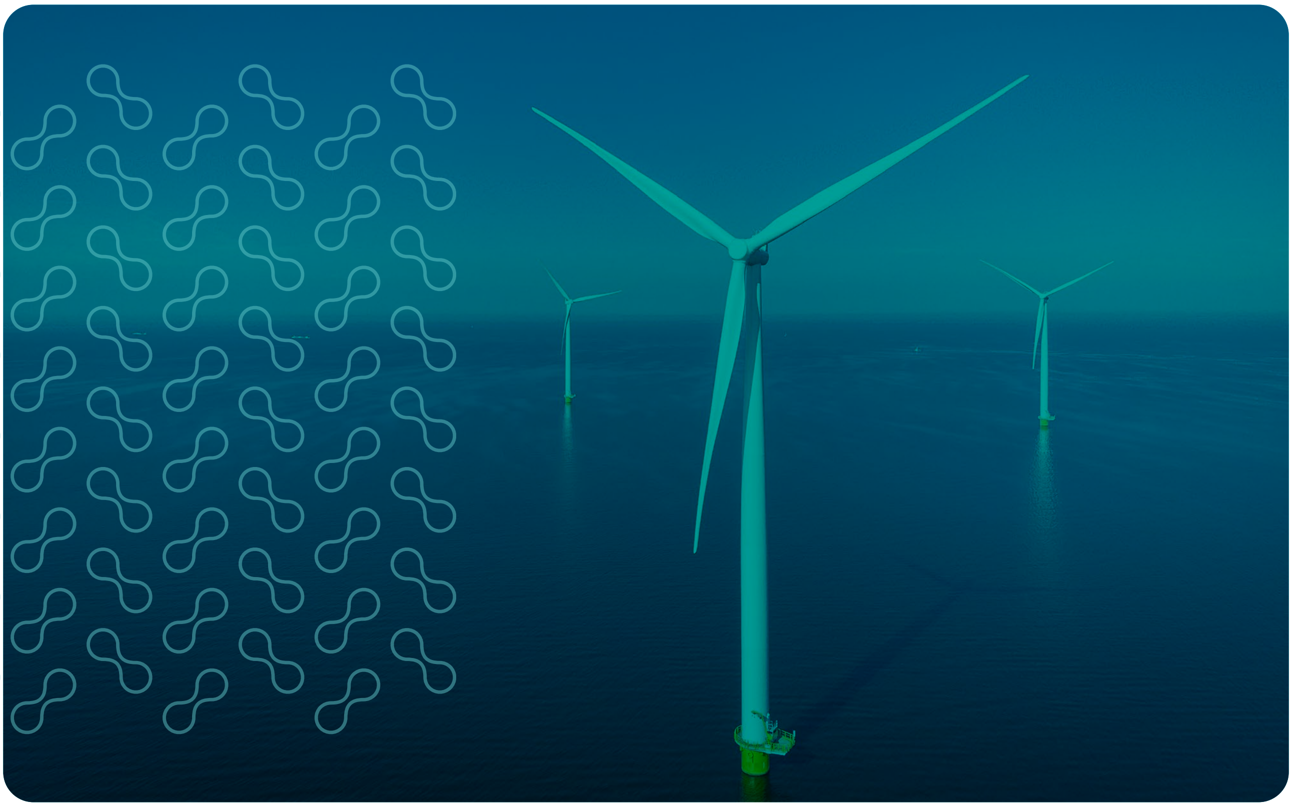
Projects in energy markets often use debt financing because it is cheaper than equity and it enables rapid scaling. Debt funding for hydrogen projects will follow the same track as seen in the LNG, offshore wind and energy storage sectors over the last few decades: the initial projects will be primarily equity funded, but project finance debt will be increasingly used as more hydrogen projects start up and lenders become more comfortable with the risks they are being asked to take on. There is, however, an urgency to implement hydrogen projects in order to meet Net Zero goals, and we need to expedite new funding structures – with similar solutions being required in other First Of A Kind technology areas such as Sustainable Aviation Fuel (SAF).

Hydrogen will be one of the cornerstones of a Net Zero economy, particularly in 'hard to abate' sectors where electrification and batteries are not so practical or efficient. This will include substituting natural gas or coal in industrial processes such as cement and steel manufacturing; substituting fossil fuels for high-load transportation such as in trains and planes; use as a feedstock to make 'green' chemicals and fuels such as ammonia, methanol and SAF; and helping to balance the power grid through long duration storage.

We are needing to rapidly develop a low carbon hydrogen industry from a zero base. Subsidies are required at the early stage of market development so as to encourage the production and supply of low carbon hydrogen (in the absence of a high carbon tax), as happened in the offshore wind industry. But we also need to build up demand, which was not a challenge for offshore wind. Most hydrogen projects starting up in the early years will be small (5 to 20 MW production rate) as it takes time for industries to become familiar with hydrogen; and it is these smaller electrolytic projects that will help create the initial liquidity while the bigger projects (such as for CCS – carbon capture and sequestration) will take longer to implement. It is the small early projects that are needed to sustain the UK supply chain and innovation base into the 2030s.

For this survey we interviewed over 40 stakeholders in the hydrogen and project finance communities in the UK, including banks, funds, law firms, financial advisers, insurance providers, brokers, Government entities, SME technology innovators and project developers. Most of the project finance lenders we talked to had been approached by hydrogen project developers although the interactions were generally limited to date; and some banks in London were not familiar with the HPBM and associated hydrogen allocation rounds (HAR).

Most of the banks and SMEs were also not familiar with the new products that have been developed recently by insurance companies to address energy technology risks, for example in back-stopping electrolyser warranties. Insurance and assurance processes will be key in future to help both equity and debt providers to price such performance risks, but they are currently at an early stage of implementation. For example the insurance company AXA XL has already underwritten US$1 billion of technology risk insurance for new types of energy projects, primarily in USA, while Munich Re and Ariel Green also provide similar products – but we are not aware that this type of insurance has been used yet for energy projects in the UK. One key finding from this study was the need for more cross-industry discussion and sharing of learnings, which is a primary aim of this report.



An ultimate objective in scaling the hydrogen industry will be for debt providers to take on most of the project risk from shareholders i.e. debt finance with 'limited recourse' to these shareholders. This has already happened in mature energy sectors such as gas-fired power, LNG liquefaction, utility solar and offshore wind, where there is generally low technology risk and a liquid economic market for the end-product. This limited recourse debt is long term (more than 10 years in tenor) and can be put in place before plant construction starts.

However, from our interviews, it is apparent that it would be difficult for many of the current hydrogen projects in the UK to procure limited recourse debt prior to construction of the plant. The first issue is minimum loan size: many of the early hydrogen projects will cost less than £30 million, with a loan requirement of £10-20 million (although some will be much larger, such as the CCS projects). But the minimum loan size for the UK Infrastructure Bank (UKIB) is £25 million, and this cut-off is even higher for many international project finance banks. Only a few banks in the UK may go as low as £10-15 million, and just for one-off energy transition deals, although Scottish National Investment Bank can provide smaller loans for projects in Scotland.

Secondly, in order for lenders to take on the project risks from shareholders, even under many of the global subsidy programmes, banks would require a set of guarantees and standby funding facilities that many SME-led projects would find difficult to provide. A limited recourse financing adds significant cash costs, time and uncertainty to the funding of a project because of these lenders' requirements: project finance lenders, unlike equity providers, have no upside and need contingency planning through risk allocation for when projects go wrong.

For most hydrogen projects it would be advisable for SMEs to partner with larger corporates or funds who can help mobilise shareholder funding for construction risk and then refinance in the project finance markets after start-up. We also see a growing number of banks and boutique lenders who can provide venture debt to SMEs, providing that there is some revenue history and an intellectual property portfolio over which lenders could take security. The tenor of venture debt can be up to 5 years, potentially long enough to bridge an SME's share of costs of a hydrogen plant before refinancing after start-up. We have even seen the development of debt crowdfunding in France and Belgium for clean energy projects, whereby 5 year loans of up to €10 million have been provided.

There is a window in which we see limited recourse debt being possible now in the UK if an HAR-type project has most of the following characteristics:

- a project size above £40 million;
- construction guarantees from a credit-worthy contractor;
- the production plant being co-located with the anchor offtaker and (if electrolytic) having a sleeved low carbon power purchase agreement at a fixed price, maybe through a private wire;
- credit-worthy warranties for the plant performance from the operator or equipment manufacturer, backed up by independent engineering assurance (and maybe by a technology risk insurance policy if not yet a commercialised technology);
- offtake contracts with investment grade users of hydrogen on a long term take-or-pay basis who have invested in facilities for hydrogen use and maybe even invested in the production facility;
- sponsors have factored in returns that allow for the extra cash costs of project financing (interest during construction and fees can add 10-15% to the capex even before any technology risk insurance); and
- a low gearing (e.g. 50%) with debt service reserve and standby facilities in the event of reduced revenues.

This window will widen as the low carbon hydrogen market garners liquidity, for example through the start-up of pipeline networks in the 2030s. However, in the near term most hydrogen production projects in the UK will be funded by equity because of the immaturity of the hydrogen markets and the costs and potential delays if using project finance debt. Feedback from lenders indicates that there are some HAR1 projects that meet enough of these criteria to be potentially financeable using limited recourse debt, and these would be critical in helping move the industry forward. Project sponsors will need to ensure that they have included financing costs such as upfront fees, insurance and interest during construction when calculating the level of subsidy required.

The key risk identified by all the lenders we spoke to is offtake. It is apparent that large corporate users of hydrogen need to step up more to support the HPBM projects, for example by committing to long term take-or-pay contracts, maybe also taking a minority investment in the production facility so as to align interests, and committing to larger decarbonisation projects. Offtakers in the UK are motivated financially to switch their fuel use to hydrogen to avoid emissions trading scheme (ETS) payments; the financial returns for doing this may only be marginal for some companies, but we would like to see more companies accelerating capex cycles so as to achieve 100% switching to low carbon fuels.

We note that the world's first project financing of a large low carbon hydrogen project (NEOM in Saudi Arabia in 2023) was successful mainly because a major corporate (Air Products) provided a long term offtake commitment plus significant construction guarantees. H2 Green Steel, another major debt-funded project, has steel purchasers as minority investors, although it also has significant guarantees from government entities, including the Swedish government and the German export credit agency. We also note that these first successful projects consume hydrogen internally and sell a commodity (ammonia or steel) into a tradable market, which helps the financing (as opposed to selling just hydrogen into a market which is not yet traded).

Government subsidy support is critical to ensuing the economic viability of hydrogen value chains globally, including the UK. Inevitably, as HPBM is an untested scheme, banks will have concerns over some of the risks that they will be asked to take on as part of the scheme – the biggest issue being how to ensure debt service if the intended offtaker is unable to pay for the hydrogen. The UK Government (DESNZ) has told us that they will review the effectiveness of the HPBM in delivering the broader hydrogen ambition, with the progress of projects from the various allocation rounds forming part of that consideration, and thereafter determine whether revision or supplementary interventions are necessary. One area of debate is whether to allow injection of hydrogen into the gas grid, particularly as a fallback 'last resort' option, for which the safety case is still being evaluated. The first DESNZ Transport and Storage business model support will not be determined until late 2025, so it will be some years until there will be hydrogen pipeline networks operating that can facilitate liquid markets.

Going forward, we also expect to see more developments in the use of insurance and engineering assurance standards to address performance risk in hydrogen and other First Of A Kind technologies. We also expect to see participation by UKIB in providing debt facilities for the larger projects, including maybe mezzanine debt for first loss risk.

However, there will continue to be challenges for SMEs in procuring debt for smaller projects, including those that are using innovative technologies developed in the UK (such as biomass-based or new electrolyser designs). We expect that many such hydrogen projects will have a capex of less than £30 million, too small for most banks to lend to; but these projects are needed, both to create a liquid hydrogen market, particularly outside the hydrogen clusters, and to sustain a UK hydrogen supply chain and innovation base. One possible solution is the creation of a Hydrogen Debt Fund, seeded by a Government entity such as UKIB or a DESNZ programme, but funded primarily by private capital with a mandate to offer loans in the £7-25 million range.

In summary, the faster that lenders can become involved in financing hydrogen projects, both large and small, the faster we can grow a liquid hydrogen market and a hydrogen economy:

Offtaker commitments are key

- Both DESNZ and industry need to expedite the creation of a liquid market, DESNZ through liberalising the offtake constraints as far as possible (so lenders can see alternative offtake options) and the large corporates in the UK through providing greater commitment to offtake. We would like to see the users of hydrogen in the HAR schemes provide bankable long term take or pay contracts and maybe take a minority stake in the hydrogen plants to align their interests;

Assurance and insurance solutions need further development

- Further progress is required in developing insurance and assurance products that can price and therefore cover technology operating risk, especially for manufacturers of hydrogen plants (whether electrolytic or biomass-based) that cannot provide bankable warranties. Some of these products already exist and have been used to enable projects outside the UK to procure debt finance, there needs to be more awareness and industry discussion of these new tools; and

A Hydrogen Debt Fund would help finance small projects

- Further discussions are needed to identify possible means of debt-funding small hydrogen projects and similar First Of A Kind energy projects; these are needed to kick-start a liquid hydrogen market and sustain a hydrogen innovation and supply chain in the UK. The larger projects such as for CCS will take a longer time to build out, we need to push the smaller projects to help build and diversify hydrogen demand and develop industry capabilities – we note that this was not needed in the offshore wind and LNG markets, where large companies drove the development. We have suggested a Hydrogen Debt Fund as a possible solution; this idea was supported by a number of participants in the survey and more research with potential fund investors is required to develop this concept.

