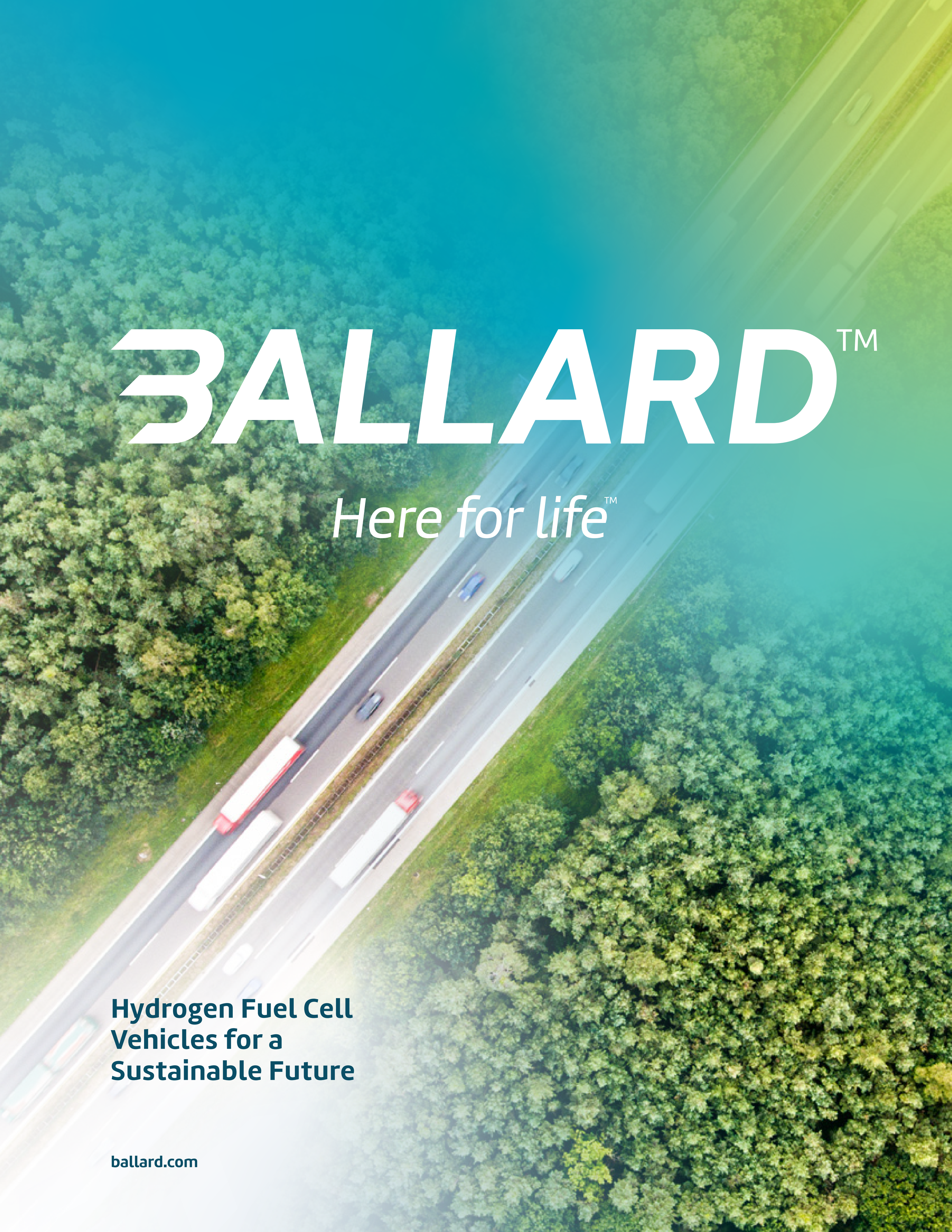


BALLARD™

Here for life™

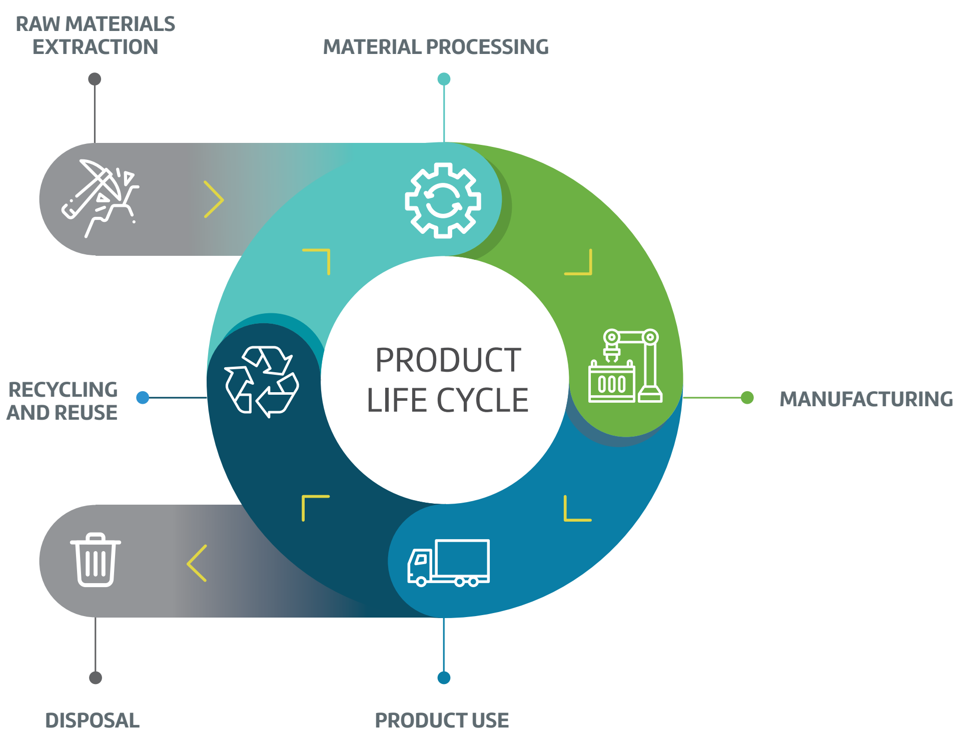
Hydrogen Fuel Cell Vehicles for a Sustainable Future

ballard.com

At Ballard, we deliver fuel cell power for a sustainable planet. Whether you are operating transit buses, trucks, forklifts in a warehouse, regional trains or ferries, Ballard is committed to powering vehicles that help you serve your customers without harming the environment. As we move together towards a zero-emission mobility future, let's ensure sustainability across the entire lifecycle of the products we create and use. Our future generations will thank us.

Sustainability of zero-emission powertrains

To achieve greenhouse gas reduction targets, the transportation sector must drastically cut emissions caused by the use of fossil fuels. The electrification of transportation is the future, with both battery and hydrogen fuel cell powered electric vehicles generating zero-emissions at the tailpipe. But the question remains – what is the carbon footprint of alternative powertrain options over the complete product lifecycle?



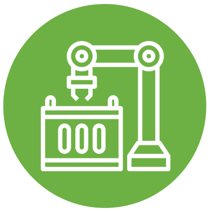
There are four stages of the product lifecycle to consider:

Raw Materials

With the growth in demand for electric vehicles, there is increased focus on the source of raw materials. Traceability and transparency of raw material supply chains are key, as is the focus on the reduction in the volume of critical raw materials needed.

The most important raw materials for batteries used in battery electric vehicles are lithium and cobalt. Today, a battery electric passenger vehicle contains approximately 5 kilograms of each.[1] There are significant environmental and societal concerns related to the production of lithium and cobalt for electric vehicle batteries.

The amount platinum catalyst used in a fuel cell electric vehicle is just 10 to 20 grams.[2] There has already been a 70% percent reduction in platinum used in fuel cell vehicles and that is expected to be reduced further.[3] In comparison, the supply chain for platinum catalyst used in PEM fuel cells is well established, as it is a material used in the catalytic converters of diesel vehicles today. The recovery process for this precious metal is in place, with approximately 95% of the platinum reclaimed at the end of life of a fuel cell.



Manufacturing

Sustainable manufacturing is the creation of manufactured products through economically-sound processes that minimize negative environmental impacts while conserving energy and natural resources.[4] Sustainable manufacturing also enhances employee, community and product safety.

For the past several years Ballard has been actively pursuing sustainability efforts that reduce our carbon footprint in product development, testing and manufacturing facilities co-located with our corporate headquarters. Our sustainability activities have, to this point, been primarily in two areas – energy management and recycling. An audit of Ballard's carbon footprint completed in 2019 will allow us to measure important progress going forward.

