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Harnessing Hydrogen

"fueling humanity's clean energy needs©"

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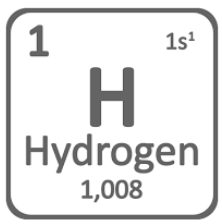
Precis:

The world is perched on a precipice, balancing two polar opposite objectives: moderating energy production's harmful and destructive environmental effects versus advancing and fueling humanity's ever-increasing, insatiable demands for reliable, sustainable energy requirements. These are conflicting objectives, yet the world demands tangible, actionable, commercially-viable, environmentally-inert solutions – harnessing the power of hydrogen as a complementary fuel source offers a solution.



This green paper will set out the rationale why we believe hydrogen can play a meaningful role in helping *"fueling humanity's clean energy needs©".*

The report is produced by Hydrogen Energy Fund
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Contents

		Page
1.	Overview	1
2.	Energy Usage	2
3.	Hydrogen	3
4.	Transportation Industry	4
5.	Challenges	6
6.	Government Sources	8
7.	Conclusion	9
Appendix 1: Energy Inefficiencies		10
Appendix 2: A Comparison of Energy Sources		11
Appendix 3: Articles		12
References		86

1. Overview

The world is ablaze – both physically and emotionally. As populations and countries develop and modernize, there exists an insatiable demand to improve basic human necessities: affordable and available shelter, accessibility to dependable potable water, nutrition-dense food sources, life-saving medical supplies, and the means to harness energy sources. Since the industrial revolution in the 18th century, fossil fuels – initially coal, then oil, then natural gas (now supplemented by renewables: wind, solar, biofuels/biomass) – have been the energy feedstock driving societal advances. But as usage rises – lifting the poorest citizens from abject poverty, while also driving technological advances as far-reaching as inter-galactic space travel – there is a dark side to this evolutionary revolution. The inescapable by-product of burning fossil fuels causes greenhouse gas emissions (GHG) which, left unchecked, may alter the Earth's climate with devastating, irreversible effects. The clarion call to action is: humanity must find actionable, commercially viable, environmentally inert solutions.

2. Energy Usage

World energy consumption usually rises in line with GDP growth; this year reflects a decline mirroring the catastrophic COVID-19 economic crisis. Despite this, by 2050, world energy usage is projected to increase by 50%, with transportation energy consumption accounting for three-fourths of the increase[1], but as policy makers shift their attention to net-zero emissions (NZE)[2], it is clear a solution for the energy demands of the transportation sector is of paramount importance. There is only one solution: harnessing hydrogen.

[1] US Energy Information Administration, International Energy Agency (IAE), World Energy Outlook 2020 (IEA.org)

[2] To reference but a few examples:

- The UK government re-afformed its goal to reach zero carbon emissions by 2025
- US President-Elect Joe Biden renewed his call (November 10, 2020) that the country's economy would reach net-zero emissions no later than 2050

3. Hydrogen

Hydrogen is:

- the first element on the periodic table, with an atomic weight of 1.008
- the most abundant element in the universe[3], including being the energy source for our sun
- a stable, inert (yet combustible) element with a limitless half-life and a boiling point of only 20° higher than absolute zero (0 Kelvin, -273°C)[4]

As a fuel source, hydrogen is:

- abundant, renewable and limitless in supply
- clean, pollution-free, carbon-neutral and non-toxic
- largely generated from, and emits as a by-product, water
- two to three times more efficient than internal combustible engines[5]
- can be stored and transported[6]
- energy-dense: one kilogram of hydrogen has the equivalent energy density of one gram of diesel[7]
- produced either using a "green" process – utilizing renewables (solar/wind) – or a "blue/grey" process – using methane or fossil fuels; over 95% of the hydrogen processed today is blue/grey, which creates GHG[8]

[3] Mainly found in water (H_2O) on Earth as in its gas form is lighter than atmospheric air and evaporates

[4] For example, in its liquid form, hydrogen is used in cryogenics and in the study of superconductivity – Max Planck Institute of Quantum Optics, Munich, Germany

[5] University of Nottingham, School of Physics and Astronomy

[6] Unlike electricity which must be produced and used at the same rate, stored hydrogen can be stock-piled and transported

[7] Energy Transition Outlook Report, 2019

[8] RBC, Experiencing Hydrogen, 2020

4. Transportation Industry

Hydrogen fuel, powering the much-hyped "fuel cell revolution", garners all the glamour today. From the major automobile manufacturers to the market darling, Tesla, companies are scrambling to introduce fuel-cell powered, zero emission vehicles (ZEV). But challenges remain:

- costs (while declining) remain significantly higher than traditional internal combustion engines
- without enormous infrastructure build-out (refueling stations), ZEV cannot economically compete

However, hydrogen fuel can play a significant role in the short-haul, point-to-point heavy duty vehicle (HDV) transportation industry.

Why?

- US Department of Transportation estimates freight volume will increase 45% by 2040
- by 2025, the EU has mandated that HDV reduce their CO_2 emissions by 15% and 30% by 2030
- HDVs:
    - are diesel powered: when burned, they emit particulates including CO_2 and nitrogen oxides
    - globally consume one-fifth of retail oil output[9]
    - are among the highest contributors to greenhouse gas (GHG) emissions (2% of vehicles registered in the US are HDVs yet they emit more than 25% of GHG)
    - spend most of their operating hours idling in the urbanized "last mile" which is the most inefficient engine output and emits pollutants most damaging to humans
    - are ill-suited for fuel-cell batteries (even leaving aside the lack of refueling stations) as the shorter recharge cycle time and lack of adequate power delivery limits their acceptability as a propellant substitute.

[9] IEA

But hydrogen (targeted as a fuel source to the HDV market) offers potential:

- refueling depots can be constructed at origin and destination points
- much of haulage is short-to-medium distances (200-500 miles), within the range of hydrogen output capacity per tank per vehicle

Hydrogen may also be useful in the train transportation sector, as it:

- replaces diesel (which, as noted above, is a GHG pollutant)
- offers end-to-end journeys simplifying the refuel infrastructure issues
- provides required engine power output

To recap, hydrogen as an energy fuel source:

- offers potential as an HDV energy substitute
- is attractive for commercialization with this targeted approach, given transportation's disproportionately large polluting energy usage (specifically HDVs)

5. Challenges

Hydrogen:

- has not been deployed commercially, at scale
- faces start-up structural, scientific and operational issues:
    - because hydrogen needs to be extracted and then compressed to be used as a fuel source, it is expensive to manufacture (but costs are declining) and storage/distribution points are limited[10] (the lack of critical mass has constrained the requisite infrastructure build-out, which has limited demand, a classic catch-22 situation)
    - in essence, hydrogen is only as clean as the energy used to produce it
    - hydrogen offers flammability concerns[11] (but no more so than oil, propane or natural gas, all of which are managed today)

While it seems certain that hydrogen will play an increased role in meeting our future energy needs, the path forward is not without substantial risks and challenges:

- hydrogen costs (per equivalent unit of energy) far exceed the costs of existing energy sources (oil and natural gas) and are even uneconomic compared to other renewable sources (wind and solar)[12], which are uneconomic themselves without government subsidies
- the steps to make hydrogen commercially scalable require significant and sustained government subsidies
- storage of hydrogen is difficult, challenging and fraught with risk

[10] As of May 2020, there were only 39 hydrogen refueling stations in the US, 35 of which are in California

[11] We are all familiar with the Hindenburg airship explosion, May 6, 1937

[12] Business case analysis:

Even industrial scale solar farms (individual house roof solar panels are debatably a feel good venture) have an operating life span of approximately 20 years (due to wear-out and decay of the panels) and the payback (on some of the industry's best performing facilities – Source: UCLA) is approximately 17 years, and this is after the cost of solar panels has declined more than 80% in the past decade. Without government subsidies or an "ESG" greenpeace warrant, most "renewables" are uneconomic.

Wind farms yield even worse economic returns, in addition to causing up to 400,000 "unnatural" bird deaths per year (Source: American Wind Energy Association, Audubon Society, MIT Review: Wind Turbines and Birds, February 2007).

- to be commercially viable, hydrogen adoption requires both:

    1. supply: adequate supplies[13] of the feedstock to manufacture hydrogen, which requires tens of billions of capital in infrastructure buildouts

    2. demand: a sustainable end-use for the product

Again, a classic catch-22 situation: without the infrastructure to produce hydrogen (at a commercially viable scale) there is no demand, which limits infrastructure spending, ad infinitum.

[13] Alberta, Canada and some Middle Eastern countries (UAE for example) are ideally positioned given their abundant natural gas supplies

6. Government Sources

- The US Energy Department (October 8, 2020) created the National Zero-Emission Truck (ZET) Coalition, an alliance between industry, government and scientific communities to study the application of hydrogen to the trucking community

- The US Energy Department's Los Alamos and Lawrence Berkley National Laboratory announced they will co-lead a fuel-cell truck consortium to "…better the position of fuel-cell trucks as a viable option in the long-haul trucking market"

- The California Fuel Cell Partnership (CaFCP) produced an "Action Plan for California", highlighting that data from the adoption of hydrogen to fuel buses "…is transferable to the trucking industry" (October 2016)

- Ballard Power Systems, discussing "Zero-Emission Drayage Trucks", outlined their views on the applicability of commercializing hydrogen as a fuel source (May 2019)

- Both the provincial government of Alberta[14] (Invest Alberta Corporation) and the Federal Government of Canada have expressed support for hydrogen adoption

- Queensland, Australia announced (March 2020) it "… is committed to being at the forefront of renewable hydrogen products by 2010"[15]

[14] Alberta is interested in hydrogen as a fuel source as it expands demand for natural gas (of which the province has ample supplies of), offers a GHG benefit and both the Province and the Federal government recognize the economic impact of large-scale, long-term infrastructure projects

[15] Queensland brands itself as "an ideal location for the development of a 'green' hydrogen sector", given its "abundant renewable energy sources and technical research capabilities" as well as its stable government, low taxes and government support (Queensland Hydrogen Prospectus, March 2020, tiq.qld.gov.au)

7. Conclusion

The commercialization of hydrogen as a transportation fuel source, specifically for the trucking industry, offers societal, environmental and economic opportunities potentially *"fueling humanity's clean energy needs©"*.

Key points:

Hydrogen	Societal Advantages	Environmental Benefits	Economic Opportunities
➢ clean and non-toxic	X	X	
➢ renewable	X	X	X
➢ pollution-free	X	X	
➢ carbon-neutral	X	X	
➢ generated from water (non-invasive to the earth)	X	X	
➢ the by-product is also reusable water	X	X	
➢ produced using renewable energy sources	X	X	
➢ energy substitute	X		X
➢ abundant, limitless supply			X
➢ can be stored, stock-piled and transported			X
➢ significantly greater energy density than diesel		X	X

Appendix 1: Energy Inefficiencies

Energy in general is the means to accomplish work. Society tends to extract it from fuel sources, in order to produce mobility, heat or light.

An important constraint is described by the second law of thermodynamics (first identified by Sadi Carnot in 1824), which broadly states that it is impossible to convert heat to work with 100% efficiency. In other words, energy wastage is inevitable.

Within the current electric grid in 2019, the US used 100 quadrillion British Thermal Units (BTUs) of energy[16] generated from the following sources:

- 37% oil
- 32% natural gas
- 12% coal
- 11% renewables
- 8% nuclear

However, on average, over two-thirds was wasted, principally in the form of radiant heat.

Wastage is a problem in numerous energy technologies:

- vehicle engines have an average efficiency of approximately 20%
- coal-fired power plants operate around one-third efficiency
- renewables are more inefficient, highlighting a key drawback of the green revolution

The round-trip efficiency of hydrogen energy production is approximately 30%, which is lower than desired but comparable to current energy delivery systems.

Science and engineering research needs to focus on improving the efficiency of energy production whether through improved internal combustible engine efficiency or by utilizing new technologies such as hydrogen.

[16] Source: Lawrence Livermore National Laboratory

Appendix 2: A Comparison of Energy Sources

Ranking of various energy sources[17]:

	Usage	Availability of Source	Availability of Delivery	Cost to Produce[18]	Round Trip Costs[18]	Environmentally Friendly	Ease of Transportation
Oil	37%	4	2	3	2	4	2
Natural Gas	32%	3	3	2	1	3	3
Coal	12%	2	1	1	4	5	1
Renewables[19]	11%	6	4	4	3	1	4
Nuclear	8%	5	6	5	5	6	6
Hydrogen	**0%**	**1**	**5**	**6**	**6**	**2**	**5**

Comments:

- petroleum and natural gas offer best cost-to-end applications (they account for approximately 70% of current global usage but produce significant GHGs)
- coal is abundant and an efficient fuel source, but is dirty
- renewables have the least environmental impact but also possess numerous disadvantages such as high costs, inefficiencies, geographical restrictions (e.g. for tidal power) and sporadic generating capabilities (e.g. for solar or wind power)
- nuclear power has similar advantages to renewables but presents additional obstacles, including the generation of radioactive waste and NIMBY location oppositions
- hydrogen is expensive to produce and currently lacks scale and commercial applications, but is abundant and is environmentally friendly

[17] World Energy Council scale: 1 is best, 6 is worst

[18] Cradle-to-grave costs (Sources: BP Outlook, IAE, Strategem internal sources)

[19] Includes solar and wind, bio-fuel/bio-mass, hydroelectric, geothermal and tidal energy sources

Appendix 3: Articles

1. A $100B Opportunity: Alberta could emerge as Canada's First Hydrogen Energy Hub, Nov. 2020
2. Enbridge Gas to Blend Hydrogen With Natural Gas for Consumers in Markham, Ontario, Nov. 2020
3. $15-Million Project to Test Hydrogen Fuel in Alberta's Freight Transportation Sector, Mar. 2019
4. End of the Road? Quebec's Goal to Ban Gas-Guzzling Cars Latest Move to Hasten Oil's Decline, Nov. 2020
5. Queensland Hydrogen Prospectus, Mar. 2020
6. Electricity Facts – Government of Canada, Oct. 2020
7. Canada's Energy Mix – Canadian Association of Petroleum Producers, Nov. 2020
8. Congo Hydrogen Plant Being Considered by European Turbine Makers, Aug. 2020
9. Visualizing America's Energy Use in One Giant Chat, May 2020
10. 6 Ways Hydrogen and Fuel Cells Can Help Transition to Clean Energy, May 2020
11. The Hydrogen City: How Hydrogen Can Help to Achieve Zero Emissions, May 2019
12. The Green Power You Aren't Hearing About, April 2021

A $100B opportunity: Alberta could emerge as Canada's first hydrogen energy hub, report says

'Potential in terms of jobs and royalties to be a game changer for Albertans'

Author of the article:

Geoffrey Morgan
Publishing date:

Nov 17, 2020 • •

The report stated that the region's low cost for natural gas, technical expertise and ability to rapidly scale up blue hydrogen production makes it possible to decarbonize industry and create new fuel markets with 90 per cent lower GHG emissions.

Article content

Alberta's hydrocarbon-based economy could be re-tooled to capture a $100-billion-per-year market in hydrogen-based energy and diversify the provincial government's revenues away from oil and gas, according to a new report.

An industrial corridor known as Alberta's Industrial Heartland north of Edmonton has the potential to be Canada's first hydrogen production hub as Canada "is strategically positioned to benefit from taking a leadership role in the transition to a net-zero hydrogen economy," according to a report released Monday by University of Calgary researchers and the Transition Accelerator, a think-tank funded by multiple family foundations and governments, including the Alberta government.

"The region's low cost for natural gas, technical expertise and ability to rapidly scale-up the production of blue (hydrogen) makes it possible to not only decarbonize industrial processes that use (hydrogen) but also create new fuel markets with up to 90 per cent lower lifecycle GHG emissions," the report notes.

Currently, Australia, China, Germany, Saudi Arabia, South Korea and the United Kingdom are pursuing hydrogen strategies to reduce carbon emissions because hydrogen produces water vapour rather than CO2 when it combusts in combination with oxygen.

Both the Canadian and Alberta governments are keen to encourage the growth of a hydrogen industry. Alberta also identified hydrogen as an important plank in its long-term natural gas strategy unveiled in October and has funded a handful of small hydrogen demonstration projects in the province.

The report released Monday expects the domestic and international hydrogen markets have the potential to be worth “$100 billion per year or more.”

The report highlights five facilities immediately north of Edmonton that produce hydrogen, including Shell Canada Ltd.’s Scotford refining complex, the NorthWest Refinery and a Nutrien Ltd. fertilizer plant.

In total, the province produces 2,250 tonnes of hydrogen per day from hydrocarbons such as oil and gas. Of that total, roughly 937 tonnes per day can be considered “blue hydrogen,” meaning the process uses a carbon-capture system to reduce emissions. Green hydrogen, meanwhile, is produced using renewable energy to electrolyze water.

The rest of the hydrogen produced in Alberta is considered “gray hydrogen,” because the CO2 emissions associated with its production are not captured.

“We already have a good hydrogen economy in Alberta. It’s an industrial economy. We make hydrogen and we use it to make fertilizer,” said Dan Wicklum, the Calgary-based CEO of Transition Accelerator.

Wicklum said governments previously tried to reduce emissions by mandating certain sectors reduce their emissions to targeted levels either through regulation or taxation, but a hydrogen-based energy system could enable countries around the world to set and meet net-zero carbon targets.

Despite the potential for Alberta and Canada to be a hydrogen supplier, international competitors are already moving into the market.

“Our competitors so far are Australia and Saudi Arabia,” Wicklum said, noting that both countries have already sold hydrogen of hydrogen to buyers in Japan.

In September, Saudi Arabia sent a shipment of blue hydrogen to Japan, said to be the world’s first shipment of the energy source.

Alberta’s abundance of natural gas will make it the second cheapest supplier of hydrogen in the world, after Russia, Alberta’s Associate Minister of Natural Gas Dale Nally said Monday.

Nally said multiple projects in Western Canada could allow Alberta to grow its hydrogen production, including two fully permitted pipelines that had been planned to connect natural gas fields with LNG export projects that could be repurposed to export hydrogen.

"It has the potential in terms of jobs and royalties to be a game changer for Albertans," Nally said of hydrogen, adding that he expects the province's oil and gas industry to continue to be a driver of economic growth.

"We have a multi-generational supply of cheap natural gas. We have a skilled workforce with experience in the oil and gas industry. We are equipped to pick up the ball and run with it," Nally said.

The province has helped fund a handful of hydrogen-based pilot projects, including for the use of long-haul trucks between Calgary and Edmonton as the transportation industry is looking to decarbonize and considers hydrogen fuel a viable alternative.

Indeed, governments around the world have been moving to ban the sale of gasoline and diesel vehicles, including in California and the United Kingdom.