Study Context

Objectives

The development of the UK's low carbon hydrogen sector is gaining traction, with a current pipeline of production capacity estimated to be 27GW and several Government-led initiatives being planned or implemented to support the sector. With 11 projects awarded contracts under the first Hydrogen Allocation Round (HAR1) and now moving towards Financial Investment Decision (FID), and with significantly more HAR2 projects expected to reach FID over the next few years, a key consideration is how these projects will be funded.

As set out in this report, debt funding is expected to play an important role as the sector develops. This is consistent with the experience of other energy sectors, such as LNG, fossil fuel power and renewable energy projects (e.g. wind, solar PV and battery storage), all of which have come to rely upon project finance debt as a key source of funding.

The use of debt for these projects stems from the large size and liquidity of the international debt markets and its low cost relative to that of equity. Consequently, in addition to being an important source of capital, the low cost of debt (alongside technology performance improvements and economies of scale) has also contributed to broader cost reductions in a range of energy transition technologies.

Given the current immaturity of the hydrogen industry, the purpose of this report is to assess whether low carbon hydrogen projects in the UK can access debt funding and, if not, what can be done to address that challenge. Specifically, this report:

- Seeks to publicly share recent developments in the financing of low carbon hydrogen production projects and to facilitate industry discussions;
- Focuses on 'green' (electrolytic or biomass-based) hydrogen production as this is where small and medium sized enterprises (SMEs) and most project developers will focus in the UK, given that 'blue' hydrogen using CCS (Carbon Capture and Storage) will be the preserve of a few large companies;
- Intends that the insights can be used to inform submissions for future government policy consultations and as well as to shape financing strategies of individual projects; and
- Anticipates that the learnings and recommendations can be applied not only to the nascent green hydrogen sector but to a diverse range of new energy infrastructure technologies.

Why Hydrogen

Hydrogen has been identified by the UK Government as one of the new low carbon solutions that will be critical to UK's transition to Net Zero by 2050. Given its potential to be a versatile replacement for high-carbon fuels in a range of UK industrial sectors and providing flexible energy for power, heat, energy storage and transportation uses, the Government believes that it could help meet up to a third of UK final energy consumption by 2050.

Whilst the actual size of the UK's hydrogen economy by 2050 will depend on several factors (including the cost and availability of hydrogen relative to alternative energy sources), the UK Government is seeking to have made significant progress in developing a UK hydrogen economy by 2030. It has therefore established a UK Hydrogen Strategy which sets out target delivery milestones through to 2035.

As part of a hydrogen economy development pathway, the UK has a stated ambition of having up to 1 GW of electrolytic hydrogen production capacity in construction or operation by 2025; and a target 10 GW of low carbon hydrogen production capacity by 2030, subject to affordability and Value for Money (VfM), with at least half of this coming from electrolytic hydrogen.

This near-term focus on establishing domestic production capacity is in contrast to the strategies of some other markets. For example, whilst the EU is targeting to produce 10 million tonnes of renewable hydrogen by 2030, it also is seeking to import 10 million tonnes. The UK is therefore placing less immediate emphasis on the role of imports in the early development phase, albeit recognising that in the longer-term global trade in hydrogen will develop and present opportunities to diversify sources of supply as well as create additional value through export markets.

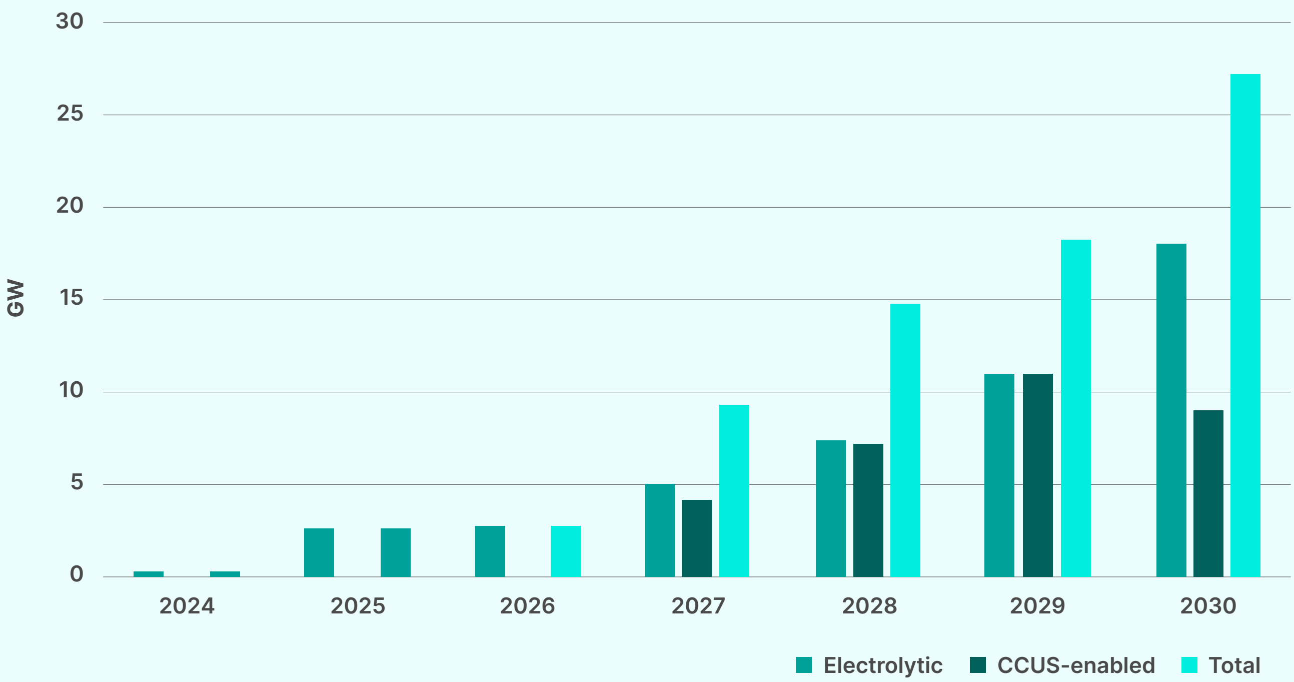
To spur the 2030 target production capacity and wider hydrogen economy the UK Government has introduced, or has under development, several interventions including grant funding and price support mechanisms. This includes the Hydrogen Production Business Model (HPBM), through which eligible green hydrogen projects are awarded 15-year price support contracts if they meet a range of criteria, such as low carbon emissions and defined offtakers with a decarbonisation application. In December 2023, it was announced that:

- Contracts under the HPBM had been awarded to 11 projects with a combined production capacity of 125 MW through the first Hydrogen Allocation Round (HAR1); and
- The second Hydrogen Allocation Round (HAR2) was open with a target capacity of up to 875 MW, with applications accepted until April 2024.

The UK hydrogen market is responding positively to the HPBM and other hydrogen initiatives, with the Government reporting in February 2024 that there is a growing pipeline of over 250 low carbon hydrogen projects across a range of low carbon hydrogen production pathways. The UK Government has set its ambition to allocate up to an additional 1.5 GW across HARs 3 and 4, launching in 2025 and 2026 respectively. According to the UK Government estimates, the potential deployment of electrolytic hydrogen production of current projects in development is estimated to be more than 17 GW by 2030, and a further 10 GW from CCS-enabled projects, as illustrated below in Figure 1.

Figure 1: Cumulative potential low carbon hydrogen production capacity in the UK

Cumulative potential total GW low carbon hydrogen production capacity



Source: DESNZ Low Carbon Hydrogen production pipeline. Note that all figures here are based on potential deployment and capacity scale up according to the projects themselves, and does not relate to decisions on the individual projects or volume support through specific funding allocation windows.

Why Now

To deliver on its Hydrogen Strategy, the UK will need to address some specific challenges. These include:

1. How to rapidly grow a grass roots hydrogen industry, with both small and large value chain projects, so decarbonisation using hydrogen can take place across a wide range of industries and communities. Current UK hydrogen production and use is heavily concentrated in the chemicals and oil refining sectors, where both production and use take place in a single integrated facility. Beyond this hydrogen is hardly used yet in the UK and, with no transport and storage infrastructure in place, it is difficult and expensive to source even fossil-fuel sourced hydrogen, let alone more expensive low carbon hydrogen, whether for hydrogen buses or for R&D use.

2. How to scale up new hydrogen technologies, for which UK Government has provided significant R&D grant support, such as the Net Zero Innovation Portfolio (NZIP), supporting progress across the hydrogen value chain (i.e. production, storage, transport and use in industrial and domestic appliances).

In order to develop a low carbon hydrogen economy the UK Department For Energy Security and Net Zero (DESNZ) has announced a number of initiatives in addition to the introduction of the HPBM/HAR schemes. Examples include:

- **CCUS-enabled hydrogen:** the Government has plans to deploy by the mid-2020s two clusters with Carbon Capture, Utilisation and Storage (CCUS) for 'blue' hydrogen production and a further two clusters by 2030 (capturing 20-30 Mt CO_2 per year), with plans to introduce a competitive UK CCUS market by 2035; each cluster will have a concentration of producers and users of hydrogen.

- **Hydrogen Transport and Storage (T&S) Business Models**
  The UK Government intends to open the first allocation round in 2024 with an initial ambition to support up to two geological storage projects at scale and associated regional pipeline infrastructure to be in construction or operation by 2030.

- **Hydrogen to Power (H_2P):** the Government is consulting on the need and design for potential market intervention to accelerate the deployment of hydrogen in power markets, from short-term peaking to long duration energy storage.

- **Green Industries Growth Accelerator (GIGA):** in November 2023, the Government announced a £1 billion GIGA fund to support private sector investment in clean energy supply chains across the UK, of which £390 million will be allocated for the CCUS and hydrogen sectors.

- **Blending:** the Government has taken a policy decision to support blending of up to 20% hydrogen by volume into gas distribution networks in certain circumstances, subject to ongoing safety assessments, feasibility and the economic case.

- **RTFO (Renewable Transport Fuel Obligation):** this long-standing scheme encourages the use of a range of low carbon fuels for transport through the sale and purchase of RTFCs (Renewable Transport Fuel Certificates). In 2018 it was amended to allow producers of renewable hydrogen to sell RTFCs. The HPBM scheme is now being dovetailed with the RTFO scheme so that producers of hydrogen can decide whether to apply for RTFO support or HPBM support (we note that HPBM does not allow subsidies for hydrogen sales via intermediaries such as retail outlets).

The recent HAR1 awards, the launch of HAR2 and the above schemes have generated significant interest in developing a range of hydrogen projects in the UK. Accessing finance will be critical if these projects are to move from the development phase to the construction phase, and if the momentum in the hydrogen industry is to be maintained.

In that context, it is noteworthy that:

- Outside of the UK there is evidence of both third-party equity and debt funding starting to be secured by some low carbon hydrogen projects, thereby enabling them to move towards construction. This includes the US$8.4 billion NEOM project in Saudi Arabia and the €6.5 billion H2 Green Steel project in Sweden – these are the first large scale-ups ever of electrolytic hydrogen technologies to have secured project finance debt as part of their funding structures (see Findings- Finance Market Conditions);

- In parallel, new insurance products are being developed to help mitigate the performance risks of early stage, or First Of A Kind (FOAK), technologies such as electrolysers (see Findings-Technology Risk Mitigation); and

- Through coordinated dialogue such as at COP28, there is a growing focus within the international finance industry on what solutions could be used to accelerate energy transition technologies, such as green bonds and sustainability-linked loans.

As such there is evidence, albeit limited at this point, that debt could play a potentially important role in the early development of the global hydrogen economy and hence expedite its growth. This report seeks to build awareness, publicly share findings, and encourage discussion on:

1. What sources of debt funding may be available for UK projects, and
2. How projects can secure access to debt funding, for example through good project design.

Why Focus on Debt for Hydrogen Projects

The IEA's global database of hydrogen production projects lists 70 UK green (biomass or power to hydrogen) projects in development, the sizes of which vary widely. For example, there are at least 5 very large projects under development in the UK with estimated electrolyser capacities of more than 500 MWel[1], with a spread of smaller project sizes as shown in Table 1 below:

Table 1: Snapshot of select UK Green Hydrogen Production Projects in Development

Size (MWel)	Number of projects	Combined Capacity (MWel)	Average Capacity (MWel)
<10	(10) (most are not databased by IEA)	(15)	(1.5)
10-50	25	675	27
51-100	8	740	92
101-500	7	2,218	316
>500	5	6,100	1,220
Unknown	15	-	-
Total	**70**	**9,800**	**178**

Source: IEA Hydrogen Production and Infrastructure Projects Database, accessed March 2024

Further details of projects in the UK can be found in a Hydrogen Project Map managed by the Hydrogen Energy Association. Scottish Enterprise also do an excellent job in databasing and supporting projects in Scotland.

A hydrogen production facility (HPF) may cost in the range £1.5-3 million per MW production capacity, depending on scale and the cost of power connection, water supply and storage as well as the electrolyser itself (each MW production capacity requires approximately 1.4 MWel of electrolyser capacity). The cost of a small scale 10 MW HPF would be in the order of £20-30 million while a very large scale 500 MW project could cost £1 billion.

The ability of individual project developers to finance these construction costs will vary:

- Some projects will be sponsored by large well-capitalised companies who will be able to use their own balance sheet to provide equity or shareholder debt; but
- Other projects, including many of those below 20 MW, will be sponsored by independent developers who do not have the required funding to pay for the project construction costs. As such, they will be seeking third-party funding in the form of equity, debt, grants, or a mixture, at least for their share of the project costs.

