ClearBridge Investments

Hydrogen and Battery Innovation Decarbonizing Heavy Transport

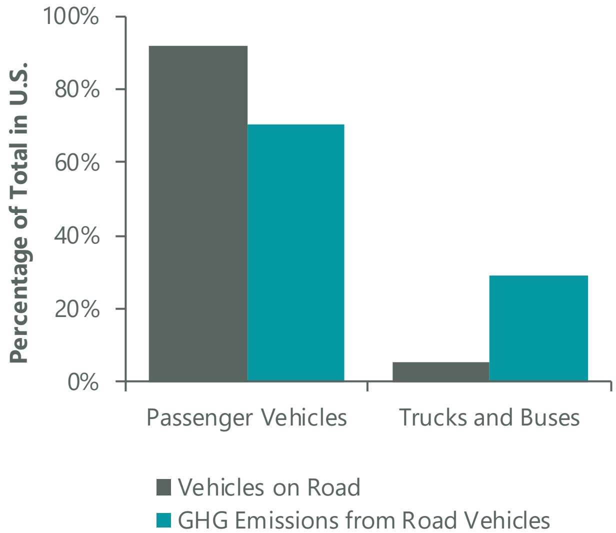
Key Takeaways

- A handful of new technologies such as hydrogen fuel cells and lithium metal batteries have the potential to decarbonize heavy transport and meaningfully lower global emissions.
- Technological advancements are being made toward getting the production costs of green hydrogen down, and governments all over the world are prioritizing hydrogen.
- Lithium metal batteries are in the early stages but could offer significant improvements on lithium-ion batteries and could jumpstart electric vehicle adoption in heavy transport, but further work is needed.

The race is on to decarbonize heavy transport — a major opportunity for lowering global carbon emissions. While much attention is paid to passenger cars as a means of lowering greenhouse gas (GHG) emissions, passenger cars are lower-utilization vehicles compared to heavy transport and account for only 7% of global emissions. For a larger impact, non-fossil fuel penetration is needed into heavy transport: trucks, buses, marine and trains, together with passenger cars, account for 14% of GHG emissions worldwide. As an example, while trucks and buses constitute only 5% of vehicles on the road in the U.S., they represent 29% of emissions owing to lower fuel economy and greater utilization (Exhibit 1).

A handful of new disruptive technologies have the potential to decarbonize heavy transport and are offering opportunities for shareholder to capitalize on. In this paper, we outline the growth and potential for hydrogen fuel cells and lithium metal batteries. The growth of these technologies is a positive for the world and major advancements are being made in both by several players. Likewise, government policy support and the efforts of corporates innovating new technologies are helping drive down the cost curve for both and large addressable markets are being opened. The development of these technologies will have major ramifications for the automotive, logistics and energy markets, among others, in the next decade.

Exhibit 1: Heavy Transport Emissions Reduction Opportunities in the U.S.



As of 2018. Source: Bureau of Transportation Statistics, National Transportation Statistics, Table 1-11; EPA, U.S. Transportation Sector Greenhouse Gas Emissions 1990-2018.

Hydrogen Can Be Green and Has Many Possible Uses

October 8 may not be a notable day on the calendar yet, but 2020 marked the fifth annual Hydrogen and Fuel Cell Day, chosen for the atomic weight of hydrogen (1.008). Hydrogen functions as an energy carrier, which means it can store and deliver energy produced by a primary energy source, such as natural gas, coal, nuclear power, solar, wind or hydro. Using hydrogen to deliver energy releases only water as a by-product, making it an attractive clean fuel.

The traditional way of producing hydrogen is through a steam methane reformer, which uses coal and natural gas to combine carbon monoxide and steam, producing CO2 and hydrogen. This is known as gray hydrogen. This way, however, the only change is where CO2 is produced. Blue hydrogen refers to a similar hydrogen production method in which CO2 is captured and stored rather than released freely. Green hydrogen, by contrast, uses renewable energy sources, such as wind, solar or hydro to liberate hydrogen through electrolysis of water and does not emit any carbon in the production of hydrogen or in its consumption in a fuel cell.

