HYDROGEN BEYOND THE HYPE:

Due diligence questions for hydrogen sector investment

ACTIONABLE INSIGHTS FOR A DECARBONIZING WORLD

Environmental Defense Fund | BUSINESS

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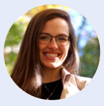
FOREWORD

Hydrogen is emerging as a critical solution to decarbonize the economy. As a carbon-free fuel, it presents an opportunity to decarbonize hard-to-abate sectors where direct electrification may prove difficult.

That said, investors must remain clear-eyed about effective deployment of the molecule for three key reasons. First, producing and transporting hydrogen requires enormous amounts of energy – and, thus, potential embodied emissions. Second, hydrogen is an indirect greenhouse gas, which, when leaked, increases the concentration of potent short-lived greenhouse gases in the atmosphere. Finally, effective management of these two risks is critical to best allocate capital to the most efficient, cost-effective, and practical decarbonization pathways, taking into account stakeholder preference, policy, and price.

At Nuveen, our climate-specific investment strategies aim to direct our clients' assets towards effective, efficient decarbonization solutions that support long-term value creation*. Hydrogen can be one of these solutions – when produced and utilized effectively. As responsible investors, we're keeping hydrogen's associated risks top of mind when monitoring and engaging portfolio companies.

EDF has long played a unique role at the intersection of science and policy which, along with their history of working collaboratively with investors, enables unique insights in the emerging hydrogen economy. We welcome their expert guidance on important questions and principles for investors to consider as we analyze the potential role for hydrogen in delivering decarbonization and financial returns.



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INTRODUCTION

Over the past several years, hydrogen has surged on a wave of attention and financial commitments for its potential to help decarbonize the global economy. And while electrification technologies have emerged as the leading solution for a range of applications like road transport and home heating, most analyses find that about 20-30% of global CO_2 emissions cannot be reduced from direct electrification alone. This is where hydrogen comes in. Managed with care from production through final end use to ensure very low emissions, hydrogen holds promise to reduce the climate impacts of hard-to-abate sectors where alternatives remain limited.

However, hydrogen is a tool, not a silver bullet. Investment in the emerging hydrogen market presents both substantial opportunities and risks associated with being an early mover in a sector where scientific, engineering, and regulatory considerations continue to evolve. In most cases, the financial opportunities associated with hydrogen stem from its potential to contribute climate benefits, making it particularly important that investors and operators of hydrogen projects consider anticipated climate impacts alongside other business considerations. A poor outcome for investors and the climate would be several years and billions of dollars invested in particular hydrogen production pathways and end uses, only to see the industry move in other directions. By avoiding poor capital allocation that could result in minimal decarbonization or even increased emissions, investors can reduce their risk of unattractive returns.

"In most cases, the financial opportunities associated with hydrogen stem from its potential to contribute climate benefits, making it particularly important that investors and operators of hydrogen projects consider anticipated climate impacts alongside other business considerations."

There are important considerations throughout the hydrogen value chain that impact its climate and environmental impacts, with implications for investment risk. For example, 99% of the hydrogen produced today is made from fossil fuels with high associated emissions. Investments focused on decarbonizing existing production are generally considered to be well positioned to provide long-term climate benefits that drive value. Similarly, financing hydrogen infrastructure that is built to avoid emissions from the start may have lower climate and business risk than investment in infrastructure with weak emissions management. Investing in hydrogen end uses where the molecule offers unique value is likely a more durable approach than financing projects where other technologies have stronger efficiency or engineering drivers. Thus, understanding the likely climate impacts of a proposed project is important to assessing potential risk and reward.

One important and under-recognized consideration in evaluating hydrogen technologies is the molecule's role as an indirect greenhouse gas. When emitted in the atmosphere, hydrogen reacts with other molecules in a way that increases the concentrations of greenhouse gases such as methane and ozone. The latest science suggests that pound for pound, hydrogen emissions are 30-40 times more powerful at trapping heat over the first 20 years after release than carbon dioxide. For this reason – and because hydrogen is a small, slippery molecule that is notoriously difficult to contain – it is especially important to design hydrogen management and transport systems from the start to avoid both leaks and routine operational emissions. Here, lessons learned from the oil and gas industry, which in many cases has had to retrofit methane management systems in order to "keep the product in the pipe," can help developers build hydrogen infrastructure right from the start.