Sectors such as LNG, solar PV, onshore and offshore wind and, more recently, battery energy storage started out being funded by equity and grants (e.g. for technology development and demonstrator projects), but then debt was increasingly employed, with construction gearing commonly reaching more than 70%. Similarly, the faster that lenders can become involved in financing hydrogen projects, both large and small, the faster we can grow a liquid hydrogen market and a hydrogen economy.

[1] MW_{el}: refers to the electrolyser electrical input capacity for power-to-hydrogen projects

Study Methodology

This report has been prepared based on insights captured through over 40 interviews conducted between January and April in 2024 with a broad range of stakeholders. They included commercial and development banks, funds, insurance companies, advisers and central and devolved government institutions, along with SME (small corporate) project and technology developers. A list of participating companies is provided in the Appendix and a breakdown of the categories is provided in Table 2 and Figure 2 below.

Table 2: Stakeholder groups interviewed

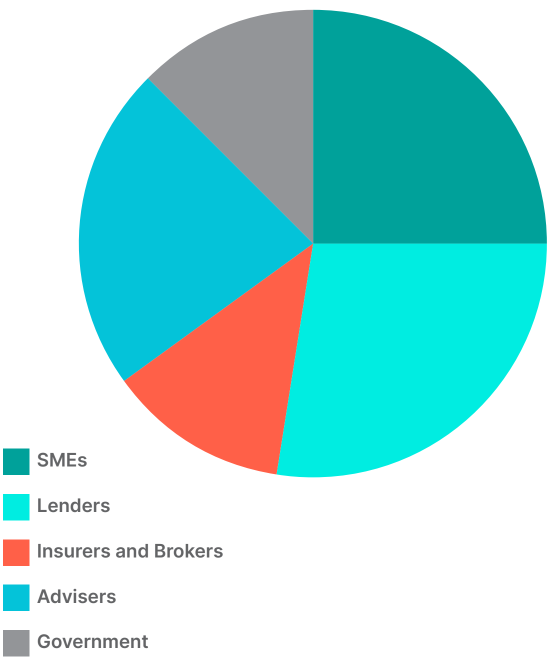
Category	Number of interviewees	Description
SME Project Developers and Technology Developers	10	Small and medium size developers of hydrogen production projects, some of whom also have new technologies that they want to commercialise.
Lenders	11	Includes specialist lenders, banks and government-funded institutions (providing debt, guarantees and other financial products); and infrastructure funds who can provide both debt and equity.
Insurers and Brokers	5	Providers and structurers of insurance products to cover project-specific performance and general business risks.
Financial, Legal and Technical Advisers	9	Providers of advice to developers, lenders and other project counterparties as well as to government agencies.
Government	5	UK Government departments and institutions responsible for setting policy and providing financial support; and economic development agencies charged with enabling local industry and investment.
Total	**40**	

The interviews were structured around the following themes:

- To identify the level of interest in debt-financing hydrogen value chain projects, the challenges faced and the potential structuring solutions, particularly for limited recourse finance;
- To consider the financing challenges for projects that may apply to win subsidies under the DESNZ hydrogen allocation rounds (HAR) and smaller-scale projects sponsored by SMEs; and
- To develop learnings that could be applied in funding hydrogen and other First Of A Kind energy projects, in particular how to mitigate technology and volume risks.

Given the range of stakeholders interviewed, a diverse set of perspectives was provided to these themes. This report presents the key learnings from these interviews and the associated recommendations.

Figure 2: Split of stakeholders interviewed



Overview of Hydrogen

Uses of Hydrogen

Hydrogen is highly versatile as an energy carrier and has the potential to be used in multiple industrial processes, power generation, transportation and chemicals production. Depending on its local cost and the availability of supporting infrastructure, hydrogen creates potential pathways for decarbonising energy-intensive industries where alternatives are not presently viable from a cost or technical standpoint.
A particular focus in the applications for hydrogen is in 'hard to abate' sectors, where electrification or batteries may not be the best practical solution. These include high temperature processes such as glass, cement and steel production and heavy-duty transportation such as trains. Also low carbon hydrogen will be the key feedstock for making 'green' ammonia (for decarbonising shipping, power generation and fertilisers), e-methanol (for shipping and chemicals)and Sustainable Aviation Fuel for aircraft. A key potential use of hydrogen that has not yet been developed is for flexible low carbon power generation capacity to ensure that the UK power system remains balanced at all times; and, in particular, for large-scale long-duration storage of energy, to help deal with intermittency in electricity supply from the UK's wind and solar farms.

The viability of these applications depends on the price. For example, we do not see low carbon ammonia projects being constructed in the UK in the near future as the price of power is way above that required (c US$30/MWh) to make ammonia that is competitive globally.

Figure 3: Potential uses of hydrogen

Form	Key Sectors	Sub Sectors	
GAS & FUEL CELL	Power & Industry	Power; Gas Distribution/ Heating; Oil & Gas Production; Heavy/Specialty Industry; Industrial Chemical Production	• Gaseous hydrogen and ammonia can be utilised as fuel substitutes in power generation, energy vector distribution and heat applications. • Hydrogen is well-suited for long duration storage for balancing the power grid. • Hydrogen is used in oil refining and can be integrated into carbon-intensive production processes for materials such as aluminium, steel and cement. • The production of ammonia, methanol, fertilisers and and other industrial chemicals requires hydrogen as a primary feedstock and intermediate.
GAS & FUEL CELL	Heavy Duty Transport	Heavy Duty/ Industrial vehicles; Cargo/ Passenger Rail; Maritime	• Gaseous hydrogen can be used with fuel cells to generate power and substitute conventional fuels (e.g., natural gas, diesel) for use in commercial and industrial vehicles (e.g., forklifts, trains). Internal combustion engine and steam-driven turbine applications using hydrogen are also being developed. • Ammonia and methanol are viable substitute fuels for various heavy-duty applications (e.g., maritime), where the energy density and ease of handling of these fuels is competitive with conventional alternatives.
GAS & LIQUID/ SYNTHETIC FUEL	Aviation & Light Duty Vehicles	Aviation; Light Duty Vehicle; Other	• Hydrogen can be combined with carbon dioxide to produce low- or net-zero emissions synthetic fuels, such as SAF (sustainable aviation fuel), depending on the initial source of carbon dioxide. • In aviation, liquid H2 fuelled aircraft designs are also being considered for short haul, regional and eventually longer haul flights. • Hydrogen-powered vehicles are a viable alternative to BEVs for larger/heavier passenger vehicles (e.g., buses), where the additional carrying capacity of fuel offsets the relatively heavier vehicle platform

Key: Form, Key Sectors, Sub Sectors

Source: adapted from Lazard Levelized Cost of Hydrogen Report, 2021

Manufacture of Hydrogen

Hydrogen can be produced using several different processes, each of which is often referred to using a colour code to reflect the level of GHG emissions; the principal colour categories are summarised in Table 3 below. The potential feedstocks for low carbon hydrogen production are water, waste biomass, biogas or natural gas (with CCS). We note that black, brown and grey hydrogen (produced using fossil fuels) do not meet the emissions intensity requirements for low carbon hydrogen, neither does some blue hydrogen, depending on the prevailing regulatory guidelines. In the UK the regulatory threshold is a maximum of 20 grams of CO_2 equivalent per megajoule of hydrogen product using Lower Heating Values (20g CO_2e/MJ LHV), as defined in the latest LCH guidelines published in December 2023.

The HAR2 scheme in the UK requires that the Technology Readiness Level for the hydrogen production method be at least TRL 7 i.e. there should be a prototype demonstration system in (or near to) operation. Most commercial hydrogen plants being built today use alkaline or PEM electrolysers to make green hydrogen and these are usually above TRL 7; alkaline electrolysers are well established but are not able to cope so well with power supply intermittency and the up/down ramping that may be required in the UK compared to the newer (though more expensive) PEM designs, and there is a wide range of other more efficient and tailored electrolyser designs in development (i.e. mostly at or below TRL 7).

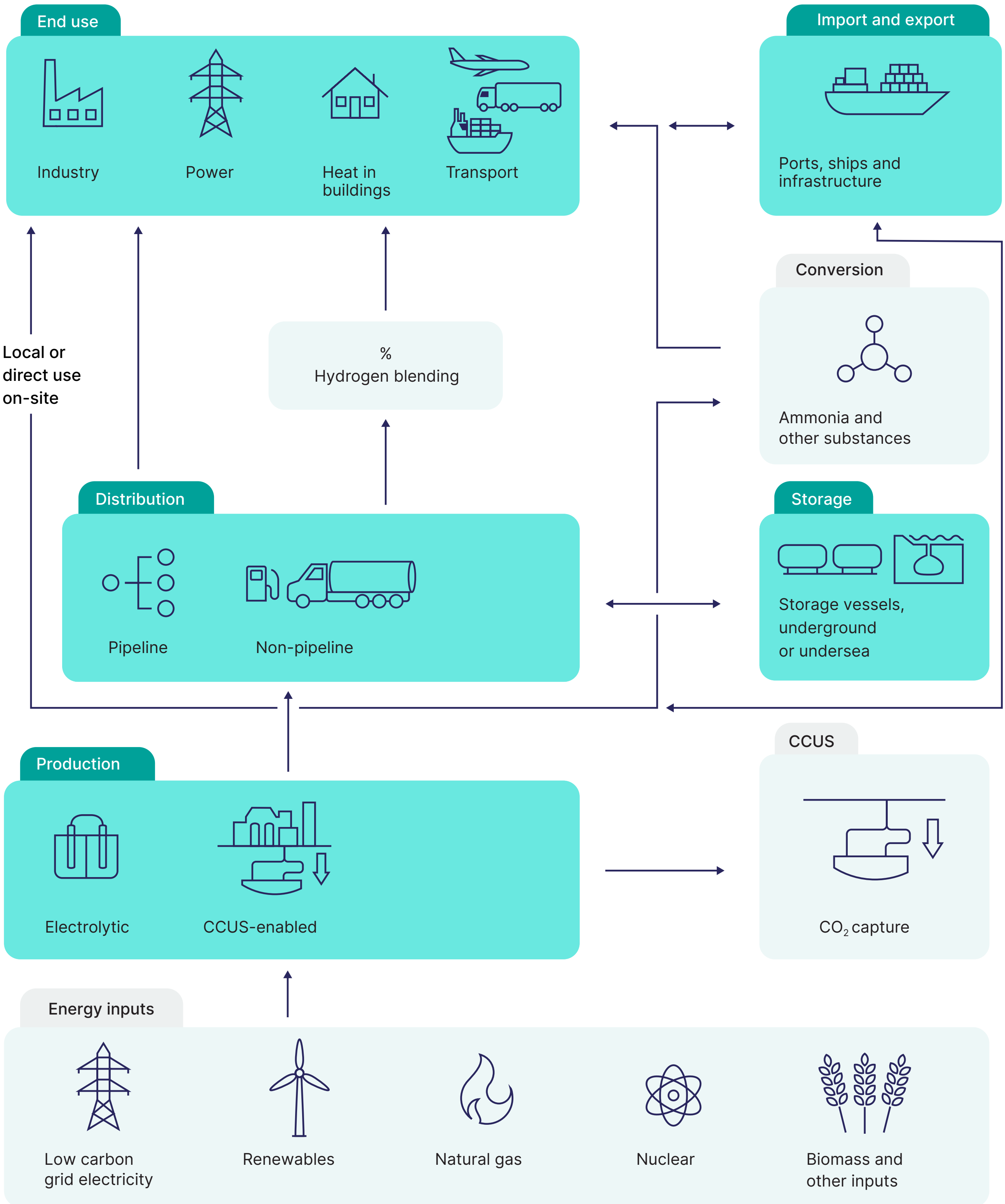
Table 3: Overview of hydrogen production processes

Production Method	Designated Colour	Process	Comments
Reforming Fossil Fuels	Grey	Reforming of natural gas (methane) with steam in a chemicals plant, or reforming of naphtha in an oil refinery; these involve the release of CO_2 or other GHG emissions	Reforming of fossil fuels is the process used currently for most of the world's hydrogen production
Reforming Natural Gas with CCS	Blue	Steam reforming of methane with capture and sequestration of CO_2	Projects are now being developed globally, including in the UK
Electrolysis of water using solar or wind power	Green (Pink if using nuclear power)	Use of power to split water into H_2 and O_2	Alkaline and PEM designs lead the market currently but many others are being commercialised or developed e.g. solid state (SOEC), anion-exchange membrane (AEM), supercritical, plasmolysis
Gasification or electrolysis of waste biomass	Green (usually)	Break-down of waste biomass to produce a range of products including H_2	The oldest way of producing H_2 was gasification of coal (making brown or black H_2 with high GHG emissions)
Methane or biomass pyrolysis	Turquoise	Splitting of hydrocarbons at high temperatures without oxygen into H_2 and solid carbon	A number of technologies are in development
Naturally occurring H_2	White (or Gold)	Naturally produced H_2 that is trapped underground and can be extracted	Exploration for natural H_2 has now started in a number of countries

The Hydrogen Value Chain

The transition to a hydrogen economy will require the development and co-ordinated integration of infrastructure at scale to support the production, transport, storage and use of hydrogen across the UK. A top-down overview of a potential ecosystem is shown in Figure 4 below (taken from the UK Government's Hydrogen Strategy):

Figure 4: Overview of the hydrogen value chain



Source: UK Hydrogen Strategy, 2021

This ecosystem is a representation of the potential 'end state' of a hydrogen economy. There are several market and industry issues that production projects will need to address, including:

- There are currently relatively few users of hydrogen with most consumption residing in the chemicals and refining sector, so the market demand for low carbon hydrogen has yet to emerge, and hence the need for the HAR schemes to kick-start the market;

- Electrolytic hydrogen production projects require both power and water as inputs to support the process. Depending on the location and infrastructure of the hydrogen production site, projects may face significant delays in accessing the grid. For example, an open letter (May 2023) from the UK's regulator, Ofgem, stated that over 40% (120GW) of all new generation capacity holding transmission connection agreements had connection dates of 2030 or beyond. The UK Government, National Grid and the wider power networks sector are working to streamline connection planning and accelerate connections for infrastructure projects (following recommendations of the Winser Report);

- There are currently no dedicated hydrogen pipelines. If implemented, Project Union will help address this by repurposing existing transmission pipelines to create a hydrogen 'backbone' for the UK by the early 2030s and connect to the proposed European Hydrogen Backbone. The first dedicated pipeline to be built in UK will likely be the HyNet North West Hydrogen pipeline;

- The safety and commercial case for blending up to 20% of hydrogen with natural gas in existing gas infrastructure remains under review;

- Tube trailers can be deployed for transport of low volumes of hydrogen, as will be required by many of the early hydrogen projects. Natural gas is already commonly transported by truck as CNG (compressed) or LNG (liquefied) in tubes or tanks in many countries; but there is an economic and practical limit to the scale and distance for carrying such fuels by road;

- The hydrogen industry supply chain is only starting to scale up, with long lead times currently for electrolysers, tube trailers and compressors - manufacturers need to invest in their respective production capacities to meet the expected growth in demand (the DESNZ GIGA programme is designed to help facilitate this investment); and

- There is relatively limited experience in the production and use of hydrogen, hence a skills shortage and a need for more training. Expanding training for new use cases also requires a new framework of regulations and corresponding standards. Local planning authorities have little experience with hydrogen projects and some design standards are unclear, which may create delays in securing the necessary project consents. This includes, for example, consideration of onsite storage for hydrogen and related safety aspects.