While the vast majority of hydrogen produced today is gray and blue, there are many projects underway classified as low-carbon hydrogen technology, commissioned to produce hydrogen for energy or climate-change related purposes, according to the International Energy Agency (Exhibit 3).

The potential for hydrogen and fuel cells in industrial, transportation and stationary power applications is promising. In industrial use, it could help decarbonize major industries such as steel. In transportation, it could power a variety of trucks, buses, marine, rail and aircraft. Volvo, for example, envisions fuel cell electric vehicles (FCEVs) as ideal for demanding long-haul trucking. Ballard Power Systems and Plug Power appear to be the technology leaders globally on hydrogen fuel cells with a focus on the bus and truck market. Plug Power has already seen success in some use cases, such as forklifts.

Cummins, which makes diesel and alternative fuel engines, believes that trains will be early adapters as they are less reliant on external infrastructure and use a return-to-base system for fueling — a central charging infrastructure would suffice to serve many engines. The company estimates the cost of hydrogen trains to be comparable to that of electrifying train lines today.

For marine use, Bloom Energy is partnering with Samsung Heavy Industries to power ships with fuel cells powered by natural gas. As nations and ports develop their hydrogen infrastructure, ships powered by fuel cells could transition from natural gas fuel to hydrogen fuel and become zero-carbon and zero-smog emitters.

For energy storage, hydrogen can also be used when there is excess wind and solar power on the grid. Backup power applications are also being explored.

With many possible uses for hydrogen, and the incentive to prioritize development of green hydrogen in order to meet ambitious emissions reduction goals, we could see exponential growth in low-carbon hydrogen production in the next decade (Exhibit 4).

Exhibit 2: Emissions Spectrum in Hydrogen Production

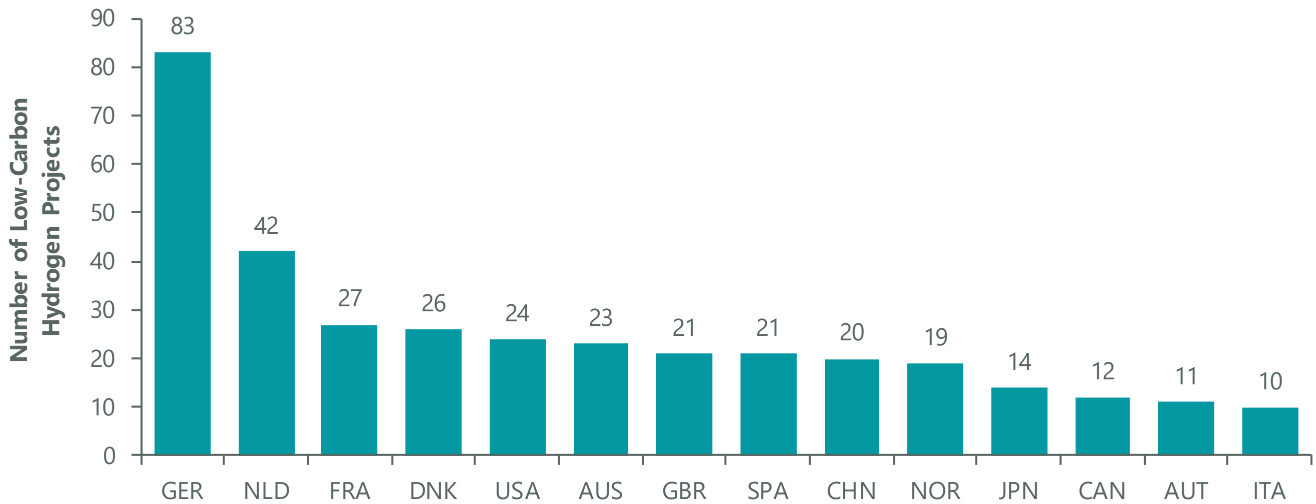
H **Gray Hydrogen:** Made using fossil fuels, which emit CO_2 as they combust

H **Blue Hydrogen:** Made using fossil fuels but with carbon capture technology preventing emission of CO_2

H **Green Hydrogen:** Made using electrolysis power by renewable energy; does not emit CO_2

Source: ClearBridge Investments.