On Monday, Quebec Premier François Legault unveiled a $6.7 billion environmental plan that includes banning the sale of new gasoline-burning vehicles by 2035 as part of its goal to reduce emissions and meet Paris climate targets.

With a file from Reuters

• *Email: gmorgan@nationalpost.com | Twitter: geoffreymorgan*

Enbridge Gas to blend hydrogen with natural gas for consumers in Markham, Ont.

November 18, 2020

By The Canadian Press
Wed., Nov. 18, 2020*timer*1 min. read

CALGARY - Consumers in the Markham area of southern Ontario will soon be receiving a little hydrogen to go with the natural gas they use to fuel their furnaces and hot water heaters.

Enbridge Gas and partner Cummins Inc. say they will proceed with a $5.2-million pilot project next year to blend hydrogen from their facility in Markham into part of the existing natural gas network.

The facility, commissioned in 2018, uses excess renewable electricity from the Ontario grid to make hydrogen from water and store it. Burning hydrogen produces only water without any greenhouse gases.

Enbridge Gas, a subsidiary of Calgary-based Enbridge Inc., says the project was approved in October by the Ontario Energy Board.

It says it will initially provide a maximum hydrogen content of up to two per cent of the natural gas stream supplied to about 3,600 customers in Markham in the third quarter.

It says customers' bills will not be affected.

"Zero-carbon hydrogen can play a role in Ontario's shift to lower-carbon, sustainable energy solutions and is an important example of investments Enbridge is making across multiple markets to green the natural gas grid while continuing to meet the demand for safe, reliable and affordable energy," said Cynthia Hansen, Enbridge president of gas distribution and storage.

The company recently announced it would reduce its greenhouse gas emissions intensity to net zero by 2050 and by 35 per cent by 2030 compared with 2018.

This report by The Canadian Press was first published Nov. 18, 2020.

Companies in this story: (TSX:ENB)

$15-million project to test hydrogen fuel in Alberta’s freight transportation sector

March 12, 2019

Posted on Tue, 03/12/2019 - 13:50

By Mark Lowey

An industry-led, $15-million project will test the ability of hydrogen to fuel the province’s heavy-duty freight transportation sector, a first step in exploring a potential made-in-Alberta hydrogen economy.

Emissions Reduction Alberta (ERA) is contributing more than $7.3 million to the Alberta Zero-Emissions Truck Electrification Collaboration (AZETEC) project, led by the Alberta Motor Transport Association. ERA is providing the funding through its competitive BEST Challenge program, which targets technologies that demonstrate potential to reduce greenhouse gas emissions in Alberta and secure the province’s success in a lower-carbon economy.

The three-year AZETEC project, scheduled to run until mid-2022, involves the design and manufacture of two heavy-duty, extended-range, hydrogen fuel cell electric hybrid trucks that will move freight year-round between Edmonton and Calgary.

These 64 tonne, B-train tractor-trailers, capable of travelling up to 700 kilometres between refueling, will be the first vehicles of this size and capacity built and tested in the world. By the end of the project, they will have travelled more than 500,000 kilometres and carried about 20 million tonne-kilometres of freight by two Alberta trucking companies, Trimac Transportation and Bison Transport.

The AZETEC project builds on more than a year’s worth of research, data analysis and scenario modelling done by the Canadian Energy Systems Analysis Research (CESAR) Initiative, examining various low or zero-carbon energy systems and the economic opportunity for hydrogen in Alberta (See “Zero-emission Transportation Fuels: Alberta’s New Economic Opportunity”). CESAR collaborated with the freight transportation sector, technology providers and other stakeholders in developing, defining and submitting the project proposal to ERA.

Freight transportation accounts for almost 70% of diesel fuel demand in Alberta and contributes about 12 million tonnes of greenhouse gas emissions (GHGs) per year in the province. The AZETEC project will test hydrogen as a zero-emissions alternative to diesel for freight transportation.

If the project is successful it will help reduce greenhouse gas emissions during the pilot, and also inform next steps for Alberta to become a global leader in the transition to a low-carbon economy.

In addition to having zero tailpipe emissions, electric trucks are able to provide higher torque than diesel-fueled trucks, which is useful for pulling heavy loads, accelerating and climbing steep grades. An electric motor paired with a fuel cell system has a more efficient powertrain than a diesel-fueled internal combustion engine. Electric fuel cell hybrid vehicles also are expected to have considerably lower maintenance costs than internal combustion engine vehicles.

The AZETEC project will be managed by Zen Clean Energy Solutions, a Vancouver-based consultancy with a wealth of experience in designing and managing hydrogen fuel cell electric projects. The fuel cell technologies at the core of the vehicles will be provided by Ballard Power in Burnaby, B.C., which will be working closely with Dana Inc., a global leader in heavy-duty electric drive axles, and Nordresa, a Quebec-based electric drive train manufacturer. The tractor bodies in which the hydrogen fuel cell electric technology will be deployed will be provided by Freightliner/Daimler.

Edmonton facilities operated by Air Products and Praxair will provide the high-purity compressed hydrogen. HTEC, based in Vancouver, will deliver their technology to fuel the trucks during the 18-month field trial that will begin as soon as the vehicles are built.

CESAR will coordinate the research and modelling activities around the project, including assessing performance of the technologies, and co-developing with academic, industry and government partners, possible transition pathways for the larger-scale deployment of hydrogen fuel cell electric vehicles and the hydrogen economy in Alberta.

In addition to the Emissions Reduction Alberta contribution, support for CESAR's work will come from the Transition Accelerator , and the Energy Futures Lab (EFL). CESAR, the Transition Accelerator and the EFL will be partnering to bring together and support innovators who share a vision for a vibrant Alberta economy based on the production, use and export of very low or zero-emission transportation fuels.

Alberta's hydrogen opportunity

Concerns about climate change and air pollution are driving companies, cities and nations to find alternatives to internal combustion engines and the gasoline and diesel fuels they use. Alberta's oil production currently provides markets with about nine times more diesel fuel than the amount consumed in the province. So if there is an energy transition away from diesel fuel to zero-emissions fuel, CESAR's analysis shows it would be in Alberta's best economic interest to be able to supply this new market, while continuing to supply oil for the remaining diesel fuel market.

Hydrogen is the most promising zero-emissions fuel, and Alberta is already a major producer of hydrogen for cracking hydrocarbons and producing nitrogen fertilizer. Extending the hydrogen market to transportation fuels offers an exciting new economic diversity and export opportunity for Alberta, while reducing GHG emissions and positively positioning the province should there be a decline in future diesel demand.

Compared with other regions of North America and the world, Alberta has a competitive advantage for the production of hydrogen as a zero-emission transportation fuels that includes:

- Vast, and under-valued, natural gas and crude oil resources that are an excellent feedstock for the low-cost production of hydrogen;
- The geology that can either use the byproduct of hydrogen production – carbon dioxide – for enhanced oil recovery or provide a permanent, safe, underground storage site for CO_2;
- Plentiful, low-cost wind and solar power potential that can be used for electrolytic production of hydrogen; and
- Superb technical and human resource expertise and an innovative spirit.

Taking full advantage of this opportunity will require rapid, transformative changes. These changes– like those seen in digital information and communications technologies – typically result from technology, business model or societal innovations that provide totally new services, enhanced convenience, comfort or efficiency, or reduced costs leading to a better return on investment for stakeholders.

Such transformative forces – including disruptive technologies like electric, connected and autonomous vehicles – are currently at play in North America's freight transportation sector. Freight transportation is an essential service in Alberta to facilitate economic growth. By coupling smart policy and regulations with heavy-duty vehicle electrification (specifically hydrogen fuel cell electric drive trains), Alberta can direct the market pull necessary for transformative systems change and to remain a key supplier of transportation fuels well into the future.

End of the road? Quebec's goal to ban gas-guzzling cars latest move to hasten oil's decline

financialpost.com/commodities/energy/end-of-the-road-quebecs-goal-to-ban-gas-guzzling-cars-latest-move-to-hasten-oils-decline

Author of the article:

Geoffrey Morgan
Publishing date:

Nov 20, 2020 • • 8 minute read

Article content

Bob Larocque's industry is planning for a future where the market for their main product, gasoline, begins to evaporate as national and sub-national governments phase out gasoline- and diesel-powered vehicles under increasingly ambitious timeframes.

"I need to understand how this will work," said Larocque, president and CEO of the Ottawa-based Canadian Fuels Association, which represents Canadian oil refineries.

The global shift started with a planned ban on oil-powered vehicles in India in 2017, then Taiwan and Japan, with major economies in the European Union following suit. Then in September, California became the first North American jurisdiction to announce a ban on internal combustion engine (ICE) cars and light trucks — representing a seismic shift in the market, as the most populous state in the U.S. represents about 10 per cent of American oil demand.

This week the trend arrived in Canada when Quebec Premier Francois Legault made his province the first jurisdiction in the country to ban the sale of gasoline-burning vehicles, beginning in 2035, as part of his massive, $6.7-billion plan to reduce carbon emissions by 37.5 per cent below 1990 levels.

"There is definitely a trend of governments regarding carbon content and the transportation industry," said Larocque.

Currently, there are fewer than 100,000 zero-emission vehicles on the road in Quebec — which represents roughly 1.1 per cent of the 8.9 million cars in the province. Legault's plan seeks to boost those numbers to 1.5 million electric vehicles on the streets in a shift that will affect the province's transportation industry, deal a blow to the province's two large refineries by hampering oil demand and, notably, provide a boost to its electric utility Hydro Quebec as the need for renewable electricity within the province will jump.

While Quebec is the first province in Canada to announce a ban, experts, economists and industry executives believe more fossil-fuel constraining policies are coming down the tailpipe. Half a dozen governments around the world and across the political spectrum have made similar announcements this year, including the U.K.'s Conservative government led by Prime Minister Boris Johnson, who as recently as 2013 was touting the potential of shale, saying his country should "leave no stone unfracked."

Industry executives also expect Ottawa to introduce its Clean Fuel Standard by the end of this year, which will likely foist new costs on refineries.

The suite of new policies have major implications for global oil markets as a growing number of governments move to ban gas- and diesel-burning vehicles in their jurisdictions. The trend is accelerating a shift to electric vehicles and could hasten a peak in oil demand despite oil companies' best efforts to reduce carbon emissions and pledge to meet stringent environmental standards.

"Are we ready to have a conversation? Yes. We're already producing ethanol and bio diesel," Larocque said, adding the oil refinery industry is looking to play a role in producing hydrogen and using existing assets, such as gas stations converted to electric charging stations, to help aid the transition. The organization still believes fossil fuels will still be in use in transportation until 2050.

Larocque said his member companies, which include Imperial Oil Ltd., Suncor Energy Inc. and Shell Canada Ltd., want to know how Quebec's climate plan will work in practice and has similar questions for the Clean Fuel Standard coming from the federal government. On Thursday, Ottawa also announced legislation to set targets to achieve net-zero emissions by 2050. If passed, Bill C-12 would require the federal environment minister to set five-year targets for cutting carbon emissions starting in 2030, and ending in 2050, when Canada hopes to hit net-zero in carbon emissions.

Suncor, which operates a 137,000-barrels-per-day refinery in Montreal that produces gasoline, asphalts, petrochemicals and other products, did not respond to requests for comment on whether it would make changes to the refinery given the incoming ban on ICE cars. Similarly, Valero Energy Corp., which operates a larger 265,000-bpd refinery outside of Quebec City, did not respond to a request for comment.

Researchers at Sarnia, Ont.-based Bowman Centre for Sustainable Energy argued in a

June 2020 report entitled Electric Vehicle Impact on the Oil Sands, that Canadian oil producers and governments should increase their support for the Bitumen Beyond Combustion initiative, which was started by Alberta Innovates, a provincial agency, and seeks to find new uses for bitumen other than fuel, including as asphalt, adhesives and in chemicals.

Experts believe a move away from gasoline- and diesel- powered vehicles will have major implications for the oil markets and, by extension, for Canada's largest export category: oil and gas.

"We think that oil consumption by light duty vehicles has already peaked globally," said Jim Burkhard, vice-president at IHS Markit and head of the consultancy's crude oil research and energy mobility research teams. This is a major shift in oil markets as until now, transportation had been the leading source of oil demand growth.

In 2019, global oil consumption for cars and light trucks peaked at roughly 29 million barrels per day, a third of the global oil consumption of 100 million bpd, but Burkhard believes oil demand for light-duty vehicles will plateau just below that level and then decline.

By 2030, IHS Markit has a base-case scenario where oil demand for light-duty transportation will average 27.6 million bpd.

While petrochemicals will remain a key growth driver of oil demand, most forecasts suggest overall oil consumption will plateau over the next two decades.

"In our base case, we see oil demand peaking around the mid 2030s," Burkhard said. "It's a trend of decelerating growth. Then it declines gently."

Similarly, a 2019 Bank of Canada study showed that sales of electric vehicles quadrupled between 2014 and 2018 and projects their share of the global vehicle fleet will grow from 4 million vehicles in 2018 to 120 million by 2030 — rising from 0.3 per cent of all cars on the road to 7 per cent.

"Our analysis shows that for every additional 100 million electric vehicles on the road in 2030, gasoline consumption would fall by about 1 million barrels of oil per day and oil prices would be 4 per cent lower," the central bank study states.

Much of the outlook for oil demand is driven by India and China, said Michael Tran, RBC Capital Markets managing director, global energy strategy in New York.

"We have yet to peak in global oil demand but we have hit the peak in OECD oil demand. We hit that back right around the (global) financial crisis about 12 years ago," Tran said.

“When we look at China, SUVs have been making up a larger and larger portion of new vehicle sales. They’re gas guzzlers,” Tran said, adding that even as China is “accelerating their climate policies” those gas-burning cars will continue to be in the mix for an average of 8 to 12 years.

But the Chinese government has a financial incentive to shift the country towards more electric vehicles. The country, which is the world’s largest importer of oil, currently controls more than half of the supply chain for batteries used in electric vehicles. That makes it a more powerful player in the EV market than Saudi Arabia is in the oil market.

Last month, the financial newspaper Nikkei Asia reported China will require all new vehicles sold in 2035 to run on “new energy,” a designation that includes electric, plug-in hybrid or fuel cell-powered cars and trucks.

While the demand for oil is expected to wane as countries ban the sale of new ICE vehicles, demand for electricity is expected to jump. Quebec, which generates a third of Canada’s total electricity output primarily from its hydroelectric generating stations, is in a position to meet that increase in demand, said Pembina Institute analyst Cedric Smith.

Smith said Hydro Quebec has been involved in previous government rollouts of electric car programs, including the Electric Circuit, and the province is in a position to use its existing hydro capacity and electric grid to met the increased demand from electric vehicles.

Additionally, Smith said the lifecycle greenhouse gas emissions for electric vehicles in Quebec, in particular, will be lower than for ICE vehicles because the province’s electricity grid already has the lowest carbon intensity in the country at 1.2 grams of CO_2 per kilowatt hour.

Still, there will be challenges in banning ICE vehicles in Quebec as base model gas-burning cars are about half as expensive as their electric counterparts.

“A lot of environmental policy has a problem with regressive policy, where the weight of the policy falls on low-income people. By banning cars, you are increasing the cost of transportation overall and what is more complicated is that low-income people need to drive more,” said Juan Moreno-Cruz, associate professor at the University of Waterloo and Canada Research Chair in energy transitions.

It’s important then that governments such as those in Quebec limit those regressive impacts either through subsidies for low-income people or additional investments in public transportation in an effort to compensate low-income people, Moreno-Cruz said.

At the same time however, research from a range of companies including Tesla Inc., General Motors Co. and investment bank Tudor, Pickering & Holt point to EV battery costs dropping in the next five to 10 years, said Jackie Forrest, executive director of the ARC Energy Research Institute.

A Nov. 19 report from TD Economics shows EV battery costs have fallen 86 per cent to US$156 per kwh, from US$1,160 per kwh in 2010.

“Industry experts expect this trend to continue over the coming years, such that the price parity between EV and ICE models could be reached as early as 2022/2023,” the TD report states.

ARC’s Forrest said a decline in EV battery costs is necessary for jurisdictions banning ICE vehicles because it’s not practical for the government to subsidize every car sold. “There would be so many vehicles that it’s a lot for the taxpayer to pay,” she said.

Moreover, the announced deadlines for bans on sales of new gas-burning vehicles are being moved to earlier dates, which makes a decline in battery costs more urgent.

“They’re getting closer all the time,” Forrest said.

Financial Post

QUEENSLAND

Hydrogen

TIQ Trade & Investment Queensland AUSTRALIA

Queensland Government

Queensland, Australia: investing in a hydrogen future

Hydrogen is the most abundant element and is widely used in a range of manufacturing and industrial processes. Around the world, hydrogen is increasingly being used as a clean fuel, and there is growing global interest in hydrogen produced from renewable sources as a versatile energy carrier to support the transition to a low-carbon economy.

Almost anything that uses energy can be powered by hydrogen. Hydrogen is a clean, flexible energy carrier that can help to reduce carbon emissions from transport, power generation and industrial sectors. Hydrogen can also play a key role in integrating renewable energy into the electricity grid and has the potential to become a valuable new export industry for Queensland.

Australia has a diverse mix of existing and planned hydrogen projects, creating a national context conducive to growing the hydrogen economy. Queensland is a hydrogen leader among the Australian states, with the Queensland Government committed to being at the forefront of renewable hydrogen production in Australia by 2030.

Queensland is well positioned to rapidly scale up a hydrogen economy utilising existing infrastructure at key ports such as Gladstone, Brisbane and Townsville. The state's abundant renewable energy sources and technical and research capabilities also make it an ideal location for the development of a 'green' hydrogen sector.

EXISTING AND PLANNED

hydrogen projects

Queensland and other Australian states and territories

WA

Clean Energy Innovation Hub ATCO

In Renewable Hydrogen Ammonia

Tara & ENGIE Hazer Group Pilot Plant Hoivr Group and MinRes

QLD

Gladstone Advanced Biofuels Pilot Plant - Northern Oil & AFC Energy

Redlands Renewable Hydrogen Plant - Queensland University of Technology

Sir Samuel Griffith Centre - Griffith University

National Hydrogen Materials Reference Facility (NHNIRF) - Griffith University

SA

Crystal Brook Energy Park - Neoen

Hydrogen Park SA (HyP SA) - AGIG and Siemens

Mawson Lakes Campus - University of South Australia

Port Lincoln Green Hydrogen Plant - Hydrogen Utility (H2U) and Thyssenkrupp

VIC

Hydrogen Energy Supply Chain (HESC) - Kawasaki Heavy Industries (KHI), J-POWER, Iwatani Corporation, Marubeni Corporation, Shell and AGL

Toyota Australia Hydrogen Centre - Toyota Australia

Centre for Hybrid Energy Systems (CHES) - CSIRO

ACT

Government Fleet and Refuelling station - ActewAGL, Neoen, Megawatt Capital, Siemens and Hyundai

Renewable Energy to Gas - Union Fenosa, ANU and ActewAGL Distribution

NSW

ARC Training Centre for The Global Hydrogen Economy - University of New South Wales

Project H_2G0 - Jemena

Fire and Explosion Testing Services (FETS) - University of Newcastle

? ***Proposed***

→ ***In progress***

✓ ***Completed***

QUEENSLAND'S competitive advantage

Queensland offers investors and business owners many advantages, including:

- stable government
- Australia's lowest payroll tax rate
- competitive labour costs
- low cost of living
- sophisticated transport and communication infrastructure
- highly skilled labour
- streamlined development approvals and project facilitation processes
- a strong private investment sector.