[1] Dongxiao Wu, et al. "Intelligent Hydrogen Fuel Cell Range Extender for Battery Electric Vehicles." World Electric Vehicle Journal, May 2019. https://www.mdpi.com/2032-6653/10/2/29
[2] Deloitte China.
[3] https://uk.reuters.com/article/uk-platinum-fuelcells/platinums-days-as-fuel-cell-car-component-may-be-numbered-idUKKBN1GZ2KO
[4] www.epa.gov/sustainability/sustainable-manufacturing

Product Use

For both battery electric and fuel cell electric vehicles, which are zero-emissions at the tailpipe, the well-to-wheel aspect of lifecycle emissions accounts for 56-64%.[5] So reducing the amount of CO_2 emissions due to fuel use is the area with the largest GHG mitigation potential.

For battery electric vehicles, electricity comes from the power grid. Grid electricity generated by burning coal or natural gas is a significant contributor to greenhouse gas emissions.

Hydrogen, the fuel source for fuel cell electric vehicles, can be generated sustainably using electrolyzers. Centralized hydrogen production from renewable electricity is one of the paths to source cost-effective green hydrogen at scale, and accelerate the decarbonization of transportation.

Disposal

Once the product has reached the end of its useful life, consideration must be taken on how to dispose of the product.

Whereas lithium batteries are said to be 95% recyclable, the practice of recycling them is not well developed at this time and most end up in landfills.[6]

In comparison, Ballard's expertise in refurbishing, reusing, and reclaiming fuel cell components means our solution is both zero-emission and low waste. Ballard's ability to reclaim 95% of the fuel cell stack means far fewer waste products end up in landfills. Every year we recycle and refurbish thousands of fuel cell stacks.

[5] IEA (2019), "Global EV Outlook 2019", IEA, Paris, www.iea.org/publications/reports/globalevoutlook2019/.
[6] www.engineering.com/ElectronicsDesign/ElectronicsDesignArticles/ArticleID/17435/Will-Your-Electric-Car-Save-the-World-or-Wreck-It.aspx

At Ballard

Ballard has adopted a 3R framework to ensure sustainability is considered over the entire lifecycle of our products.

REUSE
REDUCE
RECYCLE

Ballard's proton exchange membrane fuel cells are:

- Made from ethically sourced materials
- Made without any hazardous, banned or toxic substances
- Manufactured in a sustainable manner, including factors such as energy efficiency and ethical labor
- Packaged using environmentally friendly packaging materials and as minimally as possible
- Made to have a long lifetime – our fuel cell stacks have demonstrated over 30,000hrs of operation in operation
- Refurbished and recycled at the end of life – to recover highly valuable precious metals and minimize waste entering the landfill

Fuel cell stack refurbishment

Ballard offers its customers a refurbishment program for fuel cell stacks that have reached the end of life. The customer returns the fuel cell stack to Ballard where we replace the MEA while reusing the existing hardware and plates. The used MEA is then sent to a 3rd-party for recovery of the platinum and other precious metals.

>95%

PRECIOUS METALS

are reclaimed during recycling

THOUSANDS

of fuel cell stacks are refurbished every year

30%

COST SAVINGS

for the customers as a result of refurbishing

Mission Zero Carbon Program

Understanding, reducing, and offsetting Ballard's greenhouse gas emissions is essential to doing our part for the environment. To that end, Ballard has undertaken a corporate emissions inventory (to evaluate our annual carbon footprint) and a lifecycle inventory of our product lines (to measure emissions at each stage of the products' lifecycle). The report will provide us with a baseline to understand our climate impact and identify opportunities to reduce emissions, in adherence to The Greenhouse Gas Protocol, Corporate Accounting and Reporting Standard published by the World Resources Institute and the WBCSD.