Exhibit 3: Countries with 10+ Low-Carbon Hydrogen Projects Underway



As of June 2020. Source: Hydrogen Projects Database, IEA https://www.iea.org/reports/hydrogen-projects-database

Challenges to a Hydrogen Future

One key issue for hydrogen as a power source is cost. Morgan Stanley estimates that it could take as much as $20 trillion in investments to 2050 to decarbonize a high-teens percentage of global emissions. For hydrogen to gain acceptance as a decarbonization force, the world will likely need to see a path for green hydrogen through water electrolysis. This is currently cost prohibitive at $10–$13/kg of hydrogen on a retail basis, which is several times more expensive than diesel.

Further up the supply chain, green hydrogen currently costs around $6/kg to produce (pre-distribution) compared to ~$1/kg for gray hydrogen. Industrial gas producer Linde has stated costs need to come down to $4/kg for green hydrogen to be competitive, though project-level economics will affect breakeven prices. The Hydrogen Council, a global initiative of energy, transport and industry companies encouraging the development and adoption of hydrogen, believes costs will need to come down to ~$2.50/kg by 2030 to make the economics compelling on a total cost of ownership basis to decarbonize long-haul trucking (Exhibit 5).

Air Products, which makes gases and chemicals for industrial use, is bringing down the cost of green hydrogen with its NEOM project in Saudi Arabia, where it will use renewable power from solar, wind and storage to produce 1.2 million tons of green ammonia (which has a high capacity for hydrogen storage and transport) per year for export globally for the transportation market.

Getting to scale will be important to ultimately getting costs low enough at the pump to be compelling. Technological advancements are being made toward getting the production costs down. Cost of electricity is a key input, but Bloom Energy believes that its solid oxide electrolyzer technology is capable of producing green hydrogen at the cost of $1.90–$3.20/kg by 2025 — significantly earlier than the Hydrogen Council's models — and as low as $1.20–$2.10/kg by 2030. We believe that this is significantly cheaper than the production cost at Air Products' NEOM project, using more established alkaline technology. Bloom is also indicating the potential to make blue hydrogen at the cost of $1.50/kg in 2025 and $1/kg in 2030. Ultimately, getting the full benefit of hydrogen in decarbonization will likely require the use of green hydrogen, but cheaper blue hydrogen can assist in the "transition" and getting to scale.

Private companies at the forefront of hydrogen are collaborating to reduce the costs of green hydrogen. In December 2020 a coalition of seven global companies announced a "Green Hydrogen Catapult" initiative aimed at accelerating the scale of production of green hydrogen. Together, ACWA Power, CWP Renewables, Envision, Iberdrola, Ørsted, Snam and Yara will seek to deploy 25 gigawatts of renewables-based hydrogen, a 50-fold increase, through 2026. The initiative will try to cut the cost of green hydrogen to below $2/kg and aims to align the production and use of green hydrogen with a goal of displacing fossil fuels at a rate consistent with achieving net zero global emissions by 2050.

In terms of distribution, significant infrastructure needs suggest the costs will be high and buildout will take time. Cummins estimates that electrolyzer investment of $350 billion would be required to replace existing hydrogen production capacity globally with green hydrogen and $2.5 trillion to replace diesel in vehicle infrastructure (which comprises heavy trucks, buses and trains).

In addition, governments all over the world are willing to invest, helping create scale that will drive down costs, which is especially important on the distribution side of the cost equation. China and the EU are the markets most likely to jump start adoption of hydrogen, but we are also watching California. The EU's recent European Green Deal, for example, features an EU Hydrogen Strategy, which involves installing at least 6 gigawatts of renewable hydrogen electrolyzers and producing up to one million tons of renewable hydrogen from 2020 to 2024; from 2025 to 2030 this grows to at least 40 gigawatts and 10 million tons, respectively, as hydrogen becomes an intrinsic part of an integrated energy system.