To help navigate this complex and fast-changing sector, EDF presents guiding principles and key questions for consideration by investors. This resource can help determine alignment between the climate case and the business case for hydrogen. Science-backed investment strategies targeting the appropriate production methods, management practices, and end uses for low-emissions hydrogen will be best suited to unlock the molecule's potential to decarbonize key sectors and generate durable returns.

GUIDING PRINCIPLES

We have an opportunity to get hydrogen right – before new systems are built at scale globally. The new hydrogen economy is still in its infancy. Now is the time to establish the practices needed to maximize hydrogen's benefits for the climate, ecosystems, and human society, while minimizing its risks.

Hydrogen should be used where it can reduce the most climate warming at the lowest possible risk and cost. On a macro level, deployment of hydrogen should be evaluated against non-hydrogen alternatives (e.g., electrification, efficiency, new technologies, etc.) to guide limited resources to applications where hydrogen provides the greatest benefits.

Hydrogen systems should be evaluated based on a full system-level assessment. Assessments should consider all climate-warming gases (i.e., methane, carbon dioxide, and hydrogen itself); multiple climate-relevant timescales (e.g. both GWP 20 and GWP 100) to account for the more potent warming impacts of the shorter-lived gases; and evolving scientific understanding and engineering considerations. Assessment should also include hydrogen's other risks and benefits, including those related to local air quality and ecosystem impacts, energy losses through national and international trade, and other relevant factors.

Hydrogen systems should be designed to minimize emissions. Operational releases and leakage of all climate-warming gases throughout the hydrogen value chain – including methane used in hydrogen production, produced hydrogen, and fuels and other molecules derived from hydrogen (e.g. ammonia) – must be minimized to avoid wasting product and compromising the intended climate benefits. Emissions performance needs to be monitored, reported, and verified.

Image: Technologies for hydrogen leak sensing have advanced rapidly in recent years

INVESTOR DUE DILIGENCE QUESTIONS

As scientific, engineering and policy considerations around hydrogen evolve, the questions below can be used to help evaluate hydrogen-related investments.

Hydrogen management and transport

1. **Is the project designed to monitor and prevent even small hydrogen losses across the value chain?** Hydrogen is an indirect greenhouse gas, and hydrogen leakage poses climate risks at volumes smaller than the leaks that have historically been monitored for safety purposes. Effective monitoring technologies and mitigation techniques for climate-relevant emissions are coming to market, and emissions prevention and monitoring should be integrated from the start of project design.

2. **Is there a comparative advantage for international trade in low-emissions hydrogen, considering the loss of energy and efficiency when hydrogen or its carriers are transported long distances?** Infrastructure to support international hydrogen trade is attracting significant investment. Large production facilities are being developed in some regions, and target import markets identified in others. Investors should assess if projects will contribute to decarbonization when considering energy losses involved in compressing or liquefying hydrogen, or converting or attaching it to and from a more transportable carrier molecule (e.g. ammonia) for long-distance transport by pipeline, truck or ship.

Hydrogen production

1. **Green hydrogen: Will hydrogen for the project be made using renewable energy that was not diverted from another end use?** The electricity needed to produce green hydrogen should be sourced from new or unutilized carbon-free sources of power to ensure that it doesn't detract from the availability of carbon-free electricity that would otherwise have been used more efficiently elsewhere, e.g. to power homes and cars. Regulations in Europe require, and proposed rules in the US would also require, that electricity be delivered within the same region and matched hourly with the hydrogen plant's power consumption, otherwise the grid could respond to constraints by ramping up fossil fuel generation, increasing system-wide emissions.