Queensland has the potential to produce and export renewable hydrogen using our natural resources, creating a new wave of high-value, innovation-focused jobs in the process.

The state is well positioned to meet the growing international demand for renewable hydrogen and to supply the domestic energy market. Our established infrastructure, proximity to Asia, significant solar resources and available land make Queensland the ideal location to produce renewable hydrogen for domestic and international use.

Moreover, Queensland's established credentials as a global energy exporter mean that we have both the infrastructure and experience to lead the export of renewable energy. The Queensland Government has already made great progress in this area, driven by its target to fuel 50% of its energy needs from renewable sources by 2030. Our solar PV capacity is world-class.

$5 billion

Queensland has $5 billion in committed renewable investment with $1.1 billion already constructed and operating and a further $20 billion in the pipeline.

THE Queensland advantage

Highly skilled workforce

- Over 15% of Queensland's workforce have STEM qualifications such as science or engineering

Established energy exporter

- 20.58 million tonnes of LNG exported in 2018

World-leading solar PV capacity

- Queensland enjoys over 300 days of sunshine per year

Pro-business government

- Queensland boasts a supportive policy and regulatory regime, with a strong focus on innovation

Queensland is the manufacturing state

- Manufacturing is the sixth-largest contributor to the Queensland economy

Proximity to markets

- Brisbane is Australia's closest eastern capital city to Asian markets

Queensland Hydrogen Industry Strategy 2019–2024

Under the *Queensland Hydrogen Industry Strategy 2019–2024*, the Queensland Government is committed to leading Australia in renewable hydrogen production.

Vision

By 2030, Queensland is at the forefront of renewable hydrogen production in Australia, supplying an established domestic market and export partners with a safe, sustainable and reliable supply of hydrogen.

Queensland Hydrogen Industry Strategy – focus areas

PRODUCTIVE | **international partnerships**

Queensland is working closely with international partners through collaborative research and development, and is supporting world-class renewable hydrogen projects.

In 2019, the Queensland Government re-signed a memorandum of understanding with the Japan Oil, Gas and Metals National Corporation that includes cooperation on hydrogen, and recently signed a statement of intent with the University of Tokyo's Research Center for Advanced Science and Technology to collaborate on hydrogen.

Also in 2019, JXTG, Japan's largest petroleum conglomerate, in partnership with Chiyoda Corporation and researchers from Japan and Queensland, tested the export supply chain by transporting hydrogen produced in Queensland to Japan. The renewable hydrogen was produced at QUT's solar-cell facility at the Queensland Government's Redlands Research Facility using JXTG's proprietary technology, which aims to reduce the cost of CO2-free hydrogen.

Professor Masakazu Sugiyama – Queensland's hydrogen envoy in Japan

In June 2019, Professor Masakazu Sugiyama from the University of Tokyo generously accepted an honorary appointment as Queensland's hydrogen envoy in Japan.

Professor Sugiyama is a highly regarded international expert in renewable energy and hydrogen technologies, with an excellent working relationship with Queensland universities and an extensive industry network in Japan.

The Europe-Queensland hydrogen connection

The Queensland Government is keen to work with European partners looking to develop hydrogen projects in Queensland.

European companies already pursuing renewable hydrogen opportunities in Queensland include ENGIE (France), Hydrogen de France (France), NEL (Norway), Siemens (Germany), Linde (Germany/USA).

Queensland is also working on providing an internationally recognised accreditation process for renewable hydrogen, with the goal of ensuring sustainable investment outcomes can be guaranteed.

The ENGIE/Springfield partnership

In December 2019, global energy and services company ENGIE and Queensland's Springfield City Group signed an historic 50-year strategic alliance to make Greater Springfield a 'net zero energy' city.

Under the alliance, investments are planned in renewable energy generation and storage infrastructure, district energy schemes, green mobility solutions, digital technology, energy-efficiency initiatives and a dedicated research and innovation centre.

The Zero Net Energy Vision for Greater Springfield is that, by 2038, the Greater Springfield community – with a forecast population in excess of 500,000 – will be generating more energy than it consumes.

SUPPORTING

hydrogen innovation through R&D

The Queensland Government is directly supporting innovation in hydrogen technology.

The government's $755 million flagship Advance Queensland initiative is supporting programs that drive innovation and build on the state's natural advantages. The Advance Queensland Strategy includes a commitment to address energy sustainability through innovation, with hydrogen identified as a priority industry.

Two of Queensland's leading tertiary institutions are at the forefront of research and development that will drive innovation to support competitive production, storage, transport and use of hydrogen.

Queensland University of Technology

Green hydrogen pilot plant

Queensland University of Technology (QUT) is leading an $8.4 million research project to establish a pilot plant producing green hydrogen fuel at the Queensland Government's Redlands Research facility.

QUT and their project partners are embarking on hydrogen research for Australian conditions. The project will develop a scalable process to evaluate the viability of decentralised renewable energy systems to generate hydrogen from renewable sources. Using two solar array technologies and battery packs, hydrogen will be produced using electrolysis technology. The resulting hydrogen will be used within the facility as well as exported. The facility will allow researchers and industry to optimise the production and use of renewable hydrogen, with the aim of scaling up into megawatt-scale development.

QUT has received financial assistance from the Australian Renewable Energy Agency (ARENA) and is working with Swinburne University of Technology, Sumitomo Electric Industries, Griffith University, Energy Developments Limited and the Queensland Government's energy company, CS Energy.

The Queensland Government has committed to providing financial support for the establishment of the facility.

Hydrogen refuelling station

QUT will also host Queensland's first hydrogen refuelling station at its Kelvin Grove campus. The state-of-the-art station will be able to refuel hydrogen fuel-cell electric vehicles in under three minutes and is being delivered by BOC Australia as part of its development of a renewable hydrogen production plant at its Brisbane industrial facility. In support of BOC's hydrogen initiative, the Queensland Government will trial up to five hydrogen fuel-cell electric vehicles in its fleet once the refuelling station is operational.

A Concentrated Photovoltaic (CPV) array is being tested in joint QUT and Sumitomo Electric Industries project.

Griffith University

National Hydrogen Materials Reference Facility

Griffith University has established the National Hydrogen Materials Reference Facility, a state-of-the-art reference laboratory focusing on hydrogen storage materials and hydrogen embrittlement. A key project has been looking at materials for energy storage and conversion.

The project addresses the globally critical issue of energy storage and conversion by developing diverse energy sources to reduce the environmental impact of energy supply and help address climate change. The research has focused on solid-state hydrogen storage; embrittlement of high-strength materials by hydrogen; energy-related materials such as superconductors, magnetic materials, battery materials and photovoltaic cells; modelling and simulation of materials, components and systems for energy supply; hydrogen production; and biophotonics.

Sir Samuel Griffith Centre – world's first hydrogen building

Griffith University also operates the $40 million Sir Samuel Griffith Centre at its Nathan campus in Brisbane – the first Australian teaching and research facility powered by photovoltaics and hydrogen-storage technology.

The building is fitted with more than 1,000 solar panels on its roof and window shades. On sunny days, this generates more than enough electricity to power the whole building. Excess solar energy produced by the photovoltaic system is stored in batteries and powers an electrolyser that splits water to make hydrogen. The hydrogen is then stored in a stable form as metal hydrides. On overcast or wet days, hydrogen can be brought from storage and used to generate electricity in a hydrogen fuel cell.

The centre has been designed to generate zero carbon emissions.

International research collaborations

Queensland is working closely with international partners through collaborative research and development, and is supporting renewable hydrogen projects with global implications.

The initial focus has been on collaborating with key trading partners in Asia, including Korea and Japan. The Queensland Government is also keen to explore opportunities with European companies seeking to invest in renewable hydrogen projects.

HYDROGEN opportunities in Queensland

Queensland is home to 173 operating or proposed renewable energy projects. Combined, they have a generating capacity of more than 22,500MW annually. These projects are complemented by exciting new hydrogen energy projects, demonstrating Queensland's commitment to clean, green energy solutions.

Renewable energy project pipeline

The Queensland Government has set a target of 50% renewable energy by 2030. Queensland was the renewable energy construction capital of Australia in 2018, with more than one-third of Australian renewables projects commissioned in 2018 located in Queensland. Queensland has 27 operating facilities that incorporate solar and wind technologies, with a total capacity of 2,288MW in the National Electricity Market. A further four solar and wind projects with a total capacity of 262MW are committed and under construction, while solar and wind projects with a total capacity of 12,668MW are being investigated. The opportunity exists to integrate renewable hydrogen into these projects as a variable load and balancing mechanism.

Renewable energy target

The Queensland Government has set a state target to reach zero emissions by 2050, with an interim target of a 30% reduction in emissions by 2030. Renewable hydrogen has the potential to play a significant role in achieving these targets and will reinforce Queensland's position at the forefront of global climate action. Queensland also has a number of government-owned corporations in the energy portfolio, including Stanwell, CS Energy, Ergon Energy, Yurika, Powerlink, Energy Queensland and Cleanco. Several are already investing in hydrogen research and development projects.

Alternative technologies for remote power stations

Queensland's Ergon Energy currently owns and operates 33 isolated power stations providing electricity to communities that are too remote to connect to the national electricity grid. These power stations are located throughout western Queensland, the Gulf of Carpentaria, Cape York, some Torres Strait Islands and on Palm Island and Mornington Island. These power stations currently use diesel-powered generators, and Ergon is investigating alternative and renewable technologies to support them. Achieving reliable and cost-competitive renewable hydrogen generation in regional and remote environments represents a significant opportunity for Queensland.

Hydrogen transport projects

In 2019, the Queensland Government announced it would trial hydrogen fuel-cell electric vehicles in its fleet to accelerate the state's drive towards a hydrogen-fuelled future. These vehicles will be integrated into the government's vehicle fleet as part of the $19 million Queensland Hydrogen Industry Strategy 2019–2024. The transport sector is one of the largest contributors to carbon emissions. A number of countries are already investing in hydrogen-fuelled transport, including trucks, trains and buses. There are opportunities in Queensland to explore the use of hydrogen for long-distance heavy-duty transport, and the development of associated refuelling infrastructure.

Renewables 400

The Queensland Government is conducting a reverse auction for up to 400MW of renewable energy capacity, including up to 100MW of energy storage. Ten projects have been shortlisted to submit detailed bids.

For more information, visit www.business.qld.gov.au, search for 'Renewables 400'.

Australian Gas Networks Injection Facility

An Australian-first $4.2 million gas injection facility will be built in Gladstone to deliver renewable hydrogen into the city's gas network, thanks to the first grant from the Queensland Government's $15 million Hydrogen Industry Development Fund. Australian Gas Networks has been offered more than $1.7 million through the fund to build a blending facility to deliver 10% renewable hydrogen into the gas network.

Hydrogen Park Gladstone (HyP Gladstone) will be Australia's first renewable hydrogen production facility, able to deliver up to 10% blended hydrogen across the city's total 770 residential, small commercial and industrial customer base.

The facility will include a 175kW polymer electrolyte membrane electrolyser, water demineralisation system and process cooling equipment. As the facility will be of modular design, it will be able to be readily scaled up in the future to produce hydrogen for wider domestic and even export markets.

It is anticipated that plant construction will commence in November 2020, with commissioning by October next year and the plant becoming fully operational in December 2021.

BOC Limited Renewable Hydrogen Production and Refuelling Project

The Renewable Hydrogen Production and Refuelling Project aims to demonstrate renewable hydrogen production at a commercially viable scale and help progress the commercialisation of hydrogen for vehicle transport in Australia.

BOC will install a 220kW electrolyser supplied by ITM Power and 100kW solar array to produce renewable hydrogen through electrolysis at its Bulwer Island site. The electrolyser will have capacity to produce up to 2,400kg of renewable hydrogen per month. The $3.1 million project will supply industrial customers and the first hydrogen vehicle refuelling station in Queensland at QUT's Kelvin Grove Campus. The refuelling station will also facilitate the trial of hydrogen fuel electric vehicles, consistent with the Queensland Government's commitment to the integration of zero-emission vehicles into the government fleet.

CS Energy projects

CS Energy's core business is the generation and sale of electricity in the national electricity market, where they have a trading portfolio of 3,535MW. CS Energy operates three power stations. They have an offtake agreement with hybrid renewable energy project the Kennedy Energy Park, and are investigating other renewable energy offtake opportunities. In the retail market, they have a 50/50 joint venture with Alinta Energy to supply electricity to customers in South East Queensland.

CS Energy is a project partner for an $8.5 million research and development project in Brisbane to produce hydrogen from renewable energy. The project has also received more than $3 million in financial support from the Australian Renewable Energy Agency, with project partners including QUT, Sumitomo Electric Industries, Energy Developments Limited, Swinburne University of Technology, Griffith University and The University of Tokyo contributing the remainder.

Dyno Nobel Moranbah Feasibility of Renewable Green Hydrogen

The world's largest green ammonia plant powered by renewable hydrogen could be built in Queensland, thanks to support from the Australian Renewable Energy Agency (ARENA). ARENA has committed $980,000 for Dyno Nobel Moranbah Pty Ltd, a business of Incitec Pivot Limited, to conduct and assess the feasibility of building a renewable hydrogen and ammonia facility at its existing Moranbah ammonia plant. The $2.7 million feasibility study will look at the potential to use renewable hydrogen produced via electrolysis to increase ammonia production at its facility to meet increased demand in the region for ammonium nitrate. If feasible, the proposed green ammonia facility would include up to a 160MW electrolyser and 210MW solar farm co-located at Moranbah.

H2U-Hub Gladstone

Gladstone has been selected as the location for The Hydrogen Utility's latest project, H2-HubTM Gladstone, a proposed multi-billion dollar chemical complex for the production of green hydrogen and ammonia at industrial scale. The project will integrate mature technologies, such as electrolysis and ammonia synthesis at industrial scale, powered by 100% renewable power to meet the emerging demand for decarbonised products in the energy, chemicals and mobility markets of north Asia.

Northern Oil Advanced Biofuels Pilot Plant

In Gladstone, Northern Oil processes waste such as tyres, green, agricultural and forestry waste and bio-solids into bio-crudes that are ultimately refined into drop-in fuels. More recently, Northern Oil has announced the trial of a hydrogen production process that utilises this bio-crude material. This hydrogen will then be exported to a fuel cell to generate on-site power for the processing plant.

Queensland Nitrates Feasibility Study for a Green Hydrogen and Ammonia Project

$1.9 million in funding from the Australian Renewable Energy Agency has also been provided to Queensland Nitrates Pty Ltd (QNP) to assess the feasibility of the construction and operation of a renewable ammonia plant at its existing facility near Moura in Central Queensland. The consortium, led by QNP and partners Neoen and Worley, proposes to produce 20,000 tonnes per year of ammonia from 3,600 tonnes of renewable hydrogen. The new plant would provide up to 20% of QNP's current ammonia requirements, which is presently manufactured from natural gas. The renewable hydrogen would also fill an ammonia production gap that QNP currently procures from third party suppliers.

The study's aim is to determine the technical and economic feasibility of producing renewable ammonia at a commercial scale, helping to further progress the commercialisation of renewable hydrogen production for both domestic and international use.

If this is proven feasible, QNP would produce hydrogen via electrolysis for one-fifth of its ammonia production. The electrolysers would be powered by a hybrid supply of wind, solar and stored renewable energy from facilities owned and operated by Neoen.

Stanwell Hydrogen Project

Stanwell is investigating the feasibility of a large (10MW or bigger) hydrogen demonstration plant at Stanwell Power Station near Rockhampton. The project would be located approximately 1km north of the existing power station.

Stanwell will produce hydrogen using electrolysis. Electrolysis uses an electrical current to split water and create hydrogen, with oxygen as the only by-product. The hydrogen would be trucked to end use customers or utilised on site for secondary production processes such as ammonia, methanation or power generation.

Queensland Hydrogen Project Map

This interactive project map provides information about publicly released renewable hydrogen projects in Queensland. A range of other projects are still confidential, and the map will be regularly updated as projects become public.

View map

Trade and Investment Queensland

Trade and Investment Queensland (TIQ) is the Queensland Government's dedicated global business agency, providing a central point of contact to navigate investment opportunities and services in Queensland.
With 16 offices in 12 international markets, TIQ has one of the largest and most dynamic networks of any Australian trade agency. Our team can provide expert advice, make the right introductions, and streamline the process of investing in Queensland or establishing a business here.

TIQ's services include:

- *Providing detailed industry knowledge about business costs*
- *Preparing business cases*
- *Arranging site visits*
- *Arranging introductions to industry and service providers*
- *Liaising with government agencies*
- *Researching market intelligence*
- *Partnering with local councils, economic development agencies and private service providers to identify investment-ready projects.*

Contact

In Europe, contact Queensland Trade and Investment Commissioner for Europe Ms Linda Apelt, at **london@tiq.qld.gov.au**

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QUEENSLAND

Hydrogen

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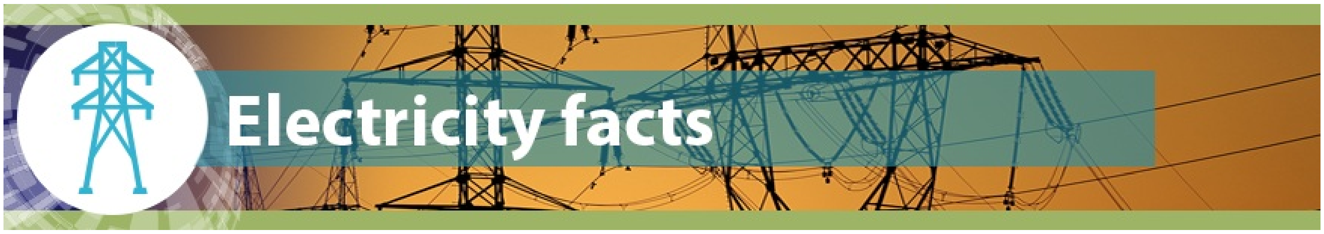
Queensland Government

Electricity facts

nrcan.gc.ca/science-data/data-analysis/energy-data-analysis/energy-facts/electricity-facts/20068



What is electricity?

