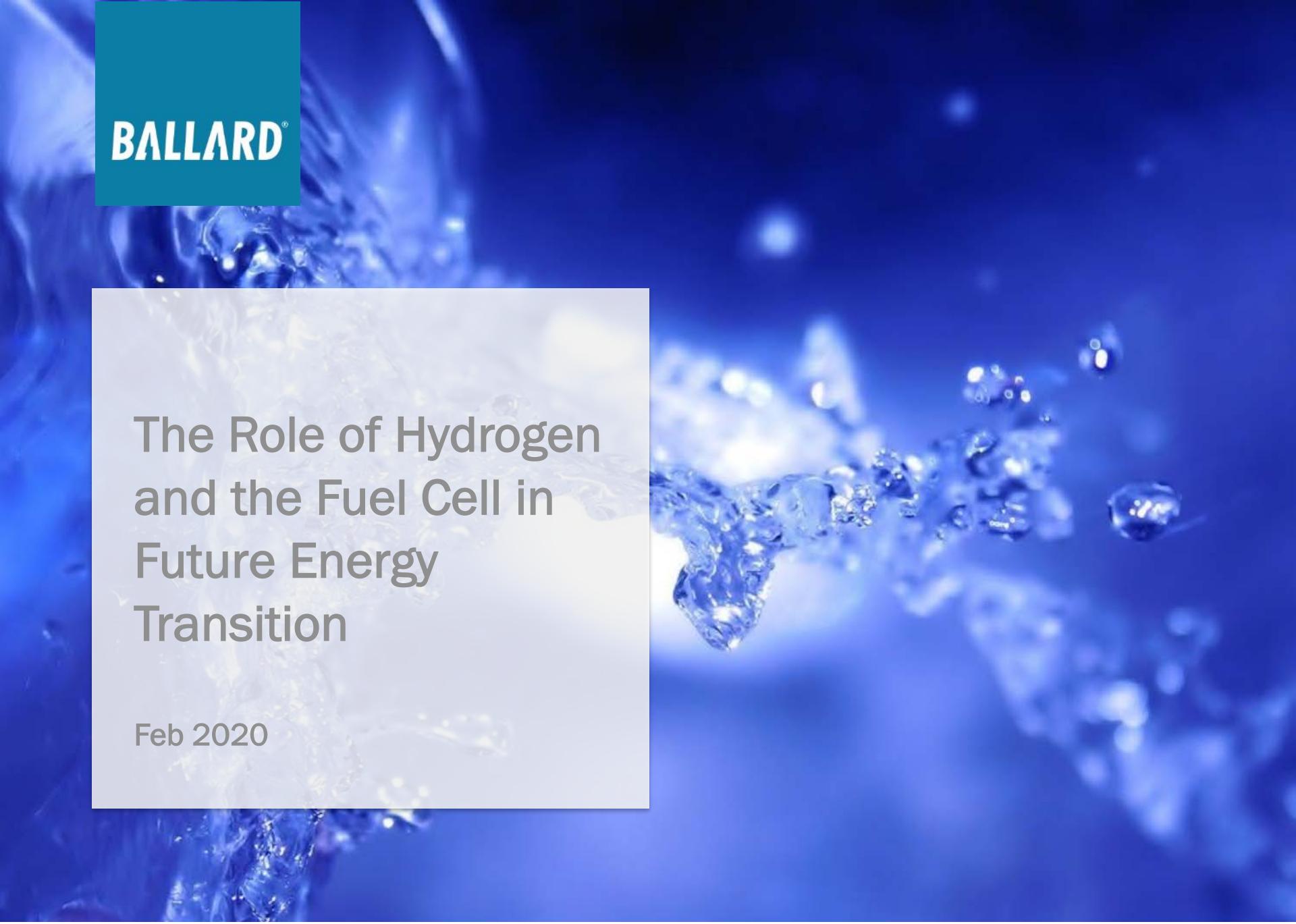


The Role of Hydrogen and the Fuel Cell in Future Energy Transition

Feb 2020

Nicolas Pocard

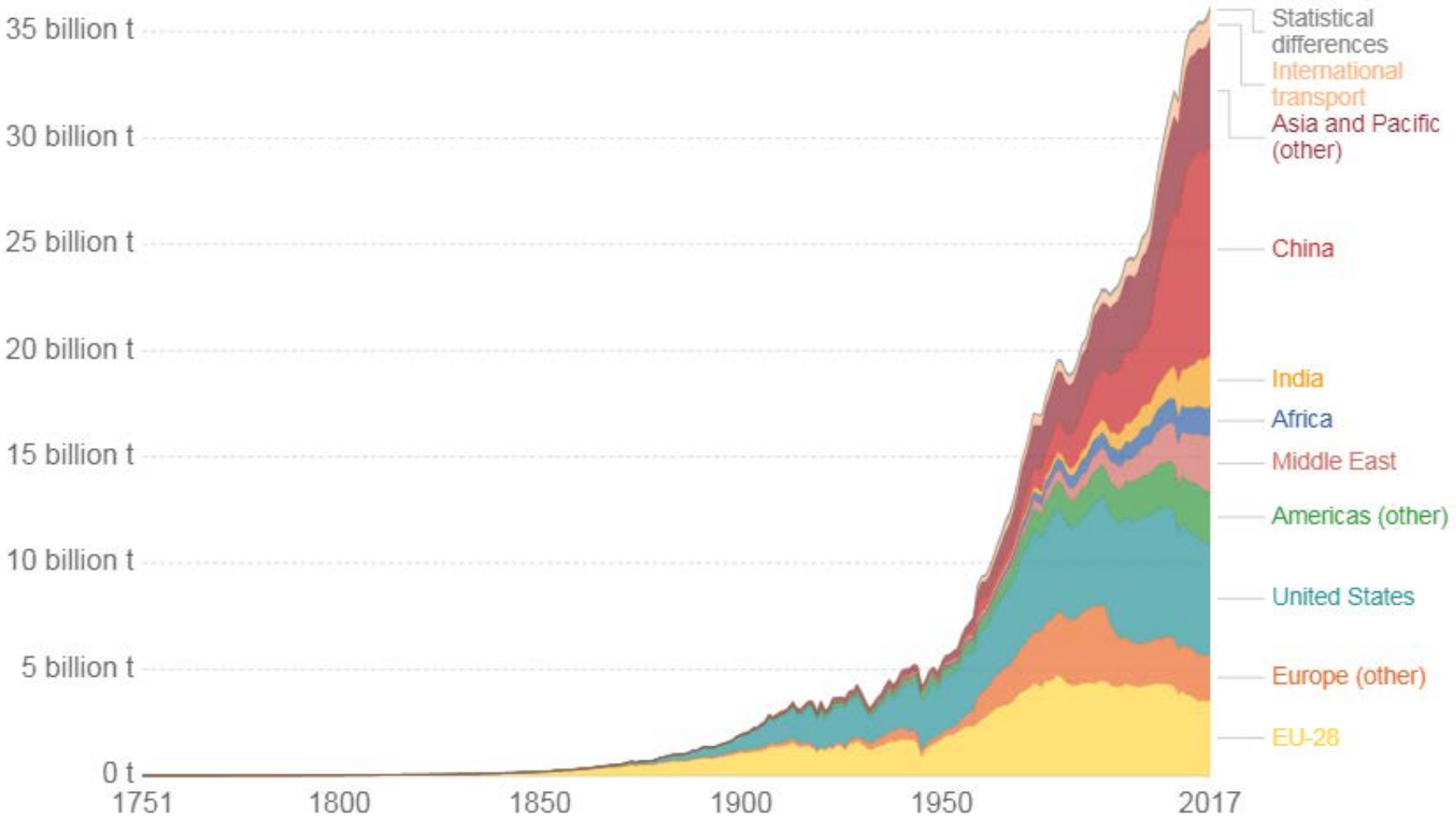
Director of Marketing

Ballard Power Systems

Agenda

1. Introduction and context
2. Hydrogen role in the energy transition
3. Fuel cell technology and applications
4. Where are we today ?
5. Hydrogen and fuel cell in Canada and British Columbia

Annual total CO_2 emissions, by world region



Source: Carbon Dioxide Information Analysis Center (CDIAC); Global Carbon Project (GCP)
Note: The difference between the global estimate and the sum of national totals is labeled "Statistical differences".
OurWorldInData.org/co2-and-other-greenhouse-gas-emissions • CC BY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