2. **Green hydrogen: Have the water demands of renewable hydrogen production been considered in the context of local water resource availability?** Renewable hydrogen production requires significant water use, so project impacts on local freshwater supplies and related community impacts have implications for social license, regulation, and project execution.

3. **Blue hydrogen: How have emissions from the production of natural gas feedstock been accounted for in the hydrogen lifecycle assessment?** Best practices for natural gas production and transport include measurement and verification of upstream emissions through the OGMP 2.0 framework or equivalent, and keeping overall methane emissions intensity at a near-zero level, such as the Oil and Gas Climate Initiative target of no more than 0.2% of production.

4. **Blue hydrogen: What is the proposed carbon capture efficiency, and what plans are in place for permanent and safe storage of the full volume of captured CO_2?** Carbon capture systems at steam methane reforming facilities can be designed and operated to reduce emissions by 95%, but many existing facilities currently remove just 30-60% of emissions, dramatically reducing the climate benefits of blue hydrogen pathways. Project plans should address the availability of adequate permanent CO_2 storage space and CO_2 pipelines to access it and should monitor actual volumes captured, rather than reporting nameplate capacity. Additionally, carbon capture and storage plans should address the potential for hydrogen leakage, groundwater contamination, earthquakes, and the potential to exacerbate or extend the lifetime of local pollution hotspots.

Major existing hydrogen end uses

1. **For large and well-established use cases like oil refining and fertilizer production, how does the project overcome the cost to switch from existing hydrogen sources to low-carbon alternatives?** About 100 million metric tons of hydrogen are produced globally each year, 99% of which is gray hydrogen made from coal or natural gas without any emissions abatement, mostly for use in oil refining and fertilizer production. Transitioning these sectors to use low-emissions hydrogen offers significant climate benefits. Meeting this existing hydrogen demand can also be an important entry point for low-emissions hydrogen and an opportunity to quickly scale its production. Investable projects will need to overcome barriers associated with adopting new infrastructure and retrofitting facilities to disrupt existing supply sources. In general, retrofitting an existing, highly polluting facility presents a stronger climate case than building new blue hydrogen production capacity.

Emerging hydrogen end uses

1. **All applications: Is the use case for the proposed hydrogen project better addressed – in terms of achieving emission reduction goals – with electrification, efficiency or other solution?** In many cases, such as for powering homes, businesses, and cars, electrification is generally cheaper and more energy efficient, yielding greater total climate benefits, than using hydrogen -- making it a likely long-term solution.

2. **All applications: How has the project considered/incorporated advanced market commitments and policy drivers?** Confidence in offtake is critical to realizing a robust hydrogen economy, and a range of advanced market commitment and policy measures address hydrogen applications. Still, as of December 2023 only 7% of announced hydrogen projects had passed final investment decision. The First Movers Coalition, organized by the World Economic Forum and the US Special Presidential Envoy for Climate, leverages the power of purchasing agreements to commercialize emerging climate technologies including those powered by hydrogen, providing financial stability to producers and decarbonization solutions to consumers. Other market drivers include the European Hydrogen Bank, a financing instrument that supports renewable hydrogen production within the EU and

internationally and which is investing €1.9 billion to boost the renewable hydrogen economy, and the upcoming 45V tax credits in the United States that are designed to reduce production costs and provide demand side incentives.

3. **Steel and other heavy industry: How does the project overcome current cost premiums?** Industrial processes requiring low or medium temperatures can often be efficiently decarbonized through electrification, but hydrogen can be an appropriate fuel choice for high-temperature heating processes, like those in steelmaking. Shifting from coal use to hydrogen offers significant climate benefits for steel, but also poses potential additional costs. Investors should interrogate how economies of scale may improve cost parity with traditional methods, whether guaranteed offtake agreements have a role to play, and whether these projects may benefit from policy or regulatory tailwinds, such as industrial performance standards in the EU, the Carbon Border Adjustment Mechanisms being considered in the EU, Australia, and the US, or "Buy Clean" programs that support federal procurement of lower-carbon materials.