Electricity is the flow of electrons from a negatively charged body to a positively charged body. Electricity is a secondary energy source with a large number of applications that include heating, lighting, and powering electric motors.

Key facts

- 67% of Canada's electricity comes from renewable sources and 82% from non-GHG emitting sources
- Canada is the world's third largest producer of hydroelectricity
- Canada exports about 8% of the electricity it generates to the United States. There are 34 active major international transmission lines connecting Canada to the U.S.

Electricity industry

The electricity industry performs three main activities:

- **Generating electricity** by using various energy sources and technologies
- **High-voltage transmission of electricity**, usually over long distances, from power plants to end-use markets
- **Distributing electricity** to end-users, usually through low-voltage, local power distribution lines

In some provinces, electricity is provided by vertically integrated electric utilities that are often structured as provincial Crown corporations. Vertically integrated electric utilities dominate every part of the supply chain and are the primary Generator, Retailer and System Operator in the electricity market.

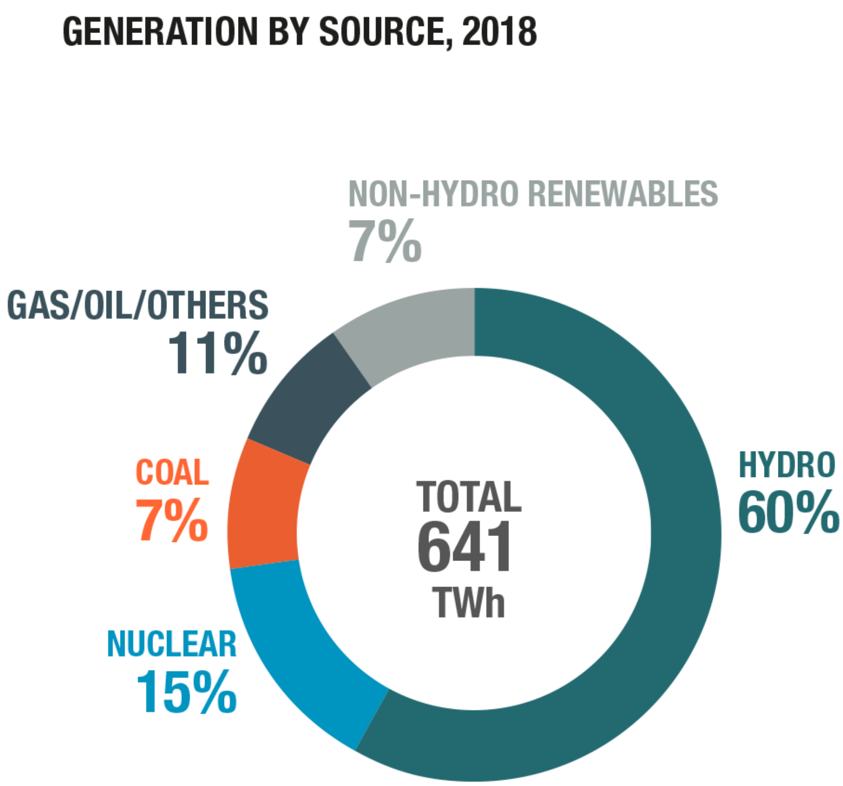
International context

Find out how Canada's electricity ranks on an international scale:

- World production
- World exports

Generation

The Canadian energy industry generated 641.1 terawatt-hours (TWh) of electricity in 2018.



- Text version

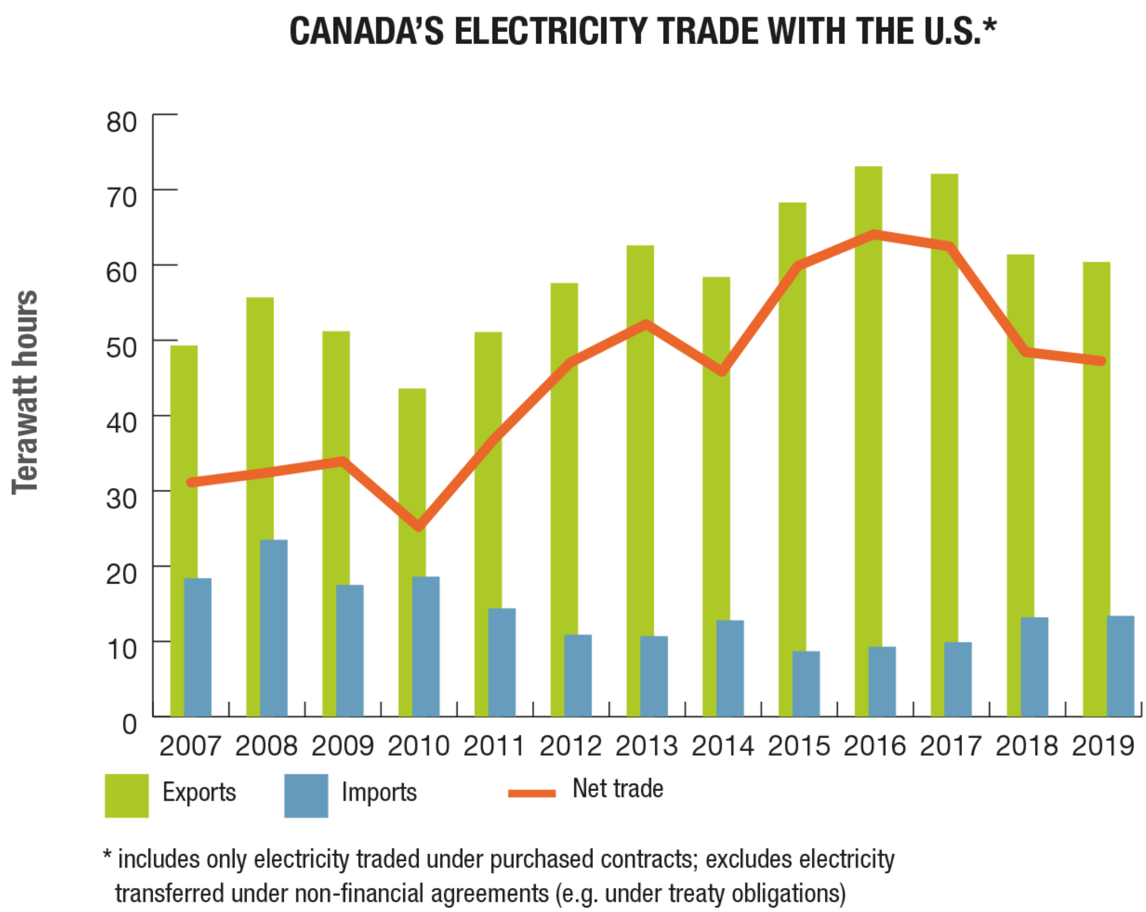
Find out about energy production by region and sources

- Hydro
- Nuclear
- Wind
- Biomass
- Natural Gas
- Petroleum
- Solar

- Coal
- Other

Trade

In 2019, Canada exported 60.4 TWh of electricity to the U.S and imported 13.4 TWh.



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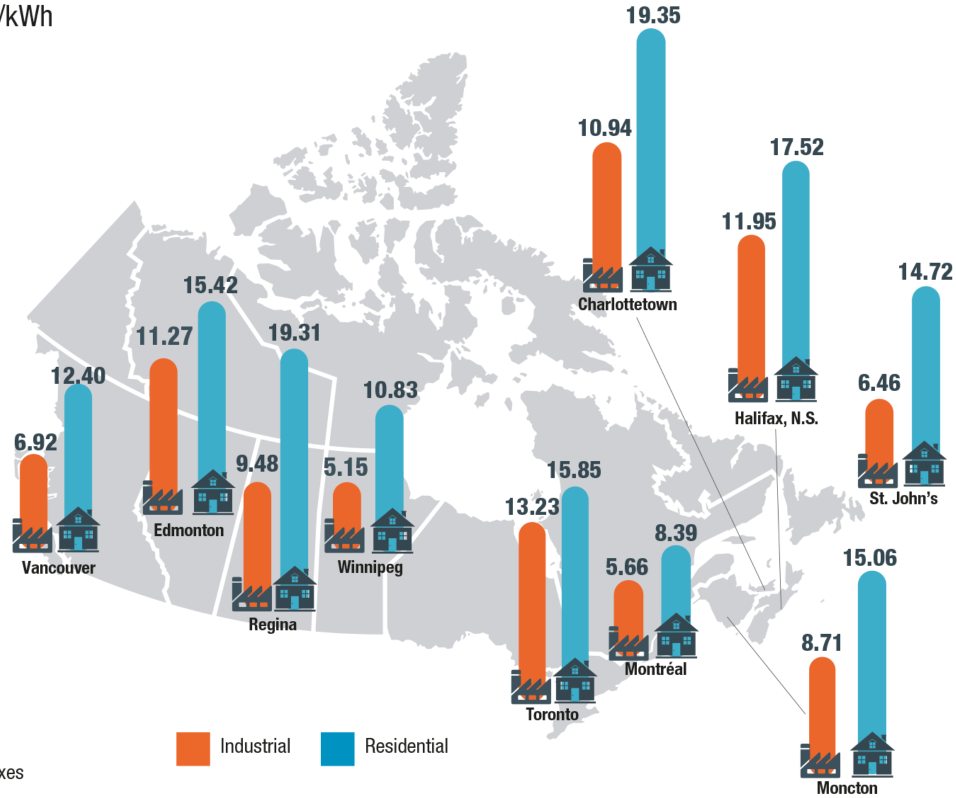
Prices

Since the means of producing electricity as well as the infrastructure to get it to its users varies across provinces, so do the prices of electricity for Canadian residents and industries.

AVERAGE LARGE INDUSTRIAL AND RESIDENTIAL ELECTRICITY PRICES* (AS OF APRIL 2019)
in cents/kWh



*including taxes

▶ Text version

Electricity energy use

The total electricity energy use in Canada in 2016 was **1,812 petajoules (PJ)**. The residential, commercial, industrial, transportation and agricultural sectors all share in the intensive demand for Canadian electricity.

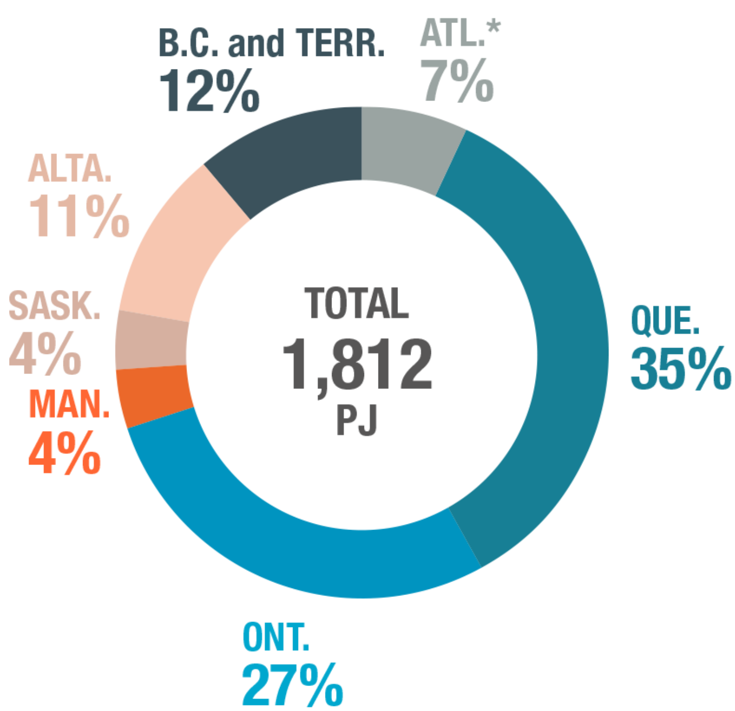
Sector	Energy use (PJ)	% of the total
Residential	604.1	33.3%
Commercial	429.7	23.7%
Industrial	739.0	40.8%
Transportation	4.4	0.2%
Agriculture	34.8	1.9%

Sector	Energy use (PJ)	% of the total
Total	1,812.0	100%

*Secondary energy use

Electricity energy use varies greatly from province to province. Provinces with plentiful and cheap electricity from large scale electricity projects like British Columbia and Quebec, tend to use more electricity per person than those provinces who rely on other energy means to do things like heat their homes and water.

ELECTRICAL ENERGY USE BY PROVINCE, 2017



* Atlantic provinces

▼ Text version

Total electricity energy use in Canada in 2017 was 1,812 petajoules. Québec has the largest share of consumption at 35%, followed by Ontario at 27%, British Columbia and the Territories and Alberta both at 12%, the Atlantic provinces at 7%, Saskatchewan and Manitoba both at 4%.

▼ Sources

- **World production and exports**: International Energy Agency database (Electricity Information [note: IEA production/generation data is expressed on a "gross" basis, i.e. before generating station use])
- **Trade**: Canada Energy Regulator Electricity Annual Trade Summary, Statistics Canada and United States Energy Information Administration table 5.1 (Retail Sales of Electricity to Ultimate Customers)
- **Canadian and provincial supply**: compiled by Statistics Canada and NRCan's Electricity Division from various sources
- **Domestic demand**: Statistics Canada table 25-10-0030-01
- **Prices**: Hydro-Québec (Comparison of Electricity Prices in Major North American Cities)
- **Electricity energy use**: Office of Energy Efficiency Comprehensive Energy Use Database.
- **Levelized cost of electricity**: Canadian Energy Research Institute: A Comprehensive Guide to Electricity Generation Options in Canada
- **World capacity**: United Nations Energy Statistics Yearbook, table 32 (Net installed capacity of electric generating plants)

Date modified:
2020-10-06

Canada's Energy Mix

capp.ca/energy/canadas-energy-mix/

Canada is a resource-rich country with a unique mix of energy sources. While we have an abundance of oil and natural gas, these are not the country's only energy sources. Much of Canada's energy is also generated from hydroelectricity, coal, nuclear power, and renewable resource installations to capture wind, solar and geothermal energy.

Energy sources in Canada, 2018.

Oil

Canada has the third-largest oil reserves in the world. Of the 168 billion barrels of Canadian oil that can be recovered economically with today's technology, 162.5 billion barrels are located in the oil sands.

In 2019, Canada produced 4.7 million barrels of oil per day (b/d), of which 94% came from producing areas in Western Canada. Total production is expected to increase to 5.8 million b/d by 2030. In 2019, Canada exported more than 3.7 million b/d to the U.S. – 99% of Canada's oil exports go to the U.S. but with improved market access and infrastructure (pipelines) Canada could gain global market share, replacing less sustainably produced oil sources.

Oil is used to create transportation fuels such as gasoline, diesel and jet fuel. It's also used for heating, and as a feedstock for petrochemicals which are used to create many products we use every day.

Natural Gas

Canada has vast reserves of natural gas, particularly in British Columbia and Alberta. At current rates of consumption, Canada has enough natural gas to meet the country's needs for 300 years, with enough remaining for export. The export of natural gas using proposed liquefied natural gas (LNG) facilities on Canada's West Coast would enable Canada to ship its abundant energy resources to markets in Asia. This would meet growing energy needs there while helping to reduce global greenhouse emissions by displacing coal.

In addition to heating and cooking, natural gas has a variety of uses including transportation, as a feedstock for petrochemical industries, and electricity generation.

Other Canadian Energy Sources

Coal

Coal is used mainly for two purposes, steel-making and power generation. Coal is by far Canada's most abundant fossil fuel, with 6.6 billion tonnes of recoverable reserves. More than 90% of Canada's coal deposits are located in the western provinces, with some deposits in Nova Scotia. Canada currently has 24 operating coal mines. (More information: Coal Association of Canada)

Hydroelectricity

Most of Canada's hydroelectricity is produced when water is stored in a reservoir behind a dam. Pumped storage is another type of hydro, where water is pumped up to an elevated reservoir for storage. When electricity generation is required, the water is released. At run-of-river facilities, water in a river directly spins a turbine to generate electricity.

Hydro is by far the largest source of electricity generation in Canada, providing more than 60% of Canada's total electricity with an installed capacity of about 85,000 MW. This makes Canada the second largest generator of hydroelectricity in the world, after China. (More information: Waterpower Canada)

Nuclear

Nuclear power plants have been producing commercial electricity in Canada since the early 1960s. Four active nuclear power plants are in operation in Canada, which generated about 15% of Canada’s electricity needs in 2017 (Canada Energy Regulator). Nuclear plants are located in Ontario and one in New Brunswick. (More information: Canadian Nuclear Association)

Wind

Installed wind power capacity in Canada has expanded in recent years and is forecast to continue growing due to increased interest from electricity producers and government initiatives. According to the Canadian Wind Energy Association, in 2018 the total installed wind capacity in Canada is 12,800 megawatts (MW), or about 6% of Canada's electricity demand.

Solar

Solar technologies use the sun's energy to heat homes and water and generate electricity. The quantity of available solar energy varies depending on the season, weather and the technology is used to harness the sunlight. According to the Canada Energy Regulator, in 2015 the installed solar capacity in Canada was about 2,100 MW or about 1.5% of Canada's energy capacity. (More information: Canadian Solar Industries Association)

Geothermal

Geothermal energy can be captured from the heat stored beneath the earth's surface. According to Natural Resources Canada, the highest temperature geothermal resources are located in British Columbia, Northwest Territories, Yukon, and Alberta.

Biomass and Biofuels

Biomass is a biological material in solid, liquid or gaseous form that has stored sunlight in the form of chemical energy, such as wood, peat and agricultural byproducts.

Biofuels derived from renewable sources are a growing form of energy in Canada. In 2013, Canada accounted for 2% of world biofuels production – fifth highest in the world after the United States, Brazil, the European Union and China (Natural Resources Canada). There are two main biofuel types produced in Canada: ethanol (a gasoline substitute) and biodiesel (a diesel substitute). (More information: Advanced Biofuels Canada).

Energy & Science

Congo Hydrogen Plant Being Considered by European Turbine Makers

By Pauline Bax
August 21, 2020, 4:15 AM EDT

- Country has potential to build world's biggest hydro complex
- Plant would be linked to the Inga dams on the Congo River

German turbine makers and natural gas companies are exploring producing green hydrogen in the Democratic Republic of Congo, home to what could become the world's largest hydropower complex.

Should the project go ahead Congo would join Morocco as a potential site for hydrogen production in Africa. The North African country this year signed a memorandum of understanding with Germany over potential production of the clean fuel. Green hydrogen is made using renewable energy.