Project developers, and their funders, need to factor the above considerations into their respective individual projects and wider portfolio strategies.

UK and International Subsidy Schemes

To stimulate investment into the nascent UK hydrogen economy, the Government has introduced several funding initiatives. Table 4 below provides a summary of the main programmes:

Table 4: Examples of UK funding schemes to support hydrogen

Scheme	Type	Funding / Scheme Cost	Description
Hydrogen Production Business Model (HPBM)	Subsidy	£2bn[2] for HAR1	A revenue support contract to be used for low carbon hydrogen production projects, allocated via the HAR mechanism (Hydrogen Allocation Rounds).
Net Zero Innovation Portfolio (NZIP)	Grant	£1bn	Designed to accelerate the commercialisation of low carbon technologies, systems and business models in power, buildings and industry. As of March 2024, £170m had been allocated to hydrogen innovation projects.
Net Zero Hydrogen Fund (NZHF)	Grant	£240m	Provides development expenditure (DEVEX) and capital expenditure (CAPEX) grants to support the development and construction costs of low carbon hydrogen production facilities.
Renewable Transport Fuel Obligation (RTFO)	Tradeable certificates	£2.5bn[3]	An obligation introduced in 2008 on suppliers of fossil petrol and diesel to supply a certain percentage of renewable fuel (including hydrogen) to the UK market, set to reach 14.6% by 2032. Producers of eligible renewable fuels receive tradeable Renewable Transport Fuel Certificates (RTFCs).
Green Industries Growth Accelerator (GIGA)	Grant	£1.08bn	Announced in November 2023, set up to support private sector investment in clean energy supply chains across the UK, of which £390 million will be allocated for the CCUS and hydrogen sectors.

The RTFO is a subsidy scheme that can be used instead of HPBM to support hydrogen production for transport, but it is not 'grandfathered' i.e. unlike the HPBM subsidy there is no certainty on how long it will last. The HAR schemes are the Government's main mechanism for advancing long-term non-CCUS production projects:

- Introduced as part of the UK Energy Act 2023, the HPBM provides price support to producers of low carbon hydrogen for a period of up to 15 years. Initial contracts are currently negotiated on a bilateral basis with DESNZ.
- Eleven projects, with a combined capacity of 125 MW, were awarded contracts in December 2023 under Hydrogen Allocation Round 1 (HAR1). DESNZ has estimated that the HPBM revenue support could total £2 billion over 15 years; and over £90 million of capex support was also allocated from the Net Zero Hydrogen Fund. The 11 projects had an average production capacity of 11 MW (ranging from 5 to 25 MW) and an average (subsidised) hydrogen 'strike price' of £241/MWh, equivalent to £9.49/kg hydrogen; while a seemingly high energy cost compared to long term targets, this average strike price for the first round is regarded by DESNZ as comparing well with that of other nascent technologies such as floating offshore wind. The 11 projects will result in £413 million of private capital investment and the creation of 760 jobs. Further details of the successful projects can be found on the DESNZ website.
- The second round (HAR2) is targeting a further 875 MW. There were a significant number of applications submitted before the19 April 2024 deadline. Application guidelines can be found here. A noteworthy change for HAR2 is the removal of any capex support for projects from the NZHF.
- The Government is set to allocate up to 1.5GW across HAR3 and HAR4, launching in 2025 and 2026 respectively.

A summary of the HPBM scheme is provided in the text box below. More details can be found on the DESNZ website.

2 Estimated funding over 15 years for the 11 projects awarded contracts under Hydrogen Allocation Round 1

3 For 2022. Source: UK Government

HPBM Summary

The HPBM is a ‘Contract for Difference’ scheme derived from that successfully used to kick-start the UK offshore wind industry. Under the HPBM a producer of blue or green hydrogen contracts with a Government entity (the Low Carbon Contracts Company) through a Low Carbon Hydrogen Agreement (LCHA) and will receive a Difference Amount; this is designed to ensure that the producer achieves an agreed ‘Strike Price’ that covers its costs, or the producer pays the Government if the sales price exceeds this Strike Price.

The Difference Amount depends on the Strike Price agreed with DESNZ, the current market price for gas (the UK NBP Month Ahead price as published on ICE Futures Europe) and the actual price paid by the offtaker (which would usually be linked to the market price for gas). The subsidy is thus linked to the market price of natural gas as there is no liquid market price for hydrogen. The Difference Amount will only apply to qualifying hydrogen volumes i.e. those that are produced below the agreed carbon intensity and sold to offtakers for use for an approved decarbonisation purpose (which currently does not include export, retail sales, gas pipeline blending or trading).

There are mechanisms to incentivise producers to maximise their sales price and to be compensated in the event of reduced volume sales. Projects under HAR1 should become operational from 2025, those in HAR2 between 2026 and 2029, and should have a minimum production capacity of 5 MW; both biomass-based and electrolytic technologies are allowed in HAR2 providing that the TRL is 7 or above. The subsidy support will last for 15 years. The HAR rules require that project sponsors provide significant evidence of project planning and deliverability of the value chain in order to be considered for HPBM support.

The requirements for projects considering bidding into HAR2 have evolved when compared to HAR1, with the main features and amendments shown below in Table 5. This evolution is likely to continue into future rounds as the hydrogen sector develops.

We note that the measure of production capacity used by DESNZ is in MW at the higher heating value of hydrogen (39.4 kWh/kg). So a capacity of 1 MW is equivalent to approximately 25.4 kg per hour production capacity of hydrogen.

Table 5: Key Project Application Requirements for HAR1 and HAR2

Feature	Original HAR1 Requirements	HAR2 Requirements
Project Location	Entirely in the UK	As for HAR1
Hydrogen Production Facilities	New build hydrogen production facilities, including new phases of existing projects adding at least 5 MW of new hydrogen production capacity to an existing plant	As for HAR1
Minimum Capacity	Minimum hydrogen production capacity of 5 MW Hydrogen (Higher Heating Value or HHV)	As for HAR1
Operational Date	No later than December 2025	Between 31 March 2026 and 31 March 2029
Core Technology	Utilization of a tested core technology with a Technology Readiness Level of 7 or more (i.e. prototype near or at planned operational system, requiring demonstration in an operational environment)	As for HAR1
Production Technology Type	Electrolytic only	One of the following: - Electrolytic - Gasification/pyrolysis of biomass/wastes (without CCS) - Gas splitting producing solid carbon
Production Technology Supplier	Identification of an electrolyser supplier	Identification and engagement with a core production technology supplier
Access To Finance	Demonstration of access to finance	As for HAR1
Offtaker Engagement	Identification and engagement with (at least) one qualifying offtaker	As for HAR1

Comparison with schemes in other markets

Other countries besides UK are putting in place mechanisms to help develop hydrogen economies across the full value chain, including production. The IEA database contains an estimated 1,700 low carbon hydrogen production projects globally with a combined capacity of 800 GW across more than 40 markets. Some examples of support mechanisms are presented below in Table 6. As can be seen, a range of tools is being implemented.

Table 6: Examples of international support mechanisms

Market	Type	Beneficiary	Description
UK	CfD	H_2 Producers	Allocation of contracts on a bilaterally negotiated basis
EU	Fixed premium	H_2 Producers	Auction of subsidies through the European Hydrogen Bank for EU producers (launched at end 2023), allied with the H2Global auction for imports of H_2 and derivatives
Germany	CfD	Industrial Users	Competition to receive a subsidy to use clean H_2 in industrial processes
India	Fixed premium	H_2 Producers	Auction of subsidies to green H_2 producers
Australia	Production credit / CfD	H_2 Producers	Competitive process for production credits for domestic H_2 and derivatives
Japan	CfD	H_2 Producers and Importers	To cover both domestically produced and imported H_2 and hydrogen derivatives, to be launched in 2024
South Korea	CfD	Power Producers	Clean hydrogen bidding for power generation, to be launched in 2024
USA	Tax Credit	H_2 Producers	IRAS includes a 10-year Production Tax Credit of up to US$3/kg H_2 but details were still being negotiated as of April 2024

The UK's HAR1 is the world's first large scale scheme to have agreed subsidies for a series of hydrogen production projects. Participants in the survey expressed satisfaction that the HPBM scheme aims to provide revenue support rather than just cost reduction, and they appreciated the efforts made by DESNZ in the due diligence of projects applying for support, including the focus on job creation and project deliverability.

Overview of Financing Energy Projects

Project Financing

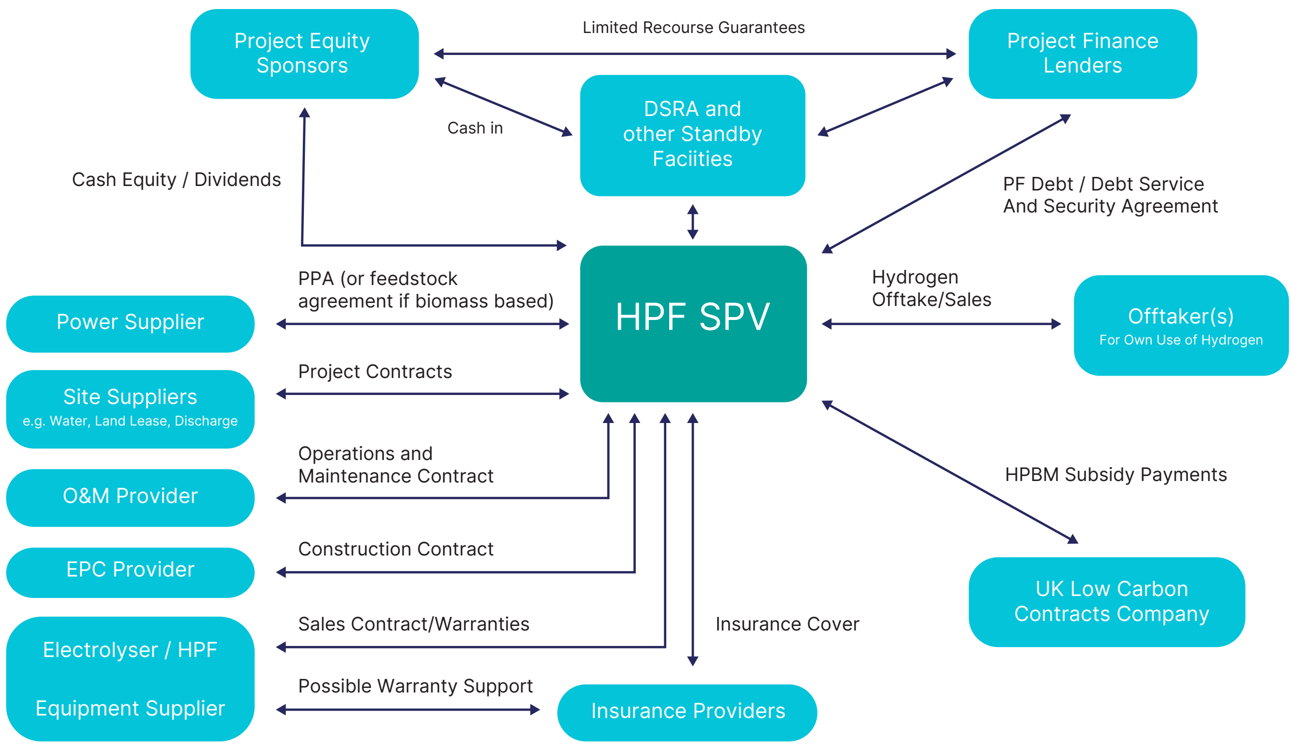
Projects in mature energy and infrastructure markets often use third party debt financing because it is cheaper than equity, so raising returns, and it allows companies to utilise their limited balance sheet to develop more projects. In this way a wider range of larger investments can be supported and done so more rapidly. Many projects in the global energy markets, including offshore wind and gas-fired power, are funded using project finance debt, typically with a 60% to 75% gearing and a debt tenor of 10 to 20 years.