4. **Shipping: How does the project fit into the net-zero framework proposed by the International Maritime Organization (IMO)?** As the global regulator of the shipping industry, the IMO plays a pivotal role in navigating the sector towards decarbonization. Last year, the IMO Revised GHG Strategy established robust emission reduction goals with emission cuts of at least 20% and 70% by 2030 and 2040, respectively, at least a 5% uptake of zero or near-zero greenhouse gas emission fuels by 2030, and ultimately a goal of net-zero emissions by 2050. Given the IMO's ambition, maritime shipping is projected to be a large future market for low-emissions hydrogen through ammonia and other electrofuel production. Achieving the IMO targets will require investments in producing these fuels, building compatible vessels, distribution, and bunkering.

5. **Aviation: How does the project support the production of high-integrity alternative fuels and fit into emerging regulatory expectations?** Sustainable aviation fuels (SAF) include both electro-fuels (also known as power-to-liquids) and biofuels. Lower-carbon hydrogen will play a growing role in producing both. Regardless of the production pathway, not all SAF is created equal: lower quality SAF could lead to greater emissions than fossil jet fuel or cause negative effects on ecosystems and public health. Additionally, the policy landscape is rapidly evolving. The new US tax credit for SAF operates on a sliding scale, with higher credits awarded to fuels that demonstrate higher reductions in life-cycle emissions. Emerging blending requirements may also support the SAF industry, such as EU regulations requiring EU-originating flights to use at least 70% SAF by 2050.

6. **Electricity generation and storage: How does the project assess the role of hydrogen versus other forms of clean power generation?** Round trip energy losses of 50-80% in the production and use of electrolytic hydrogen generally make large-scale (e.g. baseload) power applications less desirable. However, hydrogen storage paired with cheap or negatively priced renewable power could play a role as a form of storage to manage long-term (e.g. seasonal) dips. However, the emergence of cheap electricity storage (i.e. long-duration batteries) should factor into investors' view of potential hydrogen use in the power sector. Note that in some markets, combusting ammonia made from hydrogen is being considered – however this practice raises considerable climate and public health concerns. EDF analysis finds that burning ammonia for power generation can increase greenhouse gas emissions over that of coal combustion in multiple scenarios; cofiring ammonia along with fossil fuels can worsen air quality and damage human health as compared to burning fossil fuels alone.

7. **Residential and commercial heating: Does the project compare hydrogen with alternatives to hydrogen for residential and commercial heating?** Options such as electrification via heat pumps, district heating, and distributed renewables are more developed than hydrogen technologies and typically offer greater climate benefits. For example, using hydrogen for home heating requires on average seven times more energy compared to direct electrification with heat pumps. Investors should also interrogate whether the project would require extensive pipeline retrofits, and how it addresses safety risks (e.g. greater combustibility and pipeline embrittlement), and health impacts (e.g. increased nitrogen oxide pollution). An analysis published in 2022 showed that the widespread use of hydrogen for heating buildings is not supported by any of the 32 independent studies reviewed.

Conclusion

The high level of investor interest in hydrogen shows an encouraging focus on decarbonization. As the global push toward decarbonization intensifies, hydrogen technologies show promise for transitioning certain hard-to-abate sectors. But it's imperative to pay close attention to the details of how hydrogen is deployed to obtain climate benefits. Open conversation about the most promising deployment pathways, guided by EDF's key principles and due diligence questions, can support sound financing decisions.

Hydrogen's complexities require careful, science-backed investment strategies to ensure meaningful emissions reductions and support long-term viability and returns. Aligning climate and business objectives can help maximize hydrogen's potential for a climate-safe future that works for business, people and the planet.

To connect with EDF's hydrogen finance team, contact Kristin Lorenzo at klorenzo@edf.org

Additional resources

EDF's Hydrogen home page

Fact sheet: Climate Impacts of Hydrogen Systems

Blog: Hydrogen investments are everywhere. Which have what it takes to succeed?

Blog: Rule #1 of deploying hydrogen: Electrify first