Officials representing two hydroelectric plant companies, a German-based unit of Austria's Andritz AG and Voith GmbH, which is based in the German town of Heidenheim, as well as natural-gas firm Verbundnetz Gas AG, met with Congo's President Felix Tshisekedi and toured the two dams on the Congo River that provide most of the nation's power. Tshisekedi visited Berlin last year.

Congo's current dams -- Inga I and Inga II -- are part of a long-delayed project known as Grand Inga that's eventually intended to produce as much as 40,000 megawatts of power, making it potentially the world's biggest power complex. Chinese and Spanish developers that want to build Inga III, an 11,050-megawatt hydropower plant on the Congo River, agreed this month to form a consortium after they competed for the $14 billion project in 2018. Their proposal is under review by Tshisekedi.

The visit was backed by the German government, which is "really enthusiastic about Congo," Peter Magauer, a delegate for special tasks on Andritz's management board, said by phone. "There's a potential for energy here that's unlike anywhere else in the world."

Europe wants to increase its capacity to produce green hydrogen as part of plans to boost a climate-friendly recovery from the economic slump caused by the coronavirus outbreak. Germany has announced plans to spend 9 billion euros ($10.7 billion) supporting its domestic hydrogen industry. Hydrogen is produced from water using electrolysis. The gas burns cleanly, leaving only water behind. Green hydrogen is made using renewable energy.

For more on the move toward hydrogen, click here

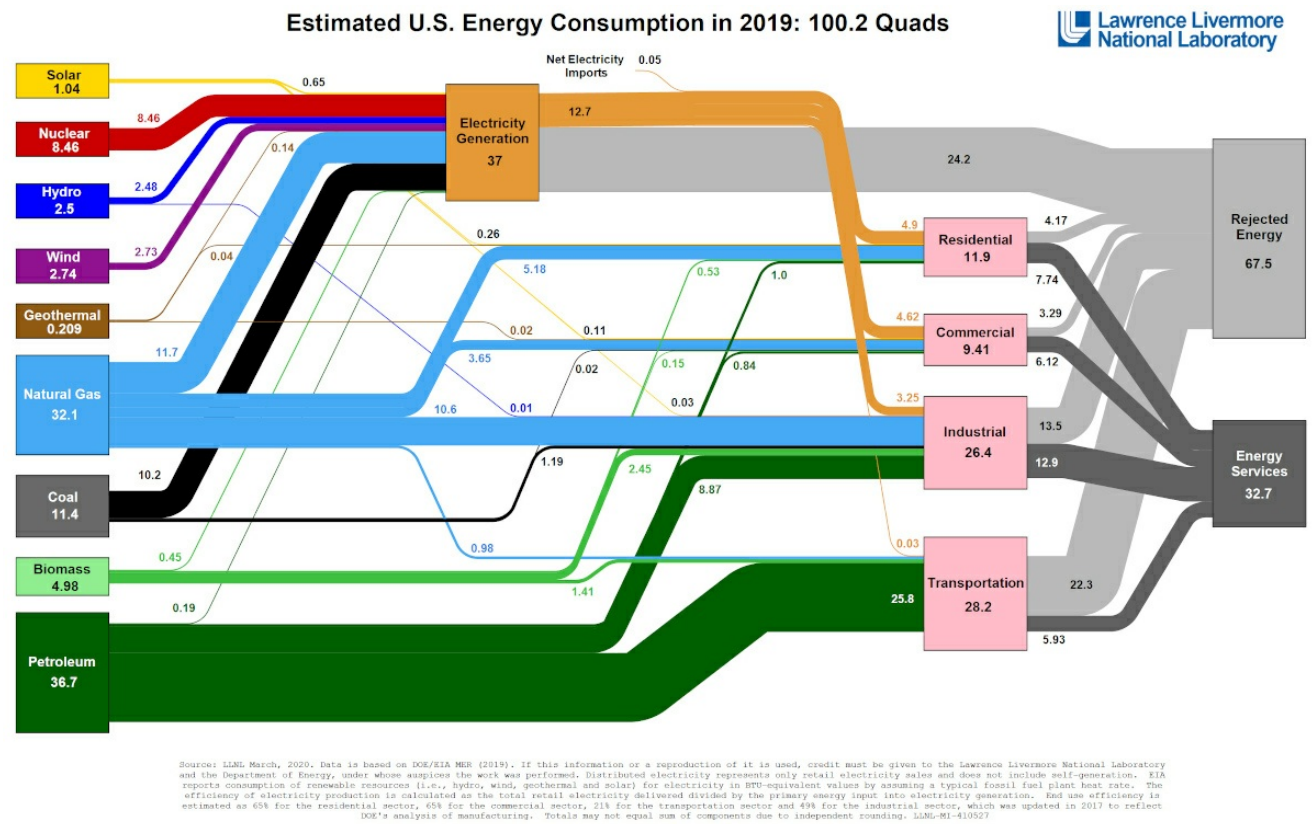
The German delegation is studying building a hydrogen plant on Congo's coast that would include a liquefaction facility. The fuel would then be shipped to Germany, Magauer said. Andritz already works with the European part of the consortium, led by AEE Power Holdings Sarl of Spain, and has its equipment included in the proposal to build the third dam. A hydrogen plant would be an "add on" to the project, he said.

"It's very important that Inga III gets started, both to improve electricity supply in the country and to push economic growth in the region," Magauer said. Producing hydrogen in Congo "makes sense in connection with the competitive and continuous energy supply from Inga."

Visualizing America’s Energy Use, in One Giant Chart

visualcapitalist.com/visualizing-americas-energy-use-in-one-giant-chart/

By Jeff
Desjardins



Have you ever wondered where the country’s energy comes from, and how exactly it gets used?

Luckily, the Lawrence Livermore National Laboratory (LLNL) crunches the numbers every year, outputting an incredible flow diagram that covers the broad spectrum of U.S. energy use.

The 2019 version of this comprehensive diagram gives us an in-depth picture of the U.S. energy ecosystem, showing not only where energy originates by fuel source (i.e. wind, oil, natural gas, etc.) but also how it’s ultimately consumed by sector.

In Perspective: 2019 Energy Use

Below, we’ll use the unit of **quads**, with each quad worth 1 quadrillion BTUs, to compare data for the last five years of energy use in the United States. Each quad has roughly the same amount of energy as contained in 185 million barrels of crude oil.

Year	Energy Consumption	Change (yoy)	Fossil Fuels in Mix
2019	100.2 quads	-1.0	80.0%
2018	101.2 quads	+3.5	80.2%
2017	97.7 quads	+0.4	80.0%
2016	97.3 quads	+0.1	80.8%
2015	97.2 quads	-1.1	81.6%

Interestingly, overall energy use in the U.S. actually decreased to 100.2 quads in 2019, similar to a decrease last seen in 2015.

It's also worth noting that the percentage of fossil fuels used in the 2019 energy mix decreased by 0.2% from last year to make up 80.0% of the total. This effectively negates the small rise of fossil fuel usage that occurred in 2018.

Energy Use by Source

Which sources of energy are seeing more use, as a percentage of the total energy mix?

	2015	2016	2017	2018	2019	Change ('15-'19)
Oil	36.3%	36.9%	37.1%	36.5%	36.6%	**+0.3%**
Natural Gas	29.0%	29.3%	28.7%	30.6%	32.0%	**+3.0%**
Coal	16.1%	14.6%	14.3%	13.1%	11.4%	**-4.7%**
Nuclear	8.6%	8.7%	8.6%	8.3%	8.4%	**-0.2%**
Biomass	4.8%	4.9%	5.0%	5.1%	5.0%	**+0.2%**
Wind	1.9%	2.2%	2.4%	2.5%	2.7%	**+0.8%**
Hydro	2.5%	2.5%	2.8%	2.7%	2.5%	**+0.0%**
Solar	0.5%	0.6%	0.8%	0.9%	1.0%	**+0.5%**
Geothermal	0.2%	0.2%	0.2%	0.2%	0.2%	**+0.0%**

Since 2015, natural gas has grown from 29% to 32% of the U.S. energy mix — while coal's role in the mix has dropped by 4.7%.

In these terms, it can be hard to see growth in renewables, but looking at the data in more absolute terms can tell a different story. For example, in 2015 solar added 0.532 quads of energy to the mix, while in 2019 it accounted for 1.04 quads — a 95% increase.

Energy Consumption

Finally, let's take a look at where energy goes by end consumption, and whether or not this is evolving over time.

	2015	2016	2017	2018	2019	Change ('15-'19)
Residential	15.6%	15.2%	14.7%	15.7%	15.7%	**+0.1%**
Commercial	12.1%	12.5%	12.3%	12.4%	12.4%	**+0.3%**
Industrial	33.9%	33.8%	34.5%	34.6%	34.8%	**+0.9%**
Transportation	38.4%	38.5%	38.5%	37.3%	37.1%	**-1.3%**

Residential, commercial, and industrial sectors are all increasing their use of energy, while the transportation sector is seeing a drop in energy use — likely thanks to more fuel efficient cars, EVs, public transport, and other factors.

The COVID-19 Effect on Energy Use

The energy mix is incredibly difficult to change overnight, so over the years these flow diagrams created by the Lawrence Livermore National Laboratory (LLNL) have not changed much.

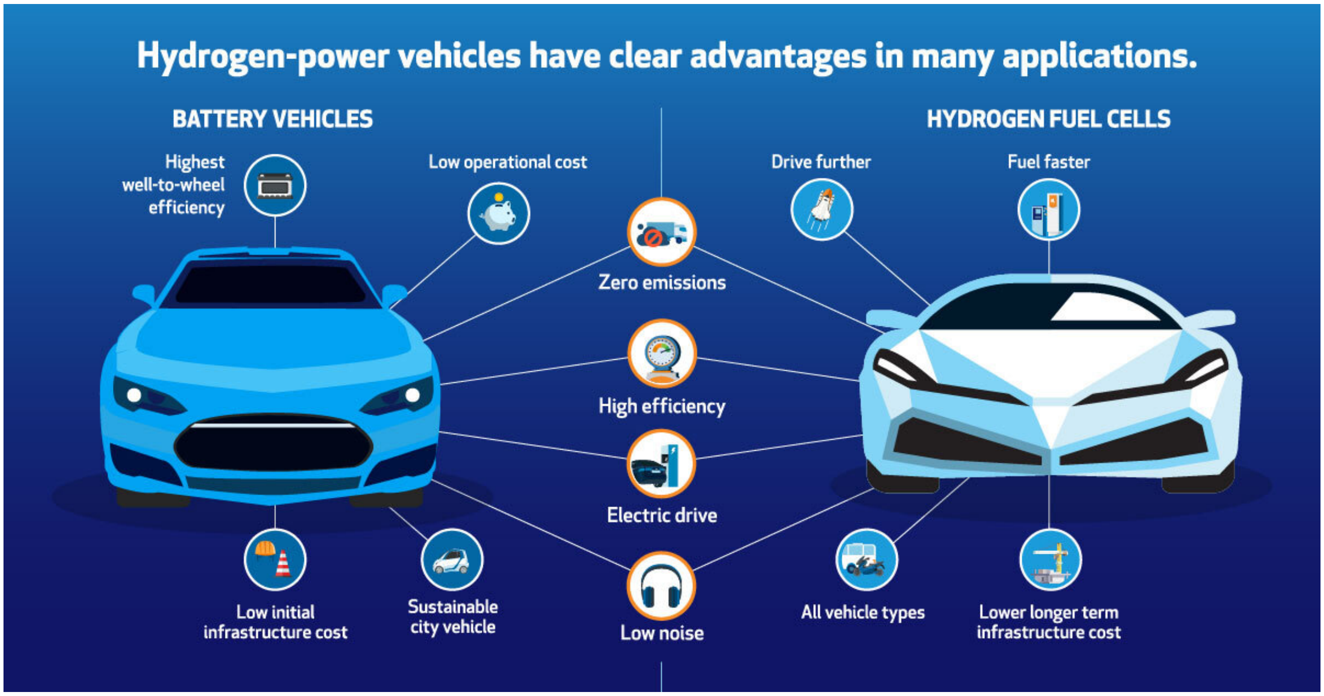
One exception to this will be in 2020, which has seen an unprecedented shutdown of the global economy. As a result, imagining the next iteration of this energy flow diagram is basically anybody's guess.

We can likely all agree that it'll include increased levels of energy consumption in households and shortfalls everywhere else, especially in the transportation sector. However, the total amount of energy used — and where it comes from — might be a significant deviation from past years.

6 Ways Hydrogen and Fuel Cells Can Help Transition to Clean Energy

visualcapitalist.com/6-ways-hydrogen-and-fuel-cells-can-help-transition-to-clean-energy/

By Nicholas LePan



While fossil fuels offer an easily transportable, affordable, and energy-dense fuel for everyday use, the burning of this fuel creates pollutants, which can concentrate in city centers degrading the quality of air and life for residents.

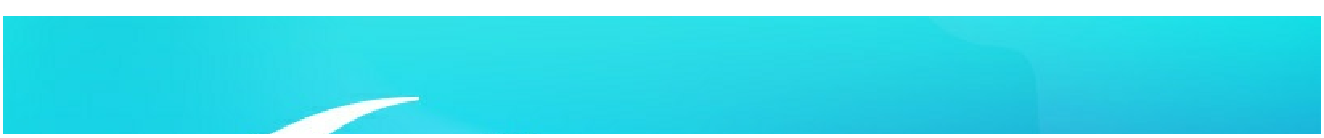
The world is looking for alternative ways to ensure the mobility of people and goods with different power sources, and electric vehicles have high potential to fill this need.

But did you know that not all electric vehicles produce their electricity in the same way?

Hydrogen: An Alternative Vision for the EV

The world obsesses over battery technology and manufacturers such as Tesla, but there is an alternative fuel that powers rocket ships and is road-ready. Hydrogen is set to become an important fuel in the clean energy mix of the future.

Today's infographic comes from the Canadian Hydrogen and Fuel Cell Association (CHFCA) and it outlines the case for hydrogen.



6 Ways Hydrogen and Fuel Cells Can Help Transition to Clean Energy

At the 2015 COP21 in Paris, 195 countries agreed to limit global warming to 2°C above pre-industrial levels.

To reach this target, the world must cut **60% of energy-related carbon dioxide (CO^2) emissions by 2050**— even as the population grows by more than two billion people.

Hydrogen and fuel cells can help achieve this urgent challenge to dramatically change our global energy system.

Here are 6 ways hydrogen is well-positioned for the transition to renewable energy.

1 H_2 safety

Hydrogen has been safely used, stored and transported in industry for over 50 years.

Fuel cell electric vehicles (FCEVs) have a proven safety record, clocking in over 10 million miles of operation.

Source: FCHEA

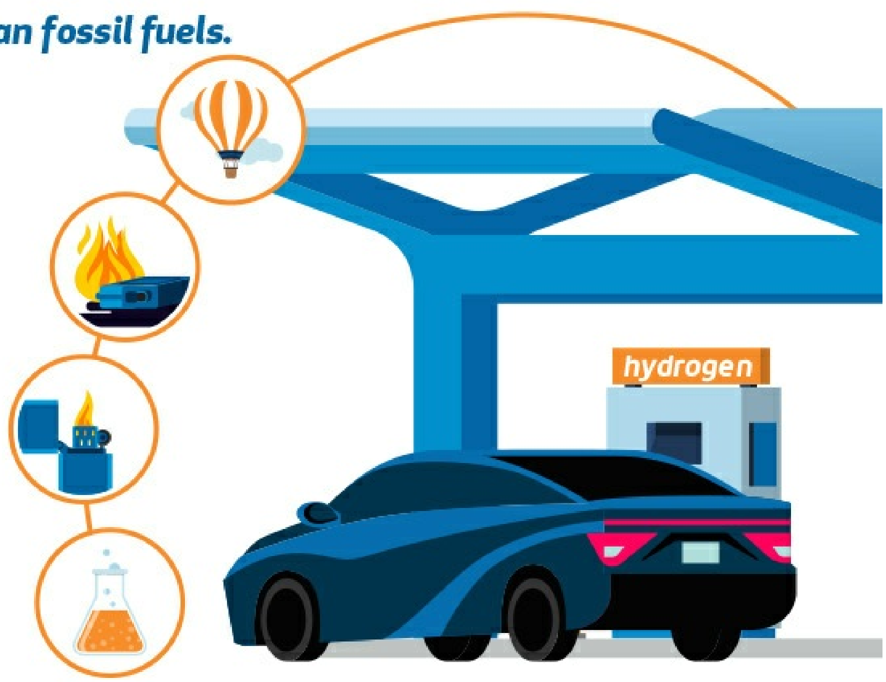
Hydrogen is safer than fossil fuels.

14 times lighter than air
Hydrogen disperses quickly

Flames have low radiant heat
Low risk of secondary fires

Less combustible
Optimal combustion mixture with air is 29% (gasoline is 2%)

Non-toxic
Only pure water is produced when it is combined with oxygen in a fuel cell to produce electricity



2 The

economics of hydrogen

Low carbon intensity hydrogen can be produced economically to supply growing demand for clean energy applications.

Source: Horner Automation

As long as there is water in the world, there is no way to

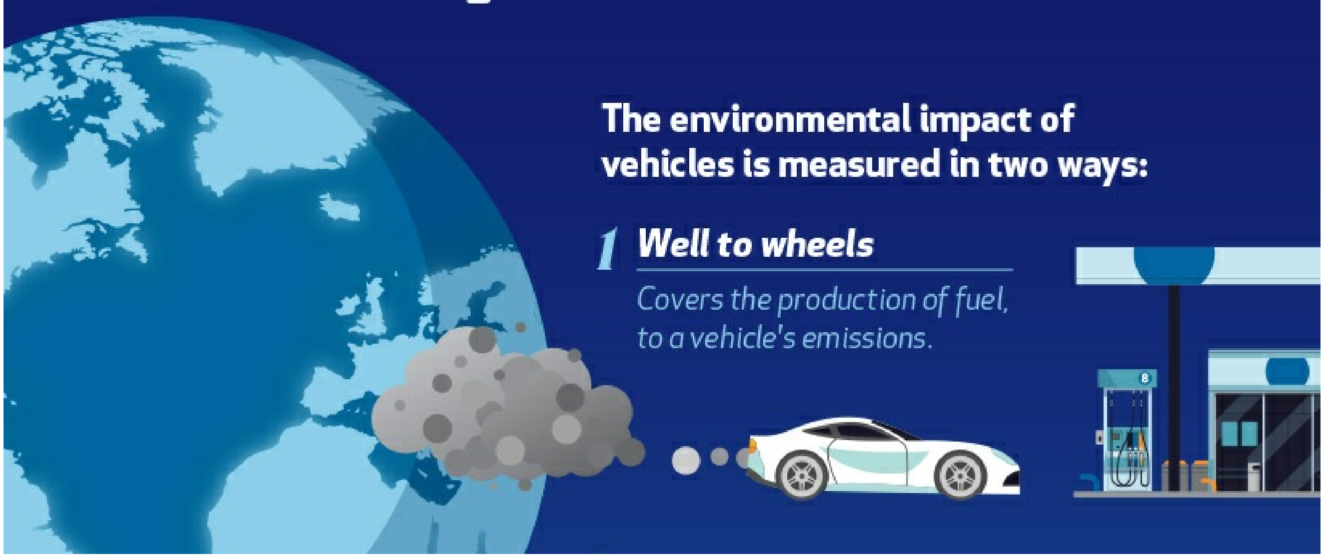
the world, there is no way to run out of hydrogen.