Project financing entails the allocation of project risk away from the shareholders to those parties that are best positioned to take specific risks i.e. to parties best able to sort out a particular problem if something goes wrong. Some of the identified risks may be passed onto insurance companies (who therefore charge for taking that risk) and project finance (PF) lenders take the residual risks. To enable this a Special Purpose Vehicle (SPV) is established which owns the Hydrogen Production Facility (HPF) and into which sponsors provide equity and lenders provide debt.

If lenders provide debt directly to the sponsors, then this is generally with full recourse to (i.e. guaranteed by) the sponsors; but if they lend to the SPV then there is only limited recourse to the sponsors. Hence project finance is often called 'limited recourse finance'. However, in such a structure shareholders may still have defined obligations which may require specific guarantees, escrow cash accounts or penalty payments. For example, a sponsor may have an Operations and Maintenance contract for the plant, under which they must pay penalties if they do not perform properly. In a PF structure the debt providers are looking to minimise their downside risk and then charge an interest rate that reflects this 'low' risk; unlike the project shareholders they have no upside if the project performs better than expected.

Figure 5 shows a typical simplified contractual structure for a project financing with HPBM support (noting that many of the contracts shown would still be required even without project finance). In practice the contractual arrangements for PF are far more complex and the legal costs and time in structuring such a deal can be significant.

Figure 5: Simplified contractual structure for project finance with HPBM support



Lenders' Risk Assessment

Unlike a shareholder, a bank has no direct control or influence over the actions of most project stakeholders such as contractors, operators or offtakers. In deciding whether to lend, a PF bank's credit committee will assess the residual risk being taken from a holistic perspective after assessing the individual risks, which for a green hydrogen project would include:

- **Construction Risk** – ensuring that the HPF is fully functional from the intended start-date with an agreed construction cost;
- **Supply Risk** – ensuring access to appropriate low carbon power at an economic price when needed for an electrolyser project (or biomass feedstock for a biomass-to-hydrogen project);
- **Operating Risk** – ensuring that the HPF performs as intended when needed, producing saleable hydrogen at the planned volumes, purity and carbon intensity;
- **Market Volume and Credit Risk** – ensuring that there are committed offtakers at all times during the life of the loan who will take and pay for the hydrogen with an eligible use as defined in the HPBM rules;
- **Market Price Risk** – ensuring that the price paid for the hydrogen by offtakers, when combined with subsidies, meets both the HPF operating costs and the debt service requirements (this is the risk that the HPBM is designed primarily to address);
- **Delivery Risk** – overlapping with market price and volume risks is the need to ensure that hydrogen is delivered safely on time to the offtaker, in the required volume and at the expected transportation cost (currently mostly by road);
- **Political Risk** – the risk that a government does not honour its subsidy scheme promises or there is a change in law that adversely impacts the project;
- **Subsidy Termination Risk** – the need to address what happens if the HPF company defaults in a way such that it loses the subsidy and the bank-financed HPF is no longer economically viable; and
- **Carbon Intensity Risk** – a subset of the above wherein the subsidy falls away because the power supply and/or HPF operation does not meet the carbon intensity standard (LCHS), or the offtaker is no longer using the hydrogen for approved purposes.

Our survey found that, for a hydrogen value chain project with HPBM subsidies, the industry stakeholders and lenders in particular generally ranked the risks as summarised in Figure 6 below. These risks are each addressed in detail in the Findings section.

Figure 6: Perceived relative importance of risks for HPBM projects

Findings

Findings
Finance Market Conditions

There is no lack of capacity in the debt or equity markets for hydrogen projects

There is substantial interest and intent by international debt and equity providers to fund hydrogen and hydrogen derivative projects. Most of the large global banks have PF teams wherein there is at least one banker focusing on hydrogen and other sustainable energy solutions. Some of these teams include engineers who are familiar with electrolysers and can assess technology risk. In the past these same teams financed oil & gas projects, more recently wind and solar projects.

Similarly, many of the infrastructure funds have remits to provide equity and potentially debt to sustainable energy projects such as hydrogen. Their challenge is actually how to find projects that are sufficiently large, economic and structured robustly to attract equity, let alone debt.

As a key finance centre, London is where much of the global PF expertise is based for banks and funds. Most teams have an international remit with a natural tendency to focus on the larger more profitable deals.

Not many hydrogen projects to date have reached financial close using debt, but this is changing

As a new industry with untested project risk, the hydrogen sector will follow the same track as seen in the LNG, offshore wind and energy storage sectors over the last few decades: the initial HPF projects will be primarily equity funded, but project finance debt will be increasingly used as more hydrogen projects start up and lenders become more comfortable with the risks they are being asked to take on.

The first limited recourse projects involving electrolysers are the NEOM and H2 Green Steel projects (see case study boxes below). The former has green ammonia as the end-product, the latter green steel, with the HPF as an intermediate step in a continuous process – rather than the intermittent HPF operation being planned for many of the electrolyser projects in the UK. In both cases there was significant support from governments and corporates. Both projects are integrated facilities with continuous-flow H_2 production and use on the same site; also both projects sell commodities (steel and ammonia) for which there already exist liquid international markets, which helps the financing. By contrast, under the UK HPBM the producers and offtakers will need to obtain separate financing, the intermediate product (green or blue hydrogen) has no liquid market and the HPF may not be operating continuously (depending on the power and offtake arrangements).

Outside the UK there are now are a number of very large electrolytic projects being developed that have a first step of making hydrogen from renewable power and then conversion to methanol, ammonia or fertiliser (all tradable commodities) – with the target sales market being primarily EU and Japan where there will be import subsidy schemes. Such production projects are now being planned in Scandinavia, Middle East, North Africa, Australia, South America and USA, where renewable power is cheap. According to participants in our survey, many of these projects initially tried to raise project finance debt but this proved too difficult and costly so the first green hydrogen and ammonia projects were financed using shareholder balance sheet (often with government support); however, the success of NEOM and H2 Green Steel is changing the perceived bankability of these hydrogen-based projects.

H2 Green Steel – Project Finance Example

H2 Green Steel will be the world's first large-scale 'green' steel plant, located in Sweden and using hydropower to supply electrolysers to make hydrogen for the reduction of iron ore. As of January 2024 H2 Green Steel had agreed project debt commitments of €4.2 billion alongside equity commitments of €2.1 billion. A significant portion of the debt was guaranteed by Riksgälden (the Swedish National Debt Office) and Euler Hermes (the German export credit agency, in support of electrolysers supplied by Thyssenkrupp Nucera). Many European manufacturers were willing to pay a premium for offtake of the 'green' steel and some were also equity investors in the project.

NEOM – Project Finance Example

In 2023 NEOM Green Hydrogen Company reached financial close with 23 banks and investment firms for US$6.1 billion of project debt as part of a US$8.4 billion project in NEOM, Saudi Arabia. This is the world's largest green hydrogen plant to produce green ammonia, with start-up scheduled for 2026. International banks were particularly attracted by the role of Air Products (one of the world's largest gas companies) in providing a 30-year offtake commitment for all the green ammonia as well as providing commitments in relation to the project construction. Air Products plans to ship the green ammonia primarily to Europe, where it will be cracked to hydrogen and liquefied for sales in EU and UK.

CEOG – Debt Financing Example

An early debt financing of a green hydrogen project was the CEOG project in French Guiana (South America) in 2021. This €170 million scheme included a 22-year bank debt facility of €105 million. The project comprised a solar plant to power an electrolyser to produce hydrogen for storage, with fuel cells to export this power under a PPA for continuous supply to EDF (but with significant support from the French government).

Many of the projects that win subsidies under HAR1 and HAR2 will ultimately be too small for most project finance banks to lend to, however bankable they may be

Most of the projects that won subsidies in HAR1 have a capacity in the range 5-15 MW, which implies a capex typically of less than £30 million. If project financed then they would have a loan requirement of £10-20 million. This is below the minimum loan size for almost all PF banks who have expertise in hydrogen.

For example, UK Infrastructure Bank has a minimum loan size of £25 million and has indicated that it will only be able to finance the larger HAR projects. Many other international banks have a minimum loan size of £25 million, some higher at £50 million, and many require that there be at least two lending banks. As a result, we think that it would be difficult for a hydrogen project to attract limited recourse debt if the capex is less than £40 million. Ideally banks would prefer projects larger than £100 million (and above £500 million for infrastructure funds).

This minimum size is because of the very significant cost and time for people required to structure a deal, each typically being bespoke, with no precedent. The due diligence that a lender has to undertake, the legal costs and the time required to close a deal are far greater than for direct loans to corporates.

The UK-focused banks (such as those with a High Street presence) typically have lower lending limits, maybe down to £10-15 million for one-off Net Zero projects in the UK; historically they have provided bilateral loans for mature renewable energy projects (i.e. with no other lenders) but they still prefer another bank to be alongside. They will still face the same structuring and due diligence costs as described above and will need to ensure adequate commercial returns on lending.

Although there is substantial interest from banks in hydrogen projects, there is limited awareness of the HAR schemes

Half of the project finance teams in London that we spoke to were not familiar with the UK HPBM or HAR schemes and had not been approached by sponsors of UK hydrogen projects, the exceptions being primarily those banks with a High Street presence. However, all the banks we spoke to were interested in learning more about hydrogen projects including HAR, and most banks already had designated individuals responsible for PF activities in the hydrogen sector.

Findings
Sources of Debt

There are different types of debt available for hydrogen value chain projects

Table 7 below summarises the sources of debt that may be obtainable for energy projects. Most loans will be 'senior' debt wherein lenders have security over project assets and have the first rights to cashflow once operating costs and taxes have been paid. The large projects (such as H2 Green Steel and NEOM) may also have 'junior' debt tranches (also called mezzanine or subordinated debt) who have lower rights to cashflow and therefore take 'first loss' risk (and charge higher interest for taking this risk). It has been common practice in the energy and infrastructure markets for development banks such as EIB (European Investment Bank) to provide mezzanine finance or other structures that attract ('crowd in') funding from commercial banks.

Table 7: Potential sources of debt

Source of Debt	Characteristics	Applicability for Hydrogen Projects
Project Finance Banks	Loans > £25-50 million (domestic UK banks may go lower) and > 10 years	Limited appetite in the next few years until projects have started up
Infrastructure Funds	Investments > £50 -100 million, have provided debt as well as equity in other energy sectors. UK insurance and pension funds are also becoming interested in energy infrastructure	Currently equity funding development companies, not yet debt for projects
Export Credit Agencies	Similar to banks but more rigid requirements, and UK Export Finance can only support exports	Will be important for many of the large international hydrogen and derivatives projects
Bond Markets	Similar to banks but larger loan size with more rigid constraints	Too early yet for most H_2 projects outside USA
Venture Debt	Loans typically £1-15 million and 5 years, if have institutional equity, secured by IP	A growing market, it could help SMEs fund their share of project construction costs
Crowd-Funding Debt	Generally for small loan amounts, but loans of up to €10 million for 5 years have been raised in Belgium and France	Not yet used in the UK energy projects but could be worth considering
Development Banks	Tasked with 'crowding in' other providers of finance. UKIB could provide significant senior and mezzanine debt (>£25 million) for large projects.	Most regional agencies can only provide small loans. But Scottish National Investment Bank could be key for smaller H_2 projects in Scotland.

UK Government institutions can provide debt funding but this is currently constrained

Small loans are available for SMEs from the British Business Bank and regional development banks. For example the Growth Finance Fund in Northern Ireland can provide a loan of up to £2 million for up to 7 years and the Development Bank of Wales can provide business loans of up to £10 million for up to 15 years, but this type of debt funding available is generally too small or not designed for PF projects.

One exception is the Scottish National Investment Bank who can provide up to £50 million of long term debt and/or equity for projects with a significant Scottish connection. The bank was only formed in 2020 and has a strong interest in providing both PF loans and investments for the hydrogen sector, although as of April 2024 the bank had not had many discussions in regard to HAR projects. As a development bank it has an impact investment mandate, tasked with 'crowding in' private sector finance (i.e. drawing in other capital), but its investments have to be on commercial terms. Developers in Scotland should certainly approach Scottish National Investment Bank as well as Scottish Enterprise for assistance.

This leaves the UK Infrastructure Bank (UKIB) as the only project finance development bank in the UK outside of Scotland, replacing the functions of EIB (European Investment Bank) after Brexit, and tasked with crowding in private finance for Net Zero projects. UKIB is a relatively young organisation and announced its first hydrogen (equity) investment only in February 2024. The UKIB hydrogen strategy, as published in September 2023, is to prioritise financing large green hydrogen production projects that win HAR subsidies, this could be via equity or debt. We note that the UKIB's minimum ticket size of £25 million means in practice that most HAR1 projects will be too small and as of April 2024 UKIB had not yet announced any debt financing for hydrogen projects. Many of the stakeholders interviewed in the preparation of this report highlighted the potential crowding-in role that UKIB could play by taking first loss risk through structures such as mezzanine finance.

Another Government entity, UK Export Finance (UKEF), was established by Act of Parliament to help finance UK exports. In 2022 UKEF provided its first support to the hydrogen sector by providing Johnson Matthey with a £400m Export Development Guarantee to boost research and development in sustainable technologies including green hydrogen. In the same year UKEF also provided a £26m working capital facility to support Wrightbus followed by an additional £50m facility in 2023, to open up new markets for the world's first hydrogen-powered, zero carbon double decker bus. However, the constitution of UKEF only allows it to support UK exports so it would not be able to fund any HAR projects in the UK. This is in contrast to some other export credit agencies such as EDC (in Canada) and JBIC (in Japan) whose constitutions allow them to finance projects in their own countries.