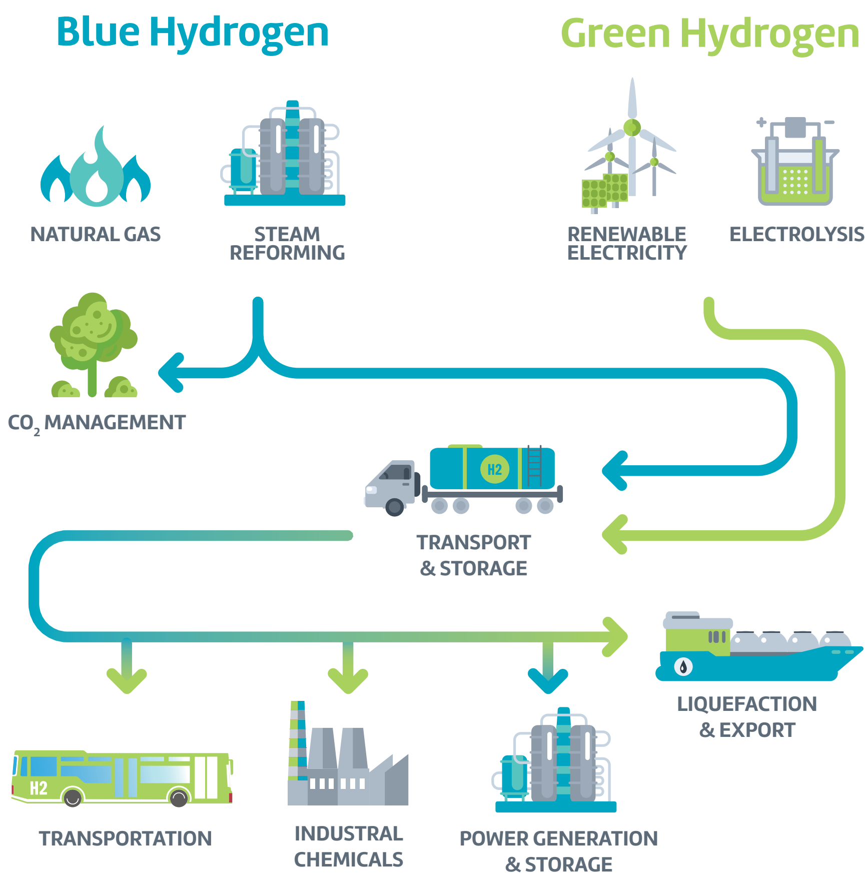
Hydrogen

Hydrogen, the most abundant element in the universe, is now being called the super fuel of the future. Clean hydrogen production will play a major role in the complete decarbonization of transportation from well-to-wheel.

Hydrogen is:

- Not a toxic gas
- Not a polluting gas
- Has no known toxicological effect (non-carcinogenic, non-teratogenic)

There are multiple routes to create hydrogen. The source of energy used and the method define whether it is considered grey, blue or green.



Grey Hydrogen

Currently, 95% of hydrogen is produced from fossil fuels, emitting some CO_2.

Blue Hydrogen

Hydrogen whose CO_2 emitted during production is sequestered via carbon capture and storage (CCS).

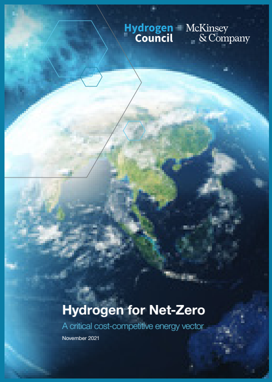
Green Hydrogen

Low or zero-emission hydrogen produced by electrolysis of water using renewable energy sources.

Both green and blue hydrogen can achieve environmental goals. Today, blue hydrogen can provide industrial-scale volumes of carbon-neutral hydrogen, while green hydrogen will increase with deployment of renewable power generation.[7]

Centralized hydrogen production from renewable electricity is one of the paths to source cost-effective green hydrogen at scale. Future energy systems will likely be challenged by large quantities of stranded renewable electricity that cannot be used in the conventional electrical grid. Using this surplus electricity for electrolysis will produce low cost green hydrogen for a variety of uses, including as transportation fuel.

[7] https://ifrf.net/ifrf-blog/green-and-blue-hydrogen-for-a-low-carbon-european-economy



Interested in reading more on this topic?

Download 'Hydrogen for Net Zero'
https://hydrogencouncil.com/wp-content/uploads/2021/11/Hydrogen-for-Net-Zero.pdf

The report "Hydrogen for Net Zero" presents an ambitious, yet realistic deployment scenario until 2030 and 2050 to achieve Net Zero emissions, considering the uses of hydrogen in industry, power, mobility, and buildings. The scenario is described in terms of hydrogen demand, supply, infrastructure, abatement potential and investments required, and then compared with current momentum and investments in the industry to identify the investment gaps across value chains and geographies.

The report is based on the technoeconomic data of cost and performance of hydrogen technologies provided by Hydrogen Council members and McKinsey & Company as well as the Hydrogen Council investment tracker, which covers all large-scale investments into hydrogen globally.

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