3 Hydrogen does not shift the burden from the tailpipe to production

The environmental impact of vehicles is measured in two ways:

1 *Well to wheels*

Covers the production of fuel, to a vehicle's emissions.



2 Cradle to grave

Covers a vehicle's production, operation, and destruction.

Both measurements show that hydrogen-powered fuel cells significantly reduce GHG emissions and air pollutants.

*They are also **2-3 times more energy efficient** than a combustion vehicle.*

2.7 g/km — Fuel cell electric vehicle (FCEV)

20.9 g/km — Battery electric vehicle (BEV)

Source: Comparative Analysis of Infrastructures: Hydrogen Fueling and Electric Charging of Vehicles

4 fuel cell or Battery

Battery and hydrogen-powered vehicles have the same goal: reduce environmental impact of oil consumption.

But, HCEVs have clear advantages in many applications.

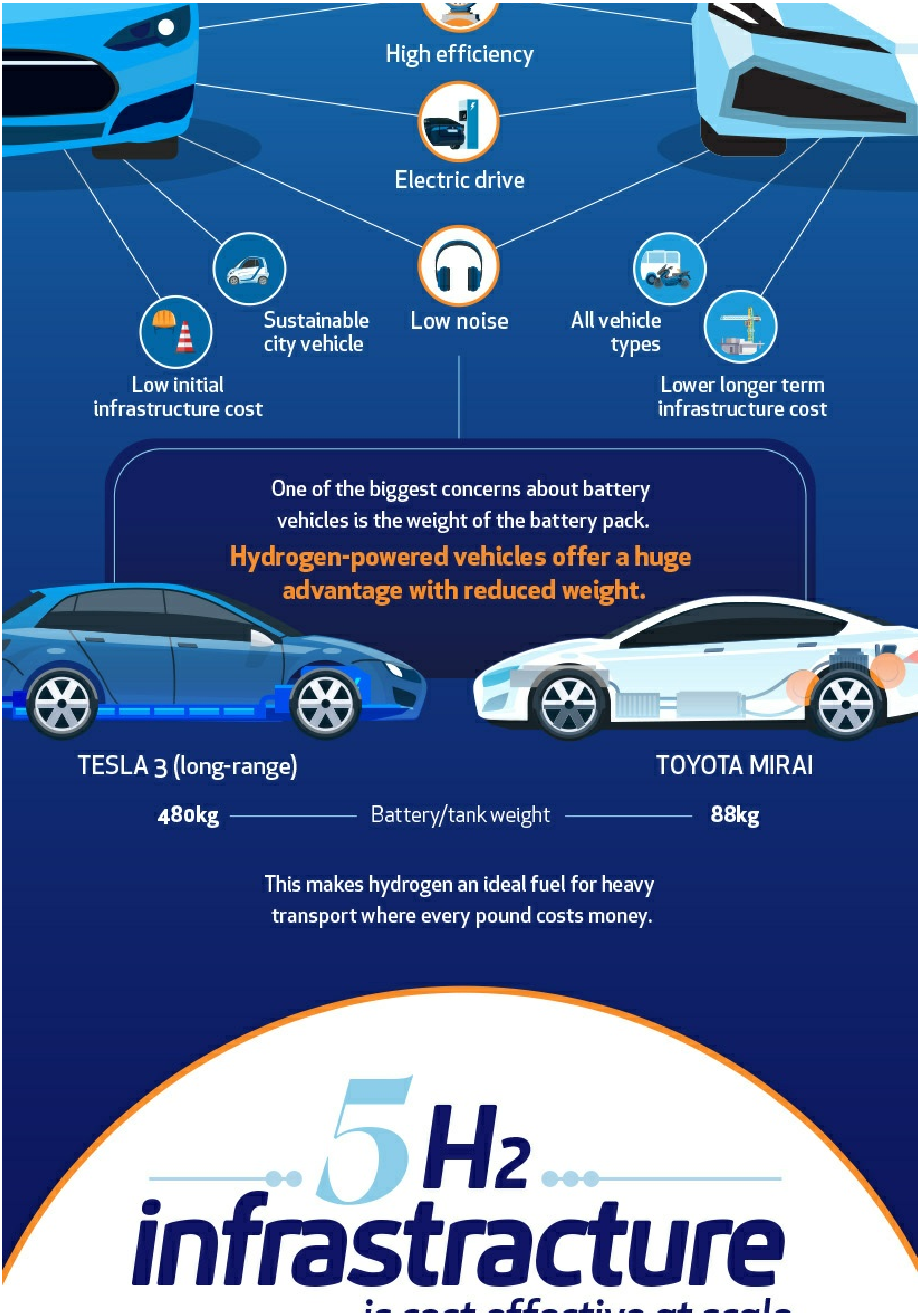
BATTERY VEHICLES

- Highest well-to-wheel efficiency
- Low operational cost

HYDROGEN FUEL CELLS

- Fuel faster
- Drive further

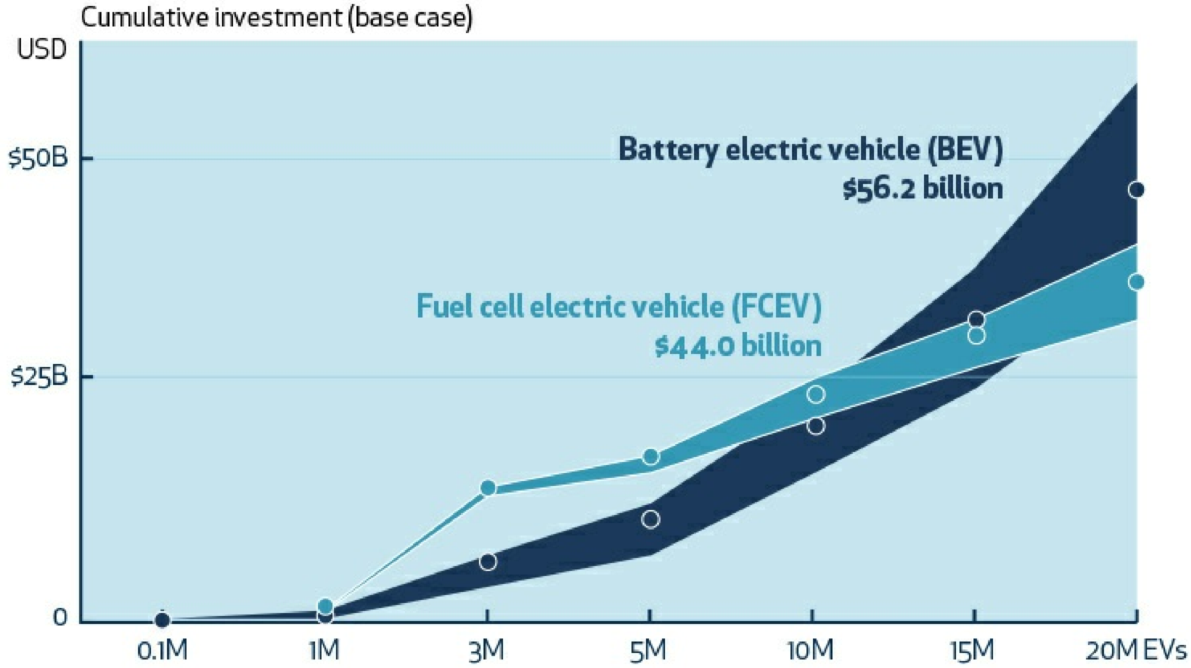
Zero emissions



High efficiency
Electric drive
Low noise
Sustainable city vehicle
All vehicle types
Low initial infrastructure cost
Lower longer term infrastructure cost
One of the biggest concerns about battery vehicles is the weight of the battery pack.
Hydrogen-powered vehicles offer a huge advantage with reduced weight.
TESLA 3 (long-range)
TOYOTA MIRAI
480kg
Battery/tank weight
88kg
This makes hydrogen an ideal fuel for heavy transport where every pound costs money.
5 H2
infrastracture

is cost effective at scale

Compared to charging BEVs, hydrogen infrastructure is more cost-effective in the long run.



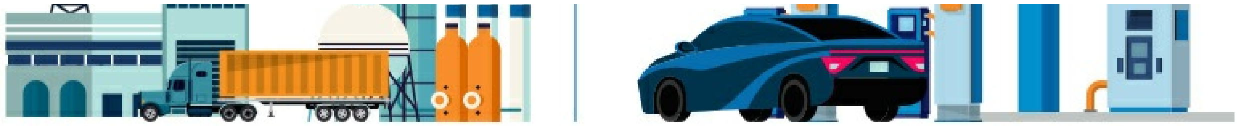
Source: Comparative Analysis of Infrastructures: Hydrogen Fueling and Electric Charging of Vehicles

6 The H2 event horizon road ready

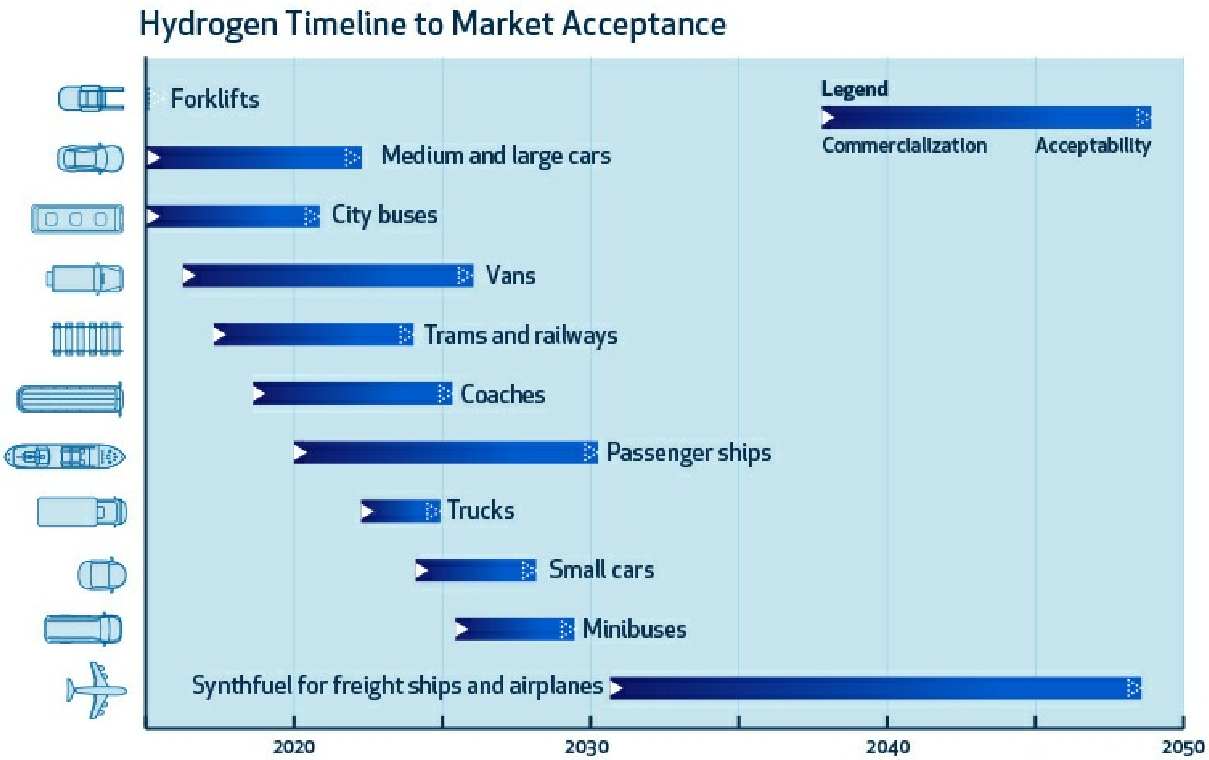
Worldwide efforts lay groundwork for near-term deployment of hydrogen and fuel cells.

In 2017, the **Hydrogen Council** was founded with support from **53 energy, transportation and other industrial companies.**

Globally, countries have announced plans to build **2800 hydrogen refueling stations** by 2025.



Source: McKinsey



Source: McKinsey

***Hydrogen fuel cell is nearing deployment readiness** in a wide range of applications.*

Hydrogen Supply and Demand

Some scientists have made the argument that it was not hydrogen that caused the infamous Hindenburg to burst into flames. Instead, the powdered aluminum coating of the zeppelin, which provided its silver look, was the culprit. Essentially, the chemical compound coating the dirigibles was a crude form of rocket fuel.

Industry and business have safely used, stored, and transported hydrogen for 50 years, while hydrogen-powered electric vehicles have a proven safety record with over 10 million miles of operation. In fact, hydrogen has several properties that make it safer than fossil fuels:

- 14 times lighter than air and disperses quickly
- Flames have low radiant heat
- Less combustible
- Non-toxic

Since hydrogen is the most abundant chemical element in the universe, it can be produced almost anywhere with a variety of methods, including from fuels such as natural gas, oil, or coal, and through electrolysis. Fossil fuels can be treated with extreme temperatures to break their hydrocarbon bonds, releasing hydrogen as a byproduct. The latter method uses electricity to split water into hydrogen and oxygen.

Both methods produce hydrogen for storage, and later consumption in an electric fuel cell.

Fuel Cell or Battery?

Battery and hydrogen-powered vehicles have the same goal: to reduce the environmental impact from oil consumption. There are two ways to measure the environmental impact of vehicles, from “Well to Wheels” and from “Cradle to Grave”.

Well to wheels refers to the total emissions from the production of fuel to its use in everyday life. Meanwhile, cradle to grave includes the vehicle’s production, operation, and eventual destruction.

According to one study, both of these measurements show that hydrogen-powered fuel cells significantly reduce greenhouse gas emissions and air pollutants. For every kilometer a hydrogen-powered vehicle drives it produces only 2.7 grams per kilometer (g/km) of carbon dioxide while a battery electric vehicle produces 20 g/km.

During everyday use, both options offer zero emissions, high efficiency, an electric drive, and low noise, but hydrogen offers weight-saving advantages that battery-powered vehicles do not.

In one comparison, Toyota’s Mirai had a maximum driving range of 312 miles, 41% further than Tesla’s Model 3 220-mile range. The Mirai can refuel in minutes, while the Model 3 has to recharge in 8.5 hours for only a 45% charge at a specially configured quick charge station not widely available.

However, the world still lacks the significant infrastructure to make this hydrogen-fueled future possible.

Hydrogen Infrastructure

Large scale production delivers economic amounts of hydrogen. In order to achieve this scale, an extensive infrastructure of pipelines and fueling stations are required. However to build this, the world needs global coordination and action.

Countries around the world are laying the foundations for a hydrogen future. In 2017, CEOs from around the word formed the Hydrogen Council with the mission to accelerate the investment in hydrogen.

Globally, countries have announced plans to build 2,800 hydrogen refueling stations by 2025. German pipeline operators presented a plan to create a 1,200-kilometer grid by 2030 to transport hydrogen across the country, which would be the world's largest in planning.

Fuel cell technology is road-ready with hydrogen infrastructure rapidly catching up. Hydrogen can deliver the power for a new clear energy era.

The Hydrogen City: How Hydrogen Can Help to Achieve Zero Emissions

visualcapitalist.com/the-hydrogen-city-how-hydrogen-can-help-to-achieve-zero-emissions/

By Nicholas LePan

In the modern context, cities create somewhat of a paradox.

While cities are the main drivers for improving the lives of people and entire nations, they also tend to be the main contributors of pollution and CO2 emissions.

How can we encourage this growth, while also making city energy use sustainable?

Resolving the Paradox

Today's infographic comes to us from the Canadian Hydrogen and Fuel Cell Association and it outlines hydrogen technology as a sustainable fuel for keeping urban economic engines running effectively for the future.


City
How Hydrogen Can Help Achieve Zero Emissions
As the world's population expands, humanity is becoming increasingly concerned about our environmental impacts.
Hydrogen and its applications could very well become our saving grace.
To keep economies moving and reduce emissions at the same time,
hydrogen fuel cell technology
can be employed.
Hydrogen has wide-reaching benefits:

Improve the air we breathe

Ensure secure and reliable energy

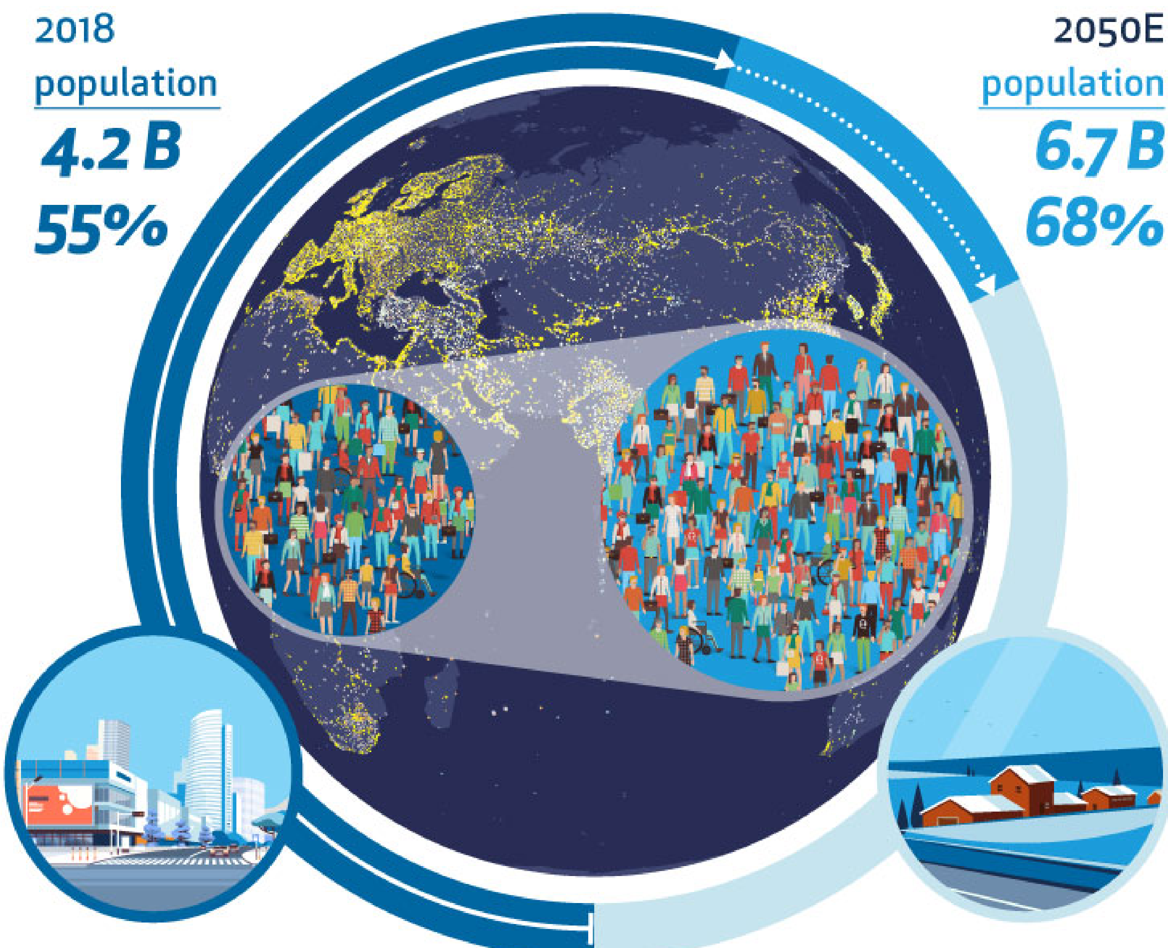
Reduce greenhouse gas emission

Create highly skilled jobs

The urban *economic* engine

Today, more than half of the world lives in cities, and this is only going to increase.