In the U.S., a 2020 report by the House Select Committee on the Climate Crisis — a document that could inform U.S. climate policy in a Biden administration — calls for Congress to invest in energy storage, new-zero emission technologies and fuels for harder-to-decarbonize parts of the transportation sector. This would include boosting funding for federal clean energy research, development and demonstration supporting breakthrough technologies for industrial decarbonization including CCUS (carbon capture utilization and storage) and low-and-zero carbon hydrogen.

Batteries Are Not Standing Still: Lithium Metal Offers Exciting Potential

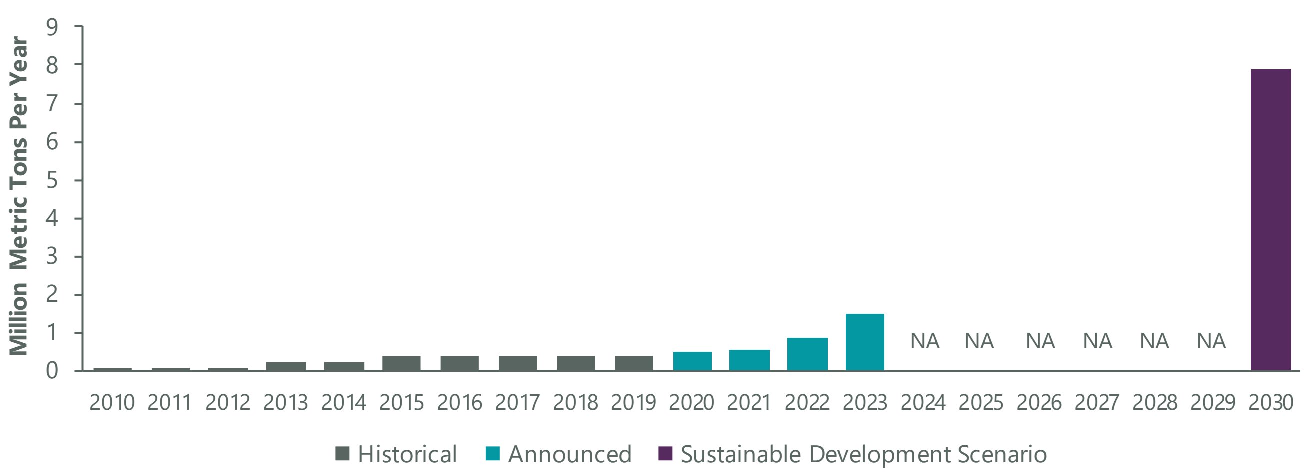
Lithium metal, or solid state, batteries are in the early stages but could offer significant improvements on lithium-ion batteries in terms of range, charging time, lower cost, and smaller size. These benefits could jumpstart electric vehicle adoption in heavy transport.

The main difference between a lithium metal and lithium-ion battery is that the former is not built with an anode, the positively charged electrode by which the electrons leave the cathode to charge. Instead, it uses a solid-state ceramic separator between the cathode and the anode current collector and creates an anode of pure lithium metal. The lithium metal anode, which holds the charge, is smaller than the anode in a lithium-ion battery.

Lithium metal batteries help solve several problems posed by lithium-ion batteries. For one, lithium metal batteries weigh less. This is crucial to long-haul trucking. The smaller size and lighter weight of lithium metal batteries allows heavy transport to haul more cargo relative to lithium-ion-powered trucks; using heavier lithium-ion batteries to deliver longer ranges has the drawback of subtracting cargo capacity, which is a major concern for shipping. Also, eliminating the anode material means lithium metal batteries are less expensive to produce both in terms of materials and manufacturing costs.