In the survey a number of stakeholders commented that there is now less debt support available from governmental (UK or European) entities for sizeable infrastructure projects compared with pre-Brexit days. In particular, interviewees pointed to the role that the Green Investment Bank played in structuring and bringing down the cost of financing offshore windfarms: the Green Investment Bank was established by UK Government in 2012 and provided 100 loans and investments in the wind, bioenergy and waste sectors. According to the National Audit Office it was able to attract £2.5 of private capital for every £1 it provided. However, in order to increase its access to funding, the bank was sold in 2017 to a private consortium, where it now has a large-scale green infrastructure focus.

The options for SMEs to obtain project finance are currently limited

SMEs wishing to develop a First Of A Kind technology invariably hit a barrier when trying to find funding at the £5 million to £30 million levels required for their first demonstration or commercial plant. In the hydrogen sector possible sources of funding for SMEs are:

- **RTFO revenue support:** for smaller projects in the transport sector this may be preferable to applying for HPBM support (which has a 5 MW minimum production capacity limit);

- **Venture debt:** there are now about 30 lenders of venture debt in the UK, from boutique funds and specialist lenders to high street banks. Venture debt is aimed at SMEs who already have institutional equity and some revenues, it is usually secured on assets such as IP and often supplements equity raising as it is less dilutive. With amounts of up to £15 million available with a tenor of up to 5 years, venture debt could help construction financing;

- **Government grants,** such as through the NZIP and GIGA programmes described in the UK and International Subsidy Schemes Section;

- **Debt and equity crowdfunding:** debt crowdfunding for renewables projects has not yet happened in the UK but loans of up to €10 million and 5 year tenors have been secured in Belgium and France, such as through Lumo. Such community funding may also work in the UK; and

- **Co-investment:** in projects by offtakers, suppliers, green energy funds or infrastructure funds who may provide a 'carry' for the SME and fund the construction phase. If the investing partner is concerned about technology risk, then this may be mitigated through the purchase of technology risk insurance as discussed in Findings - Technology and Risk Mitigation section below.

SME project developers applying for HPBM support could initially look for large corporates and/or funds as partners to secure equity funding for the development and construction phase; and plan to refinance projects (maybe as a portfolio) in the debt markets once they have been de-risked after start-up. One model is the approach used by Carlton Power, who won 3 of the 11 HAR1 awards and is in partnership with Schroders Greencoat (see the case study below).

Carlton Power – Financing Case Study

Carlton Power had the largest number of successful applications under HAR1, with three projects receiving subsidy awards (totalling 38 MW production capacity). Carlton Power is an established UK independent developer of energy infrastructure with significant experience in project financing power plants. For its hydrogen projects Carlton Power chose to JV with Schroders Greencoat LLP, a specialist investment manager in renewable infrastructure. Carlton Power will be managing the development of these projects while Schroders Greencoat will provide the equity financing.

Findings
Technology Risk Mitigation

Engineering assurance methods can help expedite the financing of new technologies

Banks are reluctant to provide debt to projects with new technology which, in their view, has not been 'commercially proven' - but the definition of this is unclear and the energy transition is pushing the boundaries of what technologies could or should be financeable. We note that the HAR2 rules allow applications for hydrogen production technologies which are only at (or near) the operational prototype stage (TRL 7). In assessing these risks banks employ their own engineers and independent consultants in order to become comfortable (or uncomfortable!) with the technology risks; this risk assessment is increasingly involving insurance brokers and classification societies in trying to define standards against which new technologies such as electrolysers can be measured. The key aim in this engineering assurance is to be able to assess the probability of failure using historical data and technical analysis, and hence be able to price the risk. If a lender or investor is unwilling to take on that risk, then it is now possible to procure technology risk insurance instead.

Technology Risk Insurance is a key new tool in financing hydrogen and First Of A Kind projects, but it is relatively unknown in the UK

Insurance contracts are an integral part of a project financing, whether covering fire or business interruption risks. But over the last decade there has increasingly been provision of technology risk insurance, principally underwritten by insurers such as Munich Re, Ariel Re and AXA XL (often through New Energy Risk in USA). In order for insurers to become comfortable with technology risk their engineers would want to see at least 1,000 hours of operational data – at least 8,000 hours would be the norm but some biomass projects cannot obtain feedstock for this long; the technology would need to be at least TRL 8 (i.e. commercial testing has been completed); and scale-up from the demonstration plant could be 5 times or up to 20 times if modular.

There are several ways in which such insurance could be structured for hydrogen. For example, it could be used to:

- Enhance the credit rating and length of the warranty from an electrolyser company, such as via Munich Re;
- Provide insurance for components that need replacing during start-up, such as via Ariel Green;
- Guarantee a minimum production volume; and/or
- Enhance the credit rating for a group of offtakers (although such insurance will not take market volume or price risk).

The buyer of such insurance would typically be an electrolyser manufacturer, the project SPV or an equity investor (not usually the project finance lenders).

The minimum risk coverage is US$10 million and, as a rule of thumb, the cost is 1% per year per risk covered. So coverage of 10 years of performance risk could add 10% to the cost of a project – it may seem expensive but it could be the difference between having or not having a financed project. Any such insurance costs would have to be taken into account in advance when negotiating an HPBM subsidy.

There are many examples. AXA XL told us that they had already underwritten US$1 billion of technology risk insurance in the new energy and renewables sectors, mostly in USA but none in the UK; this includes a comprehensive performance risk policy that enabled investment to be procured by a pioneering plant in the USA making Sustainable Aviation Fuel from municipal waste. In March 2024 the London-based insurance broker Howden announced a First Of A Kind insurance policy to cover leakage of CO_2 from commercial CO_2 capture and storage facilities. We expect more such innovations in the market.

Below we share some case studies for Ariel Green, a new subsidiary of Ariel Re.

Ariel Green - Technology Risk Insurance

In a hydrogen project in South Korea the sponsors and lenders were concerned about the ability of a fuel cell provider to stand behind its 15-year maintenance agreement. Ariel Green assessed the technology risk and provided backing for the service agreement including a mechanism to identify an alternative (back-up) service provider who could assume all the responsibilities, including scheduled stack replacements.
For a novel biomass-to-fuels gasification project in USA Ariel Green provided a long-term investment grade Technology Performance Insurance (TPI). This policy provided protection against cost overruns during start-up and against underperformance during commercial operations for the life of the senior debt.

Findings
Construction Risk

Construction and start-up risks for electrolysers have not yet been tested in the UK

Lenders are concerned that projects start up properly on time and on budget. These risks are significant in a sector such as hydrogen where there is very little UK experience of commissioning electrolysers and integrating with the balance of plant, and where there may be supply chain hold-ups. Cost overruns beyond the contingency limit can result in late start-up; and delays in start-up increase the interest during construction and rolled up costs.

To mitigate construction risk traditionally project finance banks have wanted creditworthy completion guarantees from sponsors or Lump Sum Turnkey (LSTK) contracts with EPC contractors, who have charged for taking this risk (typically costing 5-10% of capex). During the survey we repeatedly heard concerns that there are now few contractors willing to provide LSTK commitments for large projects, in part due to the lower number of qualified EPC contractors both in the UK and overseas.

However, we see construction as less of a risk for the smaller hydrogen projects (below £100 million capex) where the residual risk is small and does not threaten bankruptcy to the EPC contractors. A large element of the construction risk will have to be taken by the electrolyser company in providing start-up and performance guarantees and making available spare parts, so the creditworthiness of the electrolyser provider then becomes more of an issue (hence the interest by insurance companies in backing up these guarantees).

In the absence of an LSTK commitment project finance lenders will need to look at the sub-contracting arrangements and require higher contingencies: and sponsors will have to provide standby equity and cost overrun facilities with cash or creditworthy guarantees to the lenders. These extra costs and the potential for extra interest during construction will have to be factored in when project sponsors negotiate HPBM subsidy levels with DESNZ.

Findings
Offtake Issues

Offtake volume and credit risk are the biggest concerns for project finance lenders – offtakers need more skin in the game

Project finance bankers are used to projects wherein there is a creditworthy and competent offtaker who guarantees to offtake the product with an agreed pricing structure over at least the loan life (so usually for more than 10 years), and pays penalties to the producing SPV if the product is not purchased. In this way both sponsors and offtakers are deeply committed to the project over the long term and an offtaker may even take a minority equity stake in the SPV so as to align interests (this is common in the LNG market).

By contrast the projects that sought subsidies under the HAR1 scheme often did not have such strong offtaker support, according to the stakeholders we interviewed.

While the buyers were interested in trialling hydrogen to replace gas or diesel their commitment to this was potentially weakened by their:

- lack of familiarity with H_2 and HPBM;
- weak relationships with the SPV sponsors;
- need to invest in fuel switching facilities or new facilities outside their normal capex cycle;
- need to invest also in hydrogen storage if taking large volumes;
- need to commit to a single supplier over 15 years, while gas and diesel suppliers can be switched immediately; and
- concern over the risk that the whole hydrogen value chain may not work.

In addition, the price incentive for offtakers to invest to switch to low carbon hydrogen is driven primarily by avoiding penalties under the UK's ETS (Emissions Trading System), and the current (April 2024) ETS prices are at the lowest since 2021. Uncertainty over the potential economic benefit of switching may limit potential offtaker appetite to enter long-term offtake contracts for low carbon hydrogen.

Our survey confirmed that many early developers focused on building an HPF with the assumption that offtake commitments would follow, but now there is a shift towards offtakers taking more of a commitment in the value chain. DESNZ has appreciated that offtake is the key project risk and has sought evidence in the HAR due diligence process that offtakers are building facilities to use hydrogen. Government grant programmes such as for Industrial Fuel Switching could also assist with this.

Many of the interviewed stakeholders highlighted the need to see more investment grade corporates committing to hydrogen offtake and use in order to build liquidity in the hydrogen market. In many projects the current named offtakers are middle-tier domestic corporates who may not have the investment grade ratings preferred by banks. Credit risk therefore becomes an issue and lenders will want to see a solution for the scenario wherein the agreed offtaker does not pay (e.g. in the case of bankruptcy) and there is a need to find an alternative buyer of the hydrogen.

Sponsors and lenders need an 'Offtaker Of Last Resort' until the market matures, such as blending into the grid

Accessing alternative offtakers will become easier once hydrogen pipelines are in place, and this first requires DESNZ to institute a Transport and Storage model – but this is not likely until 2025, so even the first hydrogen pipeline networks may not be ready until 2030. As of April 2024, DESNZ is still considering whether to allow the blending of hydrogen into gas grids, which we understand first requires HSE to define the safety case. A number of stakeholders in the survey said that allowing blending would help increase the bankability of HPBM projects as it would provide a fallback ('last resort') offtake. The associated hydrogen volumes would be small compared to the current natural gas flows so dilution would be minimal but the permitting procedures around this would have to be carefully managed by DESNZ. We note that only projects physically close to a gas pipeline would benefit from such a fallback option; and an alternative future fallback option would be sale into a long duration storage project.

Offtake risk can be reduced if there is a combination of the following:

- The core offtaker is committed to decarbonise a substantial part of its operations and is prepared to invest upfront to prepare for hydrogen offtake;
- The core offtaker commits to the project through some form of long-term obligation (ideally ‘take or pay’) and maybe takes a minority investment in the production facility;
- The core offtaker has an investment grade rating, particularly if lenders are reliant on a long-term offtake contract, or there is a set of potential offtakers at a lower credit rating who could offtake a multiple of the production capacity of the HPF;
- The HPF is located adjacent to the anchor offtaker (so there is potential access to utility services and there are no transport problems) or located where a number of alternative offtakers may be more easily accessed if a core offtaker defaults; location within a UK cluster project may be helpful so hydrogen can be supplied to new users by (yet to be built) pipelines rather than long distance trucking in a tube-trailer; and
- There is diversification in the offtake in terms of industry type. One example might be to have a portion of the hydrogen sold to retailers with RTFO rather than HPBM subsidies (although we note lenders may be concerned that the RTFO scheme has a higher risk of being adversely modified by Government).

Findings
Operating Risk Issues

Operating risk is the initial risk highlighted by financiers, but this can be mitigated

Electrolysers have been used successfully for decades in industries such as chlorine manufacture. There is technology risk for new designs of electrolysis plants and biomass gasification but there are measures to address this. If the probability of equipment failure can be assessed, then the risk can be priced and covered as described above.

Many manufacturers of electrolysers only give 18 or 24-month warranties and the credit rating of the guarantor may be too low to be of value to banks – so there may be a need for engineering assurance and/or an insurer standing behind the warranty until at least the first scheduled stack replacement. A project developer needs to ensure that the warranties and assurance tests satisfy their target equity partners as well as potential lenders – much of the technology risk insurance placed in USA was actually at the behest of private equity investors.

The impact of intermittency needs to be considered for operating risk in the UK

Intermittency in the supply of wind or solar power in the UK and variability in power pricing may require electrolysers to frequently ramp up and down, which can result in stack degradation (in the absence of any battery storage, which is expensive). In addition, there may be uncertainty in hydrogen demand requirements, particularly in the early years of the offtake structure. This will require buffer hydrogen storage facilities at the HPF and offtaker site, as well as electrolysers that can cope with variable use, hence the general preference in the UK for PEM over traditional alkaline electrolysers (we note that in 2023 the Kuqa project in China had safety issues with electrolysers after repeated turndowns).

Findings
Other Risk Issues for HPBM Projects

Power Supply Risk

Electrolytic projects will need a long term dedicated reliable source of renewable power such that the produced hydrogen meets the LCHS criteria. We note that the HPBM subsidy is not indexed to power price (as it is indexed to gas price) so it would be preferable for projects to obtain a long-term power purchase agreement (PPA) of LCHS-compliant power at a fixed price. Some HPF projects rely on the adjacent construction of a new wind farm or solar farm, which are separately financed; while laudable and encouraged by DESNZ this is not welcomed by PF lenders, who see project-on-project risk as a problem. However, one advantage of using an adjacent wind or solar farm as power supplier is the ability to use a private wire supply and avoid grid connection costs and delays.

We note that for blue (CCS-enabled) projects the HPBM scheme provides a built-in price hedging mechanism: the supply is natural gas and price of the hydrogen produced is linked to the market price of gas, so any fluctuations in the cost of feedstock are automatically hedged.

Supply risk may be higher for biomass-based projects: adequate and timely delivery of waste biomass of the requisite quality may be manageable, but it may not be possible to fix a long term price.

Delivery Risk

Currently hydrogen is delivered to external customers by road in tube trailers. Hydrogen for tubes has to be compressed to high pressures, typically to between 230 and 350 bar with 500 bar trailers in development; some companies are also looking to transport H_2 as a liquid. Such transportation by road is common for other gases (such as compressed or liquefied natural gas), so safety and reliability risks can be properly mitigated. For large volumes a pipeline would usually be more reliable and cheaper but there are no hydrogen pipelines yet operating in the UK. For HPFs co-located with an anchor customer only a very short pipeline is required.

Political Risk

The HPBM is new and untested but we did not hear any survey participants question the long term commitment of the UK Government to make the scheme work. The CfD model and the related subsidy schemes that kick-started the offshore wind industry were cited as examples of good governance. As such, the political risk for HPBM is regarded as small.

Subsidy Termination Risk

Default by project operators can result in termination of the HPBM subsidy, for which lenders will need some form of cure period, recourse such as step-in rights and agreement from DESNZ to reapply for subsidies. However, the termination clauses in the LCHA are similar to those used in the offshore wind CfD projects, for which lenders became comfortable. We believe that this risk can be overcome through minor amendments to the HPBM that may be suggested by banks' legal advisers.

Emissions Intensity Risk

This is a key subset of Subsidy Termination Risk: in order for projects to retain HPBM support, operators need to ensure that the produced hydrogen always meets the Low Carbon Hydrogen Standard (LCHS). Specifically, this requires that the final GHG emission intensity be less than 20 grammes of CO_2 equivalent per megajoule of hydrogen product (20g CO_2e/MJ on LHV basis). Lenders will require technical reports to ensure that this is always the case. In addition, lenders would need to check that the HPF satisfies all the other compliance requirements, such as a suitable source of feedstock for a biomass HPF, and that the offtaker is not using the hydrogen for non-qualifying purposes such as export, retail sales, trading or gas pipeline blending. We note that there will be significant costs associated with the administration of the HPBM scheme, such as compliance monitoring in regard to meeting LCHS requirements.

Findings
Overall Bankability Assessment

Credit Committees at banks take a holistic view on whether a project can service its debt

As noted before, the major banks and infrastructure funds are wanting to provide debt to well-structured hydrogen projects. Each project in this sector has a unique set of risks that need to be assessed but a risk scoring matrix can only go so far. A bank's credit committee will look at a wide range of factors when considering whether to provide project finance debt – the historic and potential relationship with sponsors is important but most critical is the perceived ability for the project stakeholders to sort out problems that may impact debt service.

Banks will need certain structuring enhancements

In any PF deal the potential lenders will obtain independent assessments of key risks associated with the project, including relating to technical and operating aspects, market volume and price, environmental concerns, supply and construction issues, tax and legal risks. A financial model is then developed to identify the ability of the project to service the debt under a range of scenarios. And a security package is designed through which lenders would have contingent ownership rights on the project assets if debt service is not met.

As noted before, project finance lenders want structures that reduce the downside risk rather than just charge higher interest rates for taking higher risk. Interest rates are defined as a fixed margin above the relevant risk free reference rate (nowadays SONIA for pound sterling loans, currently at approximately 5% pa). The margin for 'senior' debt in higher risk energy projects often ranges from 2% to 3%, so current project interest rates may be as high as 8% per year. Interest rates for mezzanine ('junior') project loans would be higher than this because lenders are then taking on more equity-type risk. For bankable early stage HPF projects we would also expect the following structures, some of which are illustrated in the earlier Figure 5:

- A gearing ratio of 50/50 debt/equity, with the more typical 70/30 ratio only available for projects with substantial support from large sponsors;
- A 9 to 12-month Debt Service Reserve Account (DSRA) rather than the usual 6 months DSRA i.e. project funds are used to fill this account (from the start), sufficient to pay 9 to 12 months of debt service if operations or sales falter, which represents a significant extra cash cost;
- Contingent sponsor and cost overrun facilities for construction risk, which again would require shareholders to deposit cash into reserve accounts or provide creditworthy guarantees;
- A cash sweep to ensure that the DSRA and any other relevant accounts remain full;
- Recourse to the shareholders or O&M provider for certain events for example, operation outside the warranted or insured window for the electrolyser, plus termination events;
- Step-in rights in the event of default by the shareholders, wherein the lenders (or sometimes the insurers) take control of the SPV and HPF, with a view to fixing the problems and then selling it to new owners; and
- Priority rights for lenders in providing additional services such as hedging or capital markets take-out, which may enhance the income to the lenders.

Findings
Forward Look

We need to develop hydrogen project finance deals faster

Finding workable PF solutions for LNG liquefaction plants took a long time in the 1990s. By contrast the development of solutions in the North Sea offshore wind industry was quicker, helped by the development of the CfD model that is now also being used in the HPBM. Financing innovations were assisted by the concentration of expertise in organisations such as EIB and the UK's Green Investment Bank (albeit this institution's role changed after its privatisation).

The challenge is greater and more complex in finding project finance solutions for HPF projects than it was for offshore wind farms. This is in part because there is no liquid market for hydrogen in the UK, whereas there has always been a liquid market for power; and the human resources and supply chains in the hydrogen industry are new and relatively untested. The market needs projects such as NEOM and H2 Green Steel wherein large corporates and funds take risk on projects that push the use of low carbon hydrogen on a large industrial scale and promote the use of PF for hydrogen; and we expect to see more of these projects in the coming year financed on a limited recourse basis, from more Middle East ammonia plants to ATOME's green fertiliser project in Paraguay.

In the UK we expect that most of the HAR1 projects will be initially equity financed, both because of the minimum lending criteria of banks and the lack of experience of PF structures with hydrogen subsidy schemes. It is however possible that some HAR1 projects can obtain pre-construction debt financing and we expect that the larger HAR projects, or a portfolio of smaller projects, could be refinanced in the project finance markets after start-up. Notably, in the survey several PF lenders indicated that they are in active discussions with both HAR 1 and HAR 2 project sponsors. Gearing levels may be not so aggressive initially, probably at the 50% debt level. As lenders become more familiar with construction and operating risk then by 2030 we will see more HPBM projects funded on a project finance basis and at higher gearing levels. Access to this debt will be critical if the UK is to meet its 2030 low carbon hydrogen deployment targets.

The same happened in the UK battery storage sector, wherein 5 years ago these projects were typically small and funded on an equity basis, whereas now some are quite large (£100 million or more) and funded using limited recourse debt. This was in part driven by banks looking hard to develop new financing solutions, and we see the same energy and intent in banks for the hydrogen sector today. There are a number of banks now involved in financing battery storage projects, we give a case study below of Santander's activities in this sector:

Santander - Project Financing of Battery Energy Storage Systems (BESS)

In 2018 Santander became the first bank to lend to a UK BESS project. Prior to this the bank invested considerable time educating client-facing and risk teams concerning the UK BESS sector, developing a lending strategy and internal governance. This was then tested through working closely with one of Santander's strategic clients to structure a deliverable debt solution for its pilot transaction in this new asset class.

Initial transactions from 2018 saw Santander as a lone provider of PF facilities for BESS and hence these were provided on a bilateral basis. This was partly a function of its appetite to support mid-market (i.e. below £30 million) debt transactions. Santander has now provided more than £500 million in the BESS sector across 20 transactions, ranging from 20 MWel/20 MWh to 300 MWel/600 MWh.

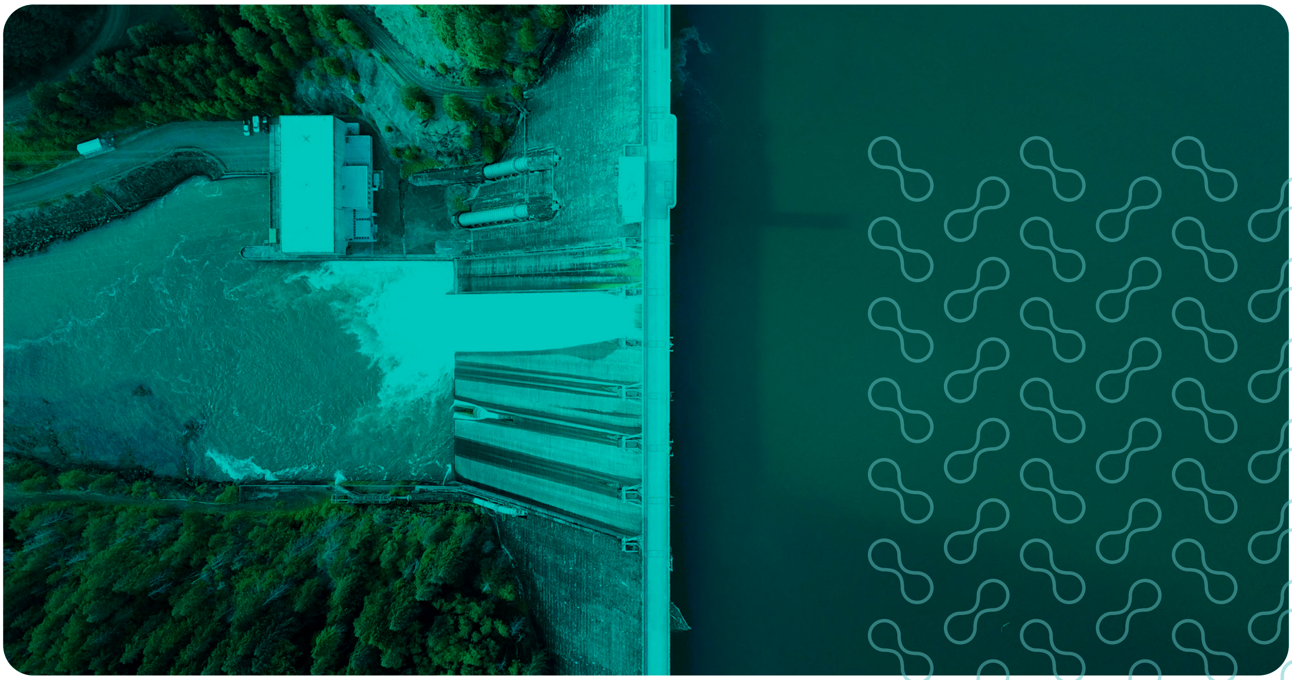
We suggest that a Hydrogen Debt Fund could help expedite a hydrogen industry in the UK

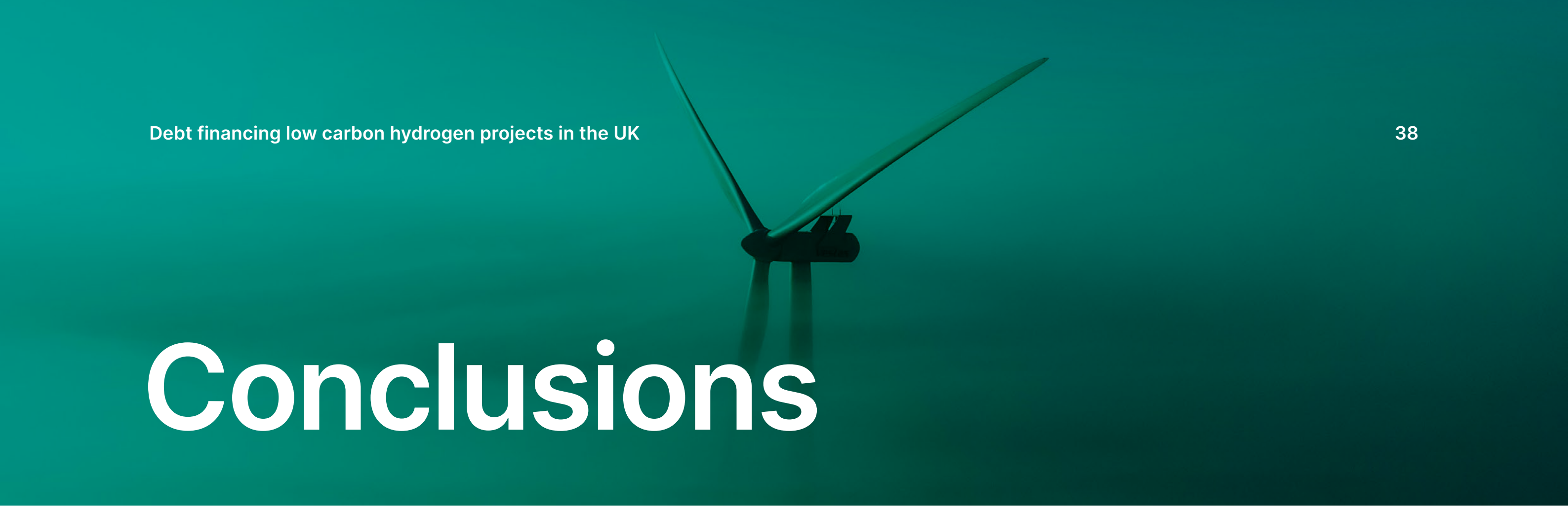
As noted earlier, most PF banks have a minimum lending limit of £25 million or more (substantially more for infrastructure funds), so in general project costs will have to be in excess of £40 million to attract PF debt. But it is the 5 MW to 20 MW projects, costing less than £40 million, that should be built first and fastest and that will create a liquid market for smaller hydrogen demands, from hydrogen buses to lime kilns . So how do we speed up these projects?