Urban share of world population



SOURCE: United Nations

Good news

Cities function as economic engines, accounting for more than **80%** of global gross domestic product (GDP)

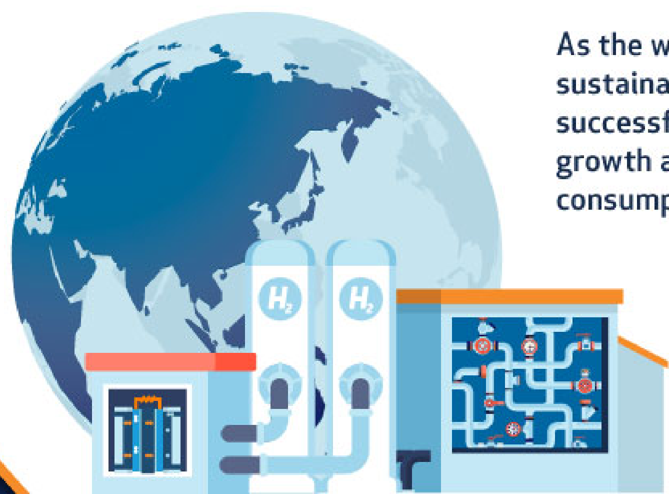
SOURCE: McKinsey

Bad news

Cities consume over **two-thirds** of the world's energy,

and account for **over 70%** of global CO2 emissions.

SOURCE: C40 Cities



As the world continues to urbanize, sustainable development relies on the successful management of urban growth and its impacts on energy consumption and the environment.

Hydrogen and fuel cell technology

can deliver clean energy at every scale in the urban landscape.

The hydrogen city

Many countries will need to meet the energy demands of growing urban economies.

The global economy and its urban hubs rely on a continuous supply of power for:

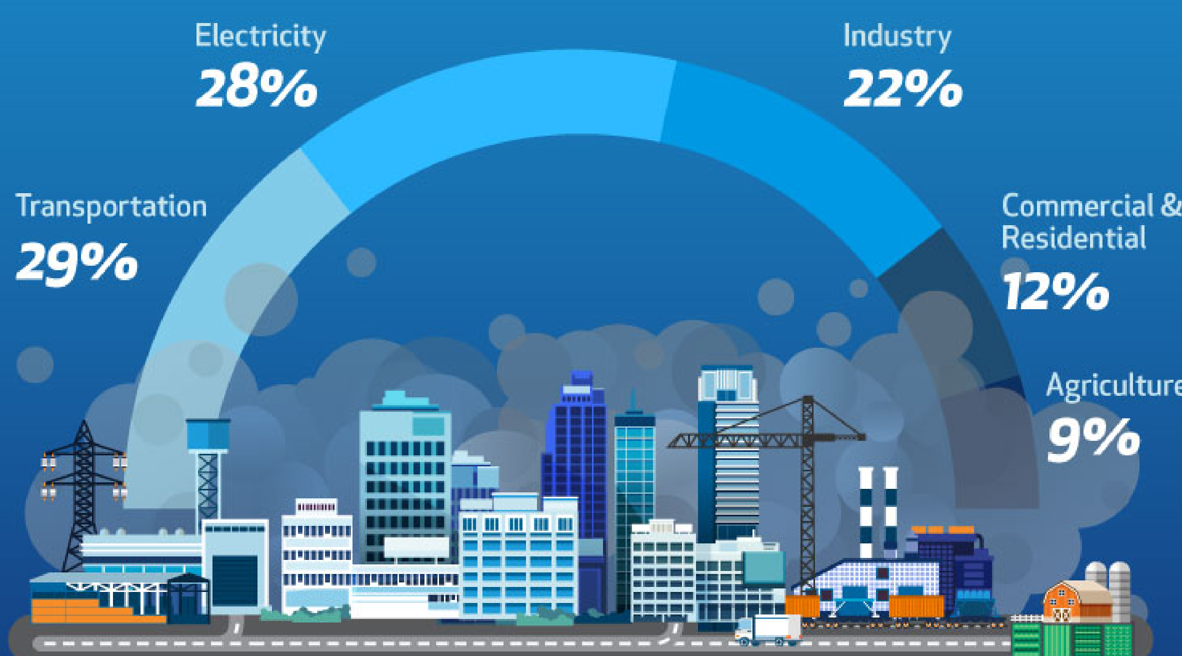
Industrial Energy

Transportation

Utilities infrastructure

The United States's greenhouse gas output by sector breaks down as so:

Share of emissions by economic sector for 2017 (%)



SOURCE: United States Environment Protection Agency

Hydrogen can be used in every sector to ensure a sustainable and resilient renewable energy infrastructure.

It can also reduce other urban problems like noise and water pollution, ensuring we have an energy system that is cleaner and more efficient.

Transport

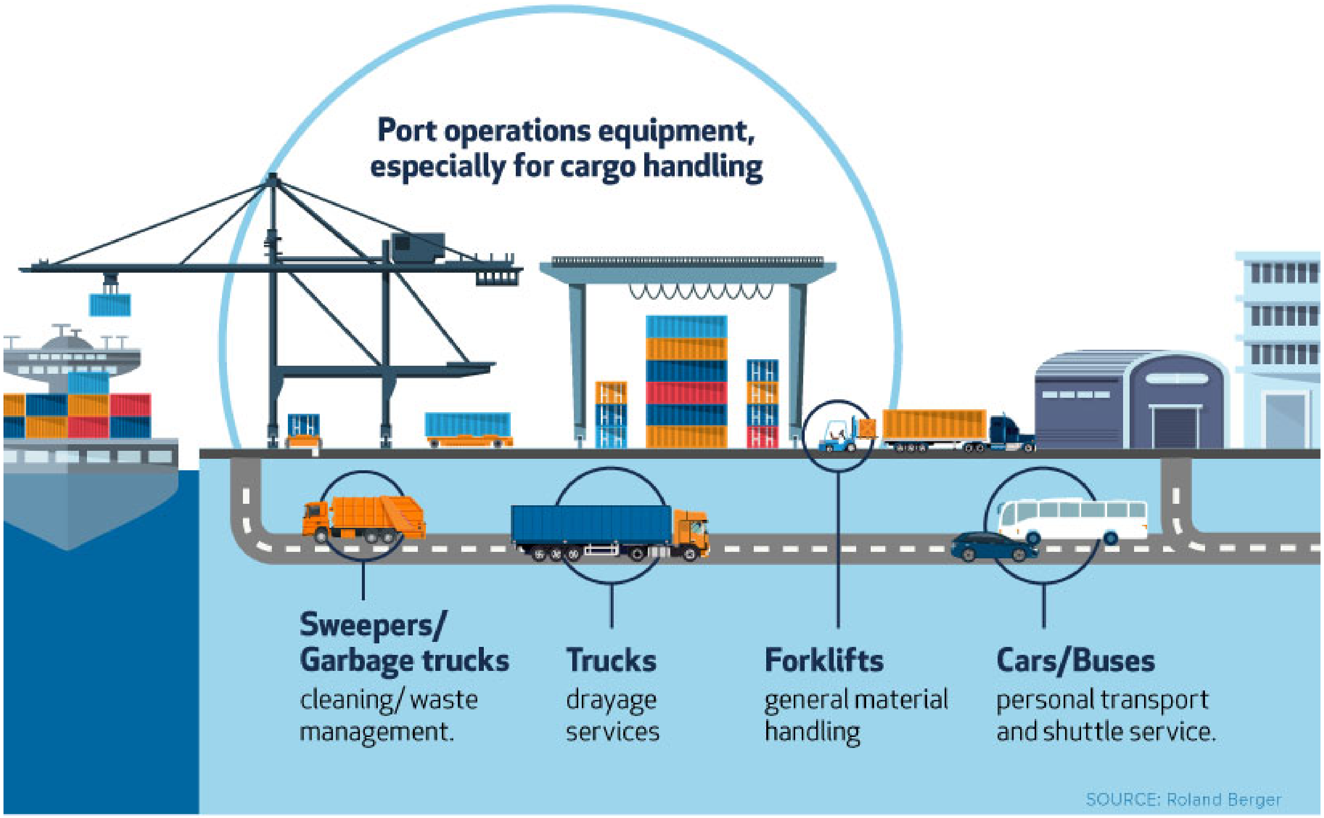
and power generation

Industries use hydrogen and fuel cells for:

Onsite power generation

Power for commercial trucks, buses and forklifts

Hydrogen provides a clean fuel alternative for heavy industrial vehicles to deliver the goods that cities need.



Transportation

Hydrogen fuel cell electric vehicles deliver extra benefits such as:

Long range

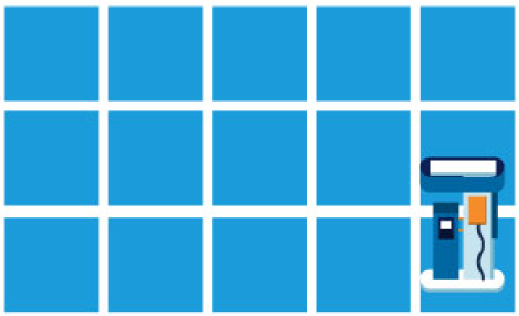
Fast refueling time

Operational cost

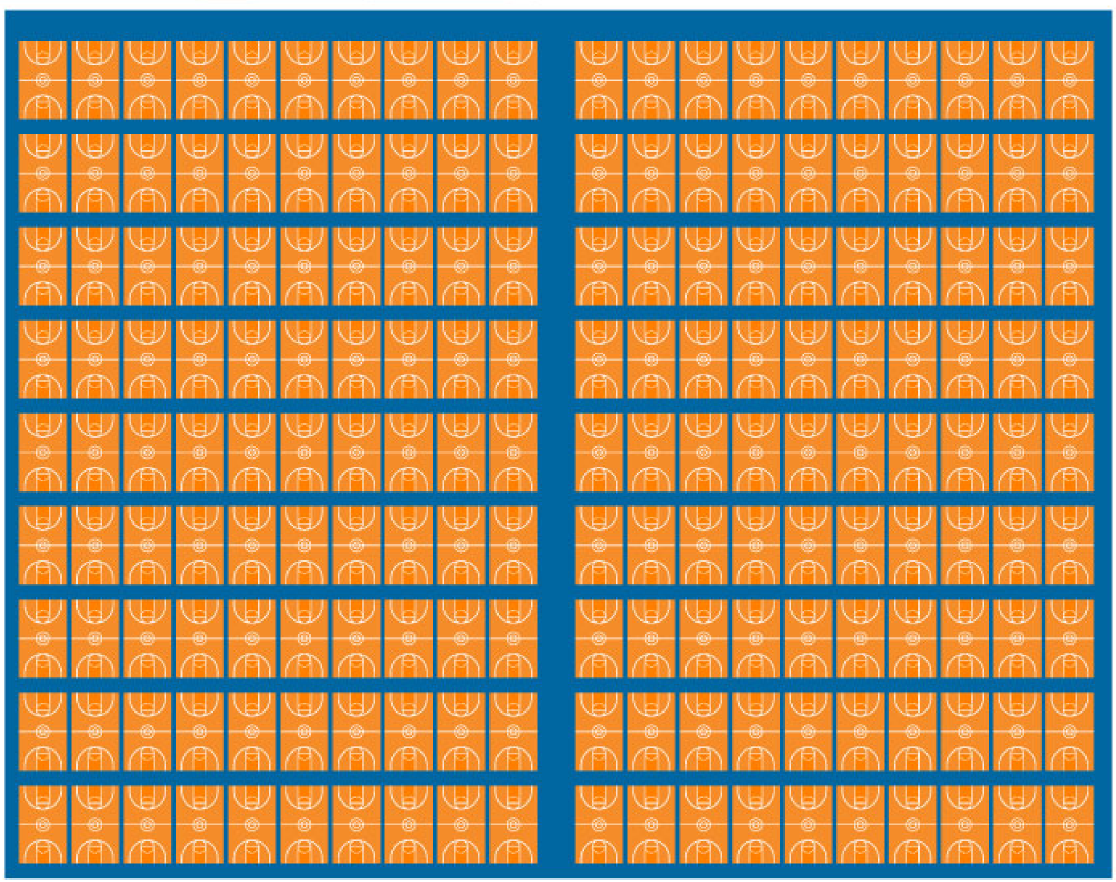
savings for heavy duty vehicles

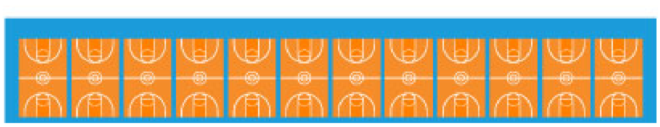
Lower space requirements for hydrogen infrastructure make it easy to adopt and scale.

Due to faster refueling times, hydrogen stations occupy **15 times less space** than battery chargers, which need more charging points due to longer charging times.



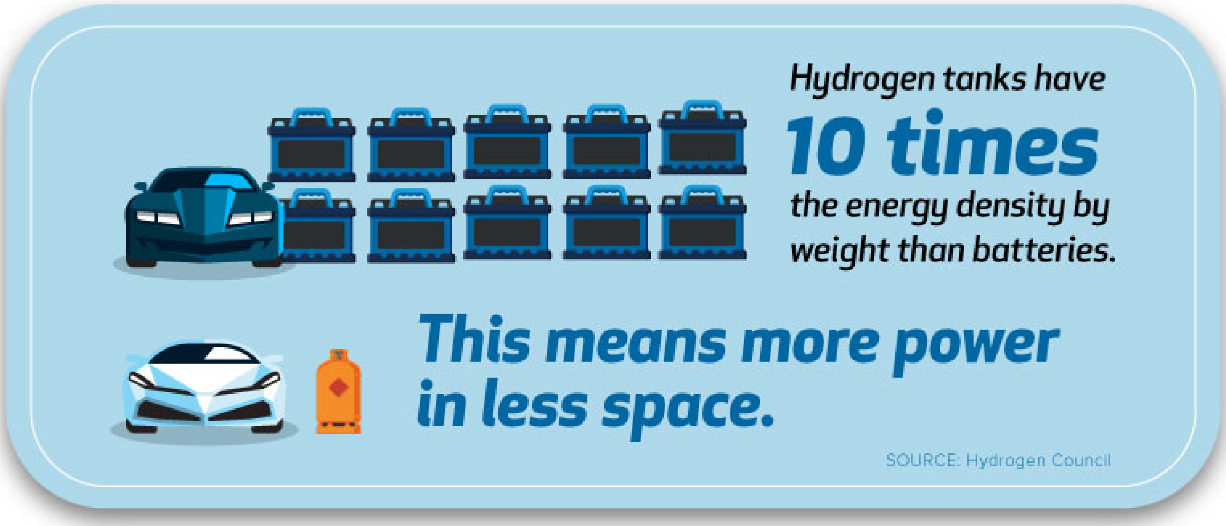
If all current taxis in New York City ran on batteries, their charging stations would require **180 NBA courts** of space





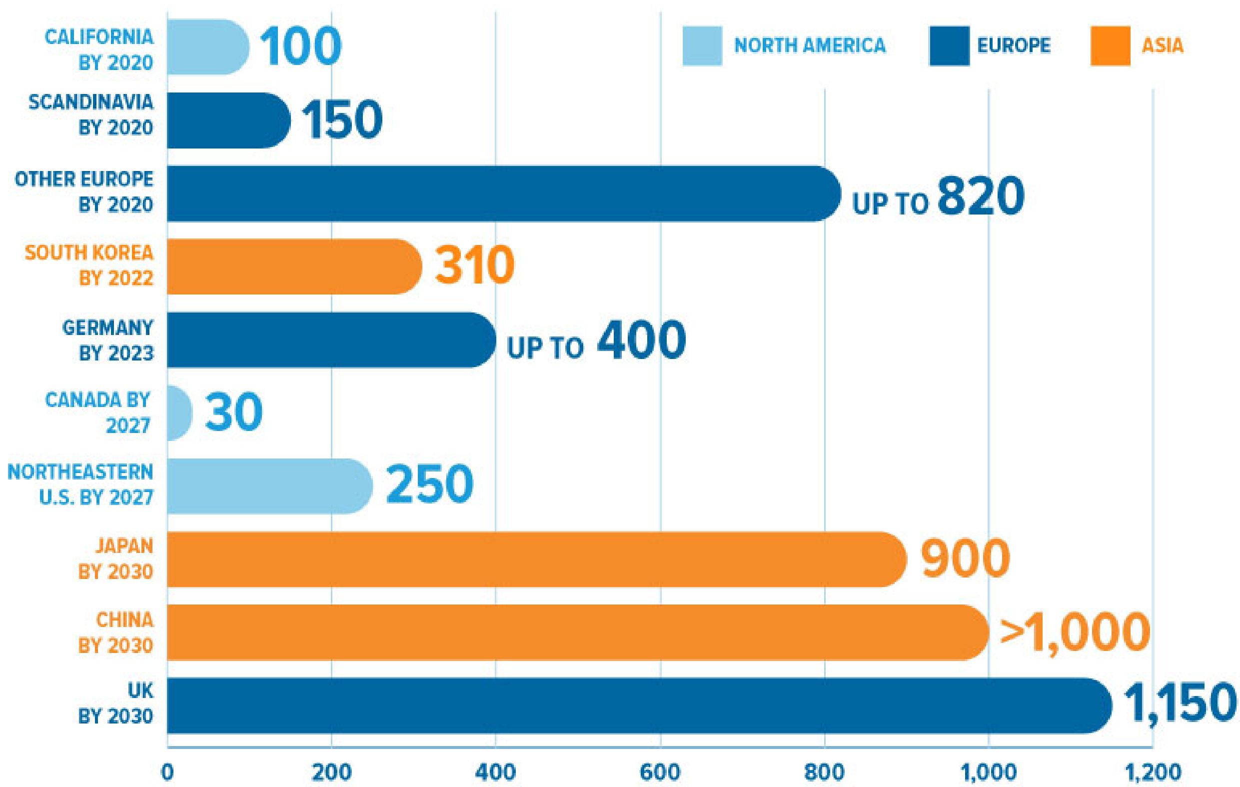
In contrast, hydrogen-powered taxis would only need to refuel using the space of **12 NBA courts** using the space of 12 NBA courts

SOURCE: Hydrogen Council



SOURCE: Hydrogen Council

Planned Hydrogen Refueling Stations (HRS)



Source: Hydrogen Council, McKinsey

Utilities infrastructure

infrastructure

Renewable energy sources, like the sun and wind, can't produce energy all the time.