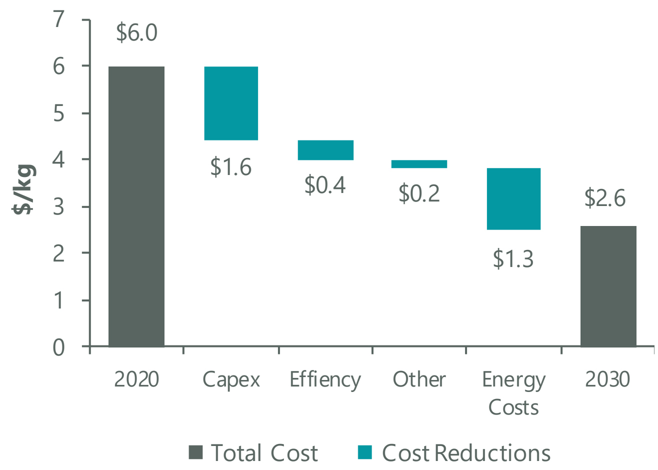
Lithium metal also compares favorably to hydrogen in this regard due to its high energy density. Industry estimates suggest that hauling capacity of a hydrogen truck is 6% or ~3,000 lbs larger than that of a battery truck using current lithium-ion technology. However, assuming a battery weight of ~12,000 lbs in a semi, a ~28% higher energy density of a lithium metal

Exhibit 4: Low-Carbon Hydrogen Production: Historical, Announced and Expected for Sustainable Development Scenario, 2030



As of June 2020. Souce: EIA.

Exhibit 5: Cost Reduction Levers for Green Hydrogen



Numbers rounded. As of Jan. 20, 2020. Source: Hydrogen Council, "Path to hydrogen competitiveness: A cost perspective."

battery versus a lithium-ion battery implies that this weight differential is overcome by switching to a lithium metal battery. Combined with quick charge times (if proven out) and less need for expensive infrastructure, lithium metal technology has the potential to compete with hydrogen.

The high energy density of lithium metal batteries, allowing them to deliver more energy per unit of weight, also increases the range potential in a vehicle application. Recent tests by lithium metal battery developer QuantumScape suggest a total driving range of 240,000 miles based on 800 discharge cycles.

In terms of charging time, QuantumScape's results show faster charging than lithium-ion batteries, going from 0% to 80% in under 15 minutes in automotive applications. However, it is yet to be shown whether such 15-minute charges are feasible over hundreds of cycles as might be required in a real-world application. Tests of 800 cycles were based on one-hour charge/discharge cycles, as opposed to 15-minute cycles, and the market is likely to require confidence in this capability as heavy transport vehicles are in constant use and refueling/recharging time has a large effect on the bottom line.

Lithium metal batteries are generally considered in the R&D phase, with the market not likely to have confidence in this technology until 2022–24. Further testing of fully built batteries is still required, as is a pathway to manufacturing to scale and potentially more work to prove out fast charging. But overall, it is still encouraging to see QuantumScape's results: 800 cycles at one-hour charge/discharge cycles with solid performance across a range of temperatures demonstrates a step forward in battery technology.

QuantumScape is not the only innovator of solid-state batteries. In December 2020 Toyota announced it will unveil a prototype solid-state battery in 2021 that it says can charge from zero to full in 10 minutes and deliver 500 km on one charge. The company hopes to sell an electric vehicle equipped with this battery in the early 2020s. There are other companies innovating on solid-state design as well.

A Multidimensional Strategy for Reducing Emissions

Reducing the effects of climate change remains a primary concern for business as well as governments and non-governmental organizations as we enter the 2020s, and solving the emissions challenge posed by heavy transport such as trucks, rail and marine transport is a crucial component in this mission. The growth in renewable energy from solar, wind and hydro sources, and the falling costs of procuring this energy for use in hydrogen fuel cells has made green hydrogen increasingly attractive and viable as a means of storing and delivering carbon-free power in many applications, among them heavy transport. Hydrogen fuel cells could be part of a multidimensional strategy to lower carbon emissions, and there is strong evidence that strategy could include lithium metal batteries as well.

About the Author

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