There are currently private and publicly listed infrastructure funds that invest equity in hydrogen projects, but there are not yet such debt funds. We propose that one solution could be the establishment of a Hydrogen Debt Fund able to provide loans in the £7 million to £25 million range. Such a fund would have a concentration of hydrogen expertise, assessing and pricing the various risks using engineering assurance as described in the Findings- Technology Risk Mitigation section. The fund would be operated on a commercial (i.e. for-profit) basis: because the fund team would focus on the hydrogen sector as a centre of expertise, the 'learning', due diligence and structuring costs would be much lower than for a typical commercial PF bank. Ultimately there would be a large number of loans across a wide range of hydrogen applications, so diversifying the risk. We would see such a fund also as instrumental in developing assurance standards in conjunction with classification societies and helping to guide future HAR and hydrogen business model guidelines. Once established and successful, we could imagine such a fund also lending into other First Of A Kind sectors such as Sustainable Aviation Fuel, where there are a number of 'small' (less than £50 million) production plants being considered.

We would expect such a Hydrogen Debt Fund to be financed primarily by the private sector. There may need to be capital seeding by a Government entity such as UKIB or DESNZ (for example through the GIGA fund described earlier), who may take first loss risk in such a fund in order to kick-start it. An example starting-point might be £50 million of Government money alongside £250 million of institutional funding; we note that a debt fund should be able to recycle its cash into new projects faster than an equity fund. More discussion is required with infrastructure funds and other stakeholders in the PF and hydrogen communities to assess how such an idea might work and who would be interested in participating.

We note that Chile is now launching a debt fund with a similar but wider intent: the Corfo Green Hydrogen Programme (also called the PFCH$_2$V) is a US$1 billion fund backed by the World Bank and other development banks to help hydrogen projects in Chile reach financial close. We would suggest that a UK Hydrogen Debt Fund have a narrower remit and be primarily private sector driven, though with input from UKIB, UKRI/HII or DESNZ. A number of participants in our survey supported this idea.





Conclusions

Hydrogen Production Business Model-supported projects are financeable, but bankability will depend on the construction and offtake arrangements

Based on the survey feedback, projects that win subsidies under the HAR schemes should be financeable i.e. the pricing subsidy and due diligence process has de-risked them to the point where equity investors should be able to fund. Whether they are bankable – wherein significant risks are transferred to lenders as project debt – depends on the specifics of each project, but particularly on the strength and length of commitments made under the offtake plus the guarantees in relation to construction and start-up. The lenders interviewed indicated to us that most of the other risks, such as for operations, can be mitigated through structuring solutions (including insurance and/or assurance processes) but there will always be some limited recourse to shareholders or other stakeholders, including the need for standby facilities and operational commitments.

Most early Hydrogen Production Business Model-supported projects will be initially equity financed rather than debt financed

Structuring debt for the first hydrogen projects up to 15 MW will be challenging because of the minimum ticket size for many lenders, the challenges in mitigating risks for a new class of project and the costs and time in structuring a debt solution. Over the past few years a number of hydrogen projects in EU and Middle East have attempted a debt structure but eventually used a shareholder-funded solution in order to save time and cash costs. However, we expect that a few of the HAR1 projects could be bankable with more so for HAR2 once the HPBM model has been tested and banks become more familiar with it. By 2030 we expect to see a number of operating HAR projects being refinanced using project finance debt, potentially even using capital markets debt.

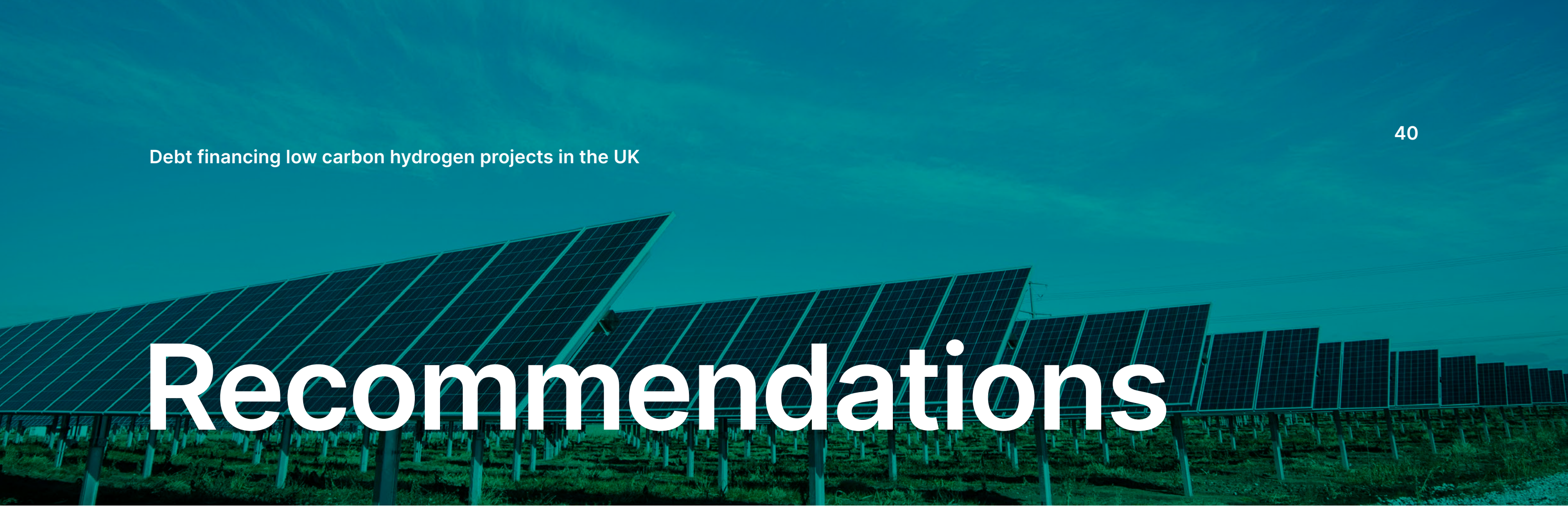
The range of debt sources is limited for SME-led projects

The core sources of project finance debt are usually the large global commercial banks who have project finance teams, with infrastructure funds and the capital markets (bonds) providing debt in mature energy markets. Export credit agencies are also important sources of debt funding for large-scale international financings, as recently happened in the NEOM and H2 Green Steel projects. However, the minimum loan size for most PF lenders, including UKIB, is £25 million, although with a few UK-focused PF banks able to go lower (maybe £10-15 million) for one-off deals, and even lower for Scottish National Investment Bank. In practice this means that most projects below £40 million in size will find it difficult to secure project finance debt.

One fast-growing source of debt for SMEs is venture debt, wherein amounts of up to £15 million for 5 years are possible for companies with some revenues and IP. This or other asset-backed debt could be used to shareholder finance the construction period with take-out via the project finance markets once the project is operating. However, the better route for SMEs in the early stages of the hydrogen industry, particularly for new technologies, would likely be to partner with large funds or corporates who could provide significant shareholder funding.

Technology Risk Insurance is available but the markets are not sufficiently aware

The HAR schemes have a minimum TRL of 7 for the hydrogen production facility i.e. there must be a demonstration pilot system with a prototype at or near operation – through which DESNZ is encouraging commercialisation of new biomass-based or electrolytic production technologies. However, banks rarely take risk on any technologies with a TRL below 9 and the energy transition requires us to push these boundaries, using engineering assurance as a first step to understand the risks. Fortunately, insurance companies such as Ariel Re, AXA XL and Munich Re have started providing significant technology risk insurance to energy projects although not yet implemented in the UK – and a key outcome of this survey is to be able to better inform the UK market of these products. Such cover is not cheap but some of the First Of A Kind gasification projects in the USA would not have been built if it were not for technology risk insurance.



Recommendations

Build liquidity through networks of small projects

- The key to a successful hydrogen industry in the UK is the development of a liquid market for low carbon hydrogen. This means not just large 'blue' hydrogen projects that meet GW targets by decarbonising refineries but also a large number of smaller production facilities that help create local markets, especially in the absence of a national pipeline network. Debt financing can help expedite this market, but DESNZ will have to be responsive to the views of bank credit committees assessing the bankability of the early HAR projects; and then amend the HPBM accordingly. For example, it is recommended that DESNZ looks at allowing blending into gas pipelines (or future long duration storage) as a last resort if the dedicated offtaker defaults; such offtake volume risk may be acceptable to equity investors in the knowledge that a liquid and lower cost hydrogen market will develop in time, but it is a more difficult risk for lenders to take. Expediting the DESNZ Hydrogen Transport and Storage business models would also help speed up the development of pipeline networks and hence finding alternative offtakers in the case of default.

Encourage offtakers to make bigger commitments

- We would like to see more commitments by large UK corporates as offtakers for HAR projects. The level of commitment by offtakers is critical for attracting both equity and debt into the production facilities and ensuring a strong value chain. Rather than regarding switching to hydrogen as a trial it should be seen as a long term take-or-pay investment, out of the normal capex cycle, with the offtaker even taking a minority equity stake in the production company (as is common in other fuels markets). To facilitate this, it is recommended that further work is done to evaluate the extent to which offtakers are sufficiently incentivised (e.g. through carbon prices) to commit to invest in a switch to low carbon hydrogen, particularly in the hard-to-abate sectors.

Co-locate electrolysers with anchor offtakers

- Developers need to weigh up the advantages of co-location with an anchor offtaker versus co-location with solar or wind farms. In our view, electrolytic projects would be more bankable if the power supply were from a project partner via a long-term sleeved PPA supplying LCHS-compliant power at a fixed and competitive price. Co-location at the anchor offtaker site would reduce transportation risks and costs for the core volumes but still allow an add-on sales activity for trucked volumes, and maybe facilitate access to utility services.

Ensure projects are structured using project finance principles

- Project developers need to factor in the costs of debt funding when negotiating a strike price with DESNZ. The cash costs associated with limited recourse debt are higher than using shareholder-guaranteed debt. Interest during construction, arranging fees and filling debt service reserve accounts can add 10-15% of capex to the total cash needs; EPC guarantees and capex contingencies can also add 10-15%; and technology risk insurance can add at least 10%. Project finance lenders will demand more cash support mechanisms for First Of A Kind technologies (like low carbon hydrogen) than for more established technologies such as wind or solar PV. Project developers should ensure that they understand the extra costs and avoid funding delays by hiring project finance expertise.

Use engineering assurance and insurance solutions for new technologies

- Developers need to ensure that adequate engineering assurance has been carried out on the chosen hydrogen production method that will meet the needs of potential investors or lenders. We note that most of the electrolyser projects that are currently being debt funded globally are in continuous production mode (e.g. making steel or ammonia) but in the UK the variability in power price and supply will require frequent up-down ramping, which can lead to more rapid stack degradation. For newer technologies and manufacturers unable to provide credit-worthy warranties there will be a need at an early stage to approach technology risk insurers. There needs to be more awareness of the existing insurance solutions and more innovation in this sector.

Create a Hydrogen Debt Fund to help finance small projects

- Further discussion is required in the finance and hydrogen communities as to the value of a Hydrogen Debt Fund to provide project finance loans in the £7 million to £25 million range. This will probably need to be seeded with capital from a government agency such as UKIB or DESNZ but we would expect most of the capital to be sourced from private markets. Such a debt fund would finance projects that the banks regard as too small, particularly those led by SMEs, and also act as a centre of expertise for the hydrogen industry; and its remit could eventually extend to other First Of A Kind challenges such as Sustainable Aviation Fuel.

Glossary

CCUS	Carbon Capture, Utilisation and Storage
CfD	Contract for Difference
DESNZ	UK Department for Energy Security and Net Zero
DSRA	Debt Service Reserve Account
EPC	Engineering, Procurement and Construction
ESC	Energy Systems Catapult
ETS	Emissions Trading System
FID	Final Investment Decision
FOAK	First Of A Kind (in reference to technology applications)
GHG	Greenhouse Gas
HAR	Hydrogen Allocation Round
HII	Hydrogen Innovation Initiative
HHV	Higher Heating Value
HPBM	Hydrogen Production Business Model, as developed by DESNZ
HPF	Hydrogen Production Facility
IP	Intellectual Property
LCCC	Low Carbon Contracts Company
LCHA	Low Carbon Hydrogen Agreement
LCHS	Low Carbon Hydrogen Standard. The UK LCHS requires a maximum carbon intensity of 20 grams of CO_2 equivalent per megajoule of hydrogen product using Lower Heating Values (20g CO_2e/MJ LHV).
LHV	Lower Heating Value
LNG	Liquefied Natural Gas
LSTK	Lump Sum Turn Key
MW	Megawatt of hydrogen (using HHV); 1 MW is equivalent to approximately 25.4 kg/h production of hydrogen
MW_{el}	Megawatt of electricity
O&M	Operations and Maintenance
PF	Project Finance
PPA	Power Purchase Agreement
RTFO	Renewable Transport Fuel Obligation
SME	Small and Medium-Sized Enterprises
SPV	Special Purpose Vehicle
TRL	Technology Readiness Level
VfM	Value for Money

List of Contributors

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