Hydrogen can be deployed to replace fossil fuels and store energy as well as provide

heat and power

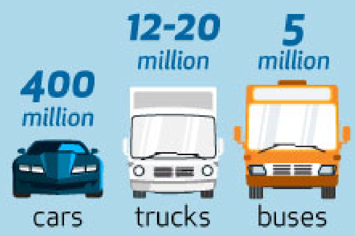
for both residential and commercial purposes.

By 2050, Hydrogen could, each year:

Generate **~1,500 TWh** of electricity

Provide **10%** of the heat and power required by households and industry

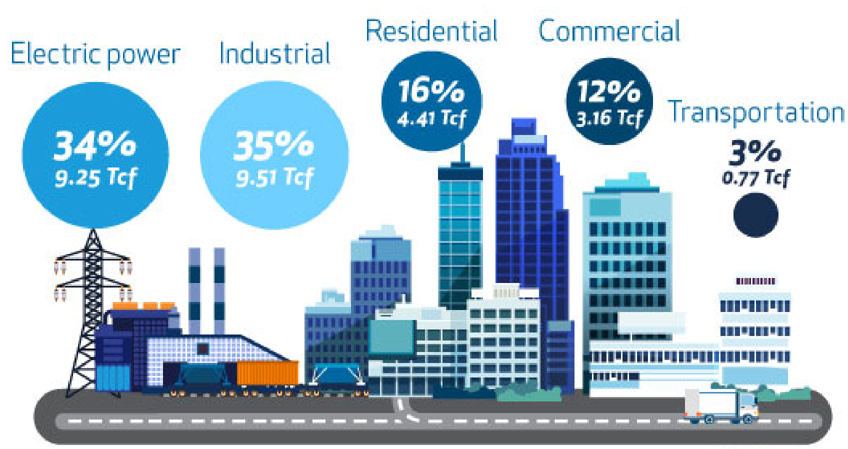
Power a global fleet of



SOURCE: Hydrogen Council

The United States used **~27 trillion cubic feet (Tcf)** of natural gas in 2017, the equivalent to the volume of one and a half Lake Eries, for a total of 29% of U.S. primary energy consumption.

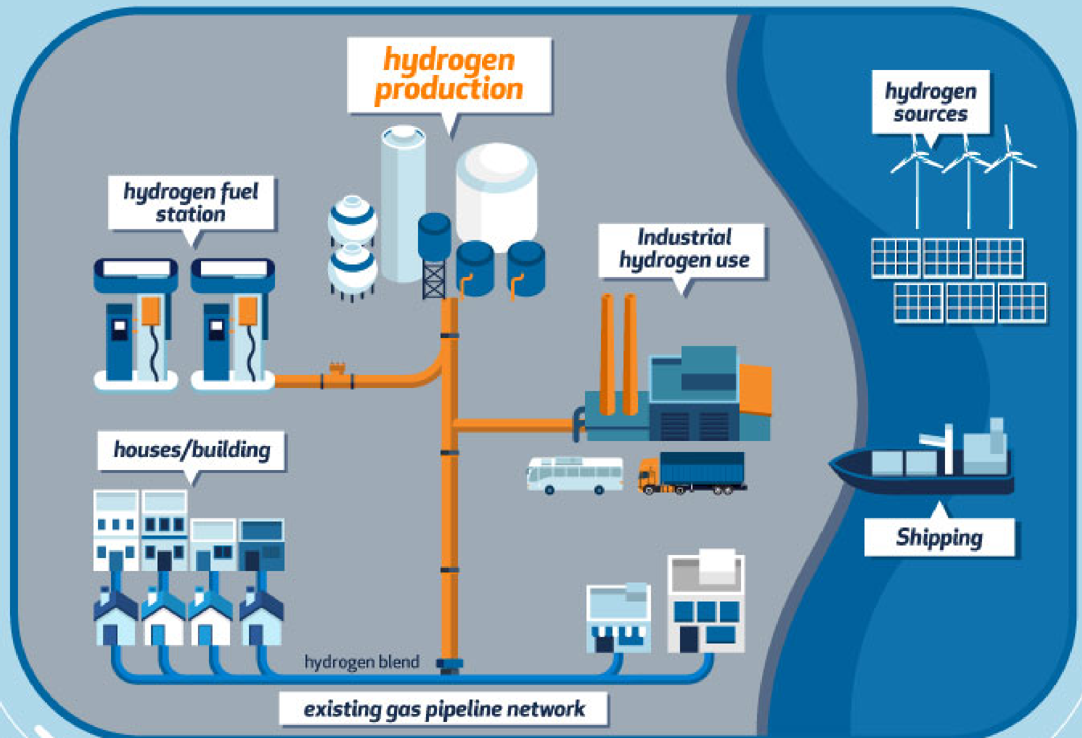
U.S. NATURAL GAS USAGE BY SECTOR:

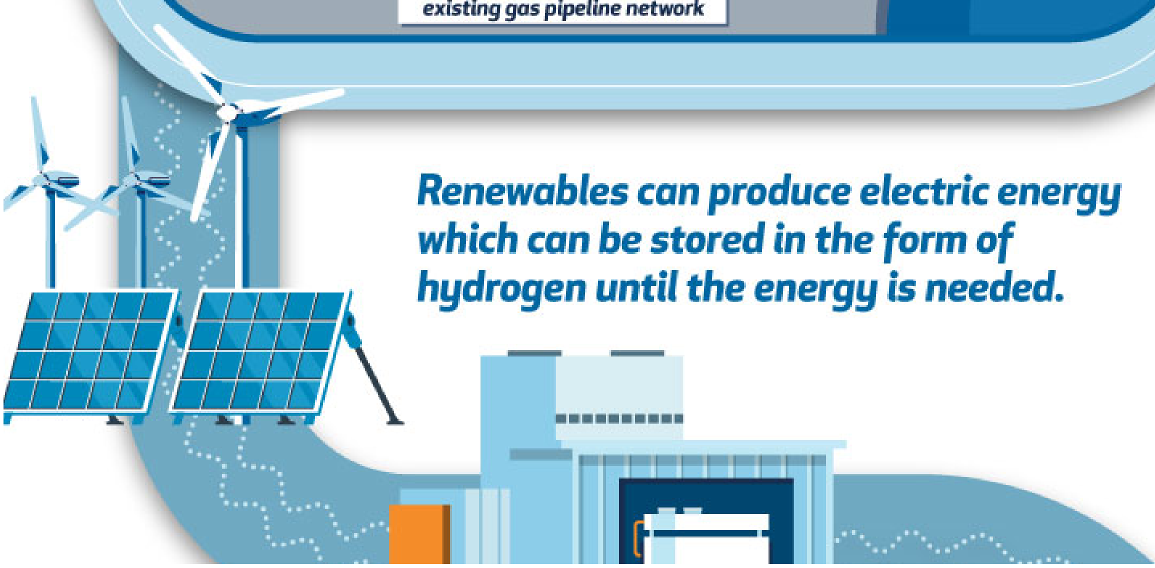


SOURCE: EIA

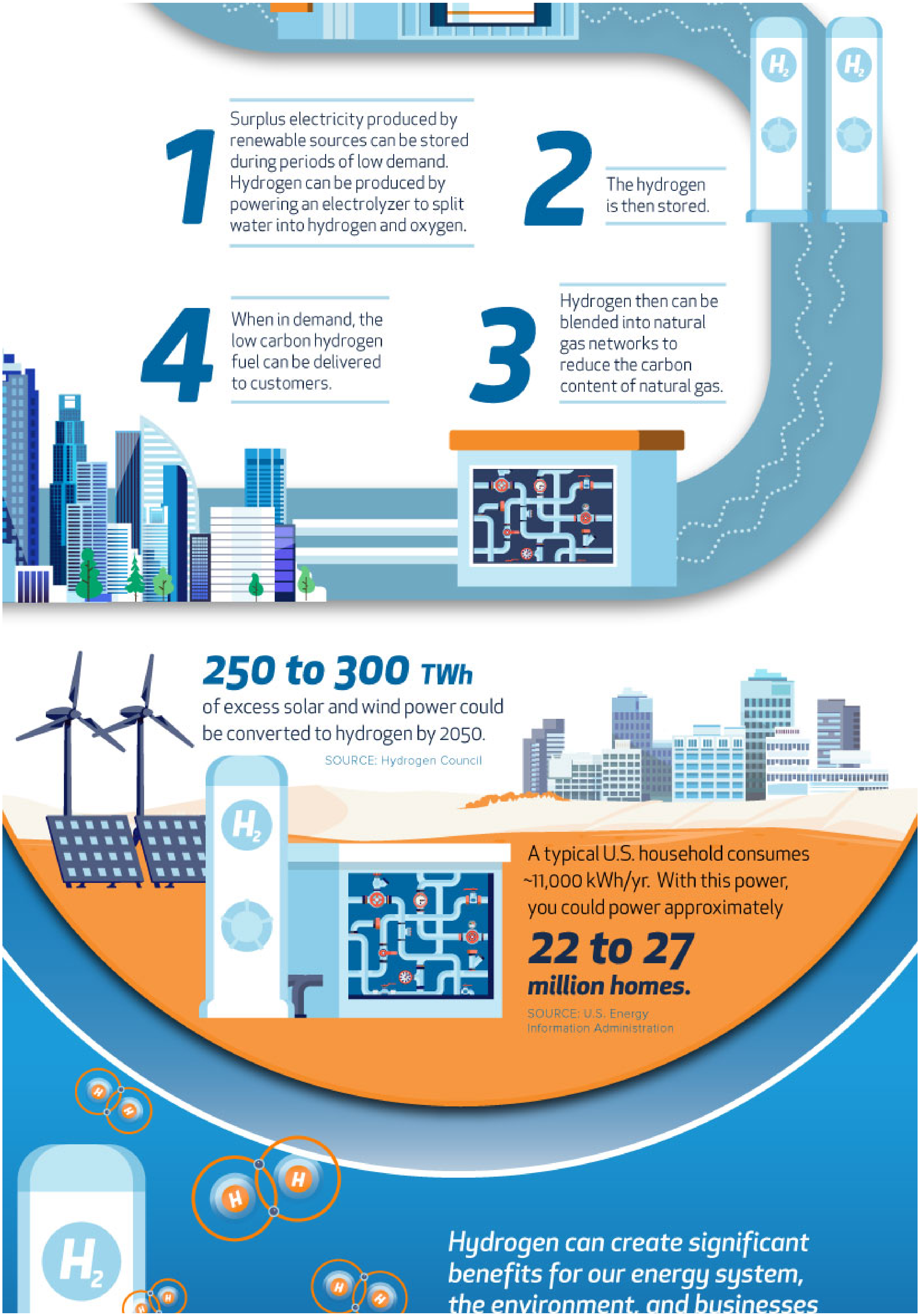
For heat and power, a gradual approach can be used,
low concentrations of hydrogen can be blended into natural gas networks,
before entire cities are converted to pure hydrogen for generating power and heating.

Hydrogen is an energy carrier which can move and deliver energy in a usable form to homes and businesses.





Renewables can produce electric energy which can be stored in the form of hydrogen until the energy is needed.


1
Surplus electricity produced by renewable sources can be stored during periods of low demand. Hydrogen can be produced by powering an electrolyzer to split water into hydrogen and oxygen.
2
The hydrogen is then stored.
3
Hydrogen then can be blended into natural gas networks to reduce the carbon content of natural gas.
4
When in demand, the low carbon hydrogen fuel can be delivered to customers.
H2
250 to 300 TWh
of excess solar and wind power could be converted to hydrogen by 2050.
SOURCE: Hydrogen Council
A typical U.S. household consumes ~11,000 kWh/yr. With this power, you could power approximately
22 to 27
million homes.
SOURCE: U.S. Energy Information Administration
Hydrogen can create significant benefits for our energy system, the environment, and businesses

The Urban Economic Engine

Today, more than half of the world's population lives in cities, and according to U.N. estimates, that number will grow to 6.7 billion by 2050 – or about 68% of the global population.

Simultaneously, it is projected that developing economies such as India, Nigeria, Indonesia, Brazil, China, Malaysia, Kenya, Egypt, Turkey, and South Africa will drive global growth.

Development leads to urbanization which leads to increased economic activity:

The difficulty in this will be achieving a balance between growth and sustainability.

Currently, cities consume over two-thirds of the world's energy and account for more than 70% of global CO_2 emissions to produce 80% of global GDP.

Further, it's projected by the McKinsey Global Institute that the economic output of the 600 largest cities and urban regions globally could grow $30 trillion by the year 2050, comprising for two-thirds of all economic growth.

With this growth will come increased demand for energy and Co2 emissions.

The Hydrogen Fueled City

Hydrogen, along with fuel cell technology, may provide a flexible energy solution that could replace the many ways fossils fuels are used today for heat, power, and transportation.

When used, it creates water vapor and oxygen, instead of harmful smog in congested urban areas.

According to the Hydrogen Council, by 2050, hydrogen could each year generate:

- 1,500 TWh of electricity
- 10% of the heat and power required by households
- Power for a fleet of 400 million cars

The infrastructure requirements for hydrogen make it easy to distribute at scale. Meanwhile, for heat and power, low concentrations of hydrogen can be blended into natural gas networks with ease.

Hydrogen can play a role in improving the resilience of renewable energy sources such as wind and solar, by being an energy carrier. By taking surplus electricity to generate hydrogen through electrolysis, energy can be stored for later use.

In short, hydrogen has the potential to provide the clean energy needed to keep cities running and growing while working towards zero emissions.

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The Green Power You Aren't Hearing About

APRIL 13, 2021

We've talked a lot about renewables and energy over the years around here. We've brought a lot of that to you.

However, our coverage — while I stand by it — leaves a whole lot we haven't discussed.

Sure, we talk a lot about transportation and how battery power fails to scale well to heavy vehicles. It will drive alternative power source engineering and manufacturing for decades to come, but that is just one application.

Specifically, the need for on-site energy production is too important not to mention.

It's hard to get a grasp in "layman's terms" for how much energy is needed that will never be converted to electricity and dumped into the grid.

That's something I think we can change, without getting into the nitty-gritty or just nibbling at the edges of the whole conversion to noncarbon energy sources.

We could go down a nearly endless list of things that need disturbing amounts of energy — normally in the form of heat — to manufacture, but nothing stands out more than steel and concrete.

There are far more energy-intensive materials that are absolutely essential to our modern life and economy, but we use virtually nothing else on the same scale. You can't build anything without both, and lots of both.

There are only two factors we need to consider here to get a grasp of how energy-intensive their production is — global emissions and temperatures required.

Steel production accounts for an estimated 8% of global carbon emissions. Concrete clocks in at 5%. All of those emissions come from what is essentially on-site power production.

Steel smelters need to use some bituminous coal, also called metallurgical coal, and "bake" it for quite a while at or around 1,100 degrees Celsius just to make it useful in the next step of steel production.

Then that "coking" coal is used to infuse, if you will, the molten iron oxide with carbon-rich gases and trace amounts of other metals to produce steel alloys that are up to snuff for construction.

Concrete is basically just a silicon-rich mix of sand and pebbles, but it needs to go through furnaces that go up to 1,400 degrees Celsius for a long while as well.

For a sense of scale, most of your pots and pans shouldn't go above 200–250 degrees Celsius.

This is not something that can ever be achieved on an economical scale by paying normal commercial rates for electricity from the grid. The power used to create this kind of heat needs to be generated on-site without interruption 24/7 to be economical.

That's our problem right there. There is no version of renewable energy that can provide a reliable source of energy for these, and many other, chemical reactions.

Batteries cannot provide an economical scale of energy without degrading by cycling too often and without massive capacitors to ramp up energy discharged to the extreme levels required.

Decarbonizing our economy means we need a replacement energy source on-site for steel, concrete, and chemical production that is virtually invisible to us.

However, it isn't invisible to all. Plans are advancing quickly to substitute hydrogen as a fuel source for these kinds of on-site applications.

For example, a steel smelter in Sweden produced the world's first hydrogen-powered steel last year. It was introduced in the mill to roll out steel to industry standards which, as you can imagine, takes a lot of energy.

Europe is heavily subsidizing hydrogen production and transportation applications to the tune of tens of billions of dollars within just a handful of years, but is also pursuing new subsidies to use hydrogen in this more obscure manner.

Even over in Australia, a nation heavily invested in coal extraction and exports, Fortescue Metals Chairman Andrew Forrest is pushing for carbon-free steel. Fortescue currently mines iron oxide ore, sends it to Chinese smelters, and then brings it back home.

Plus, all of the timelines for these new applications to be fully scaled up and in operation line up well with the decarbonization of vehicles — somewhere around five years for some projects, with the goal of complete transition within 30 years.

It's a long shot, but it is happening. And the timetables keep moving forward, a rare thing for capital-intensive infrastructure and energy projects.

Make no mistake about it, the new hydrogen paradigm has only just begun. Readers of *The Crow's Nest* are already well-positioned with a company at the cutting edge of this trend, and even more opportunities and accelerated growth are in the works.

While we have and will continue to pull in profits from hydrogen fuel cell vehicles worldwide, the same tech will be used to provide virtually unlimited carbon-free power to everything else that we rarely consider.

Take care,

Adam English

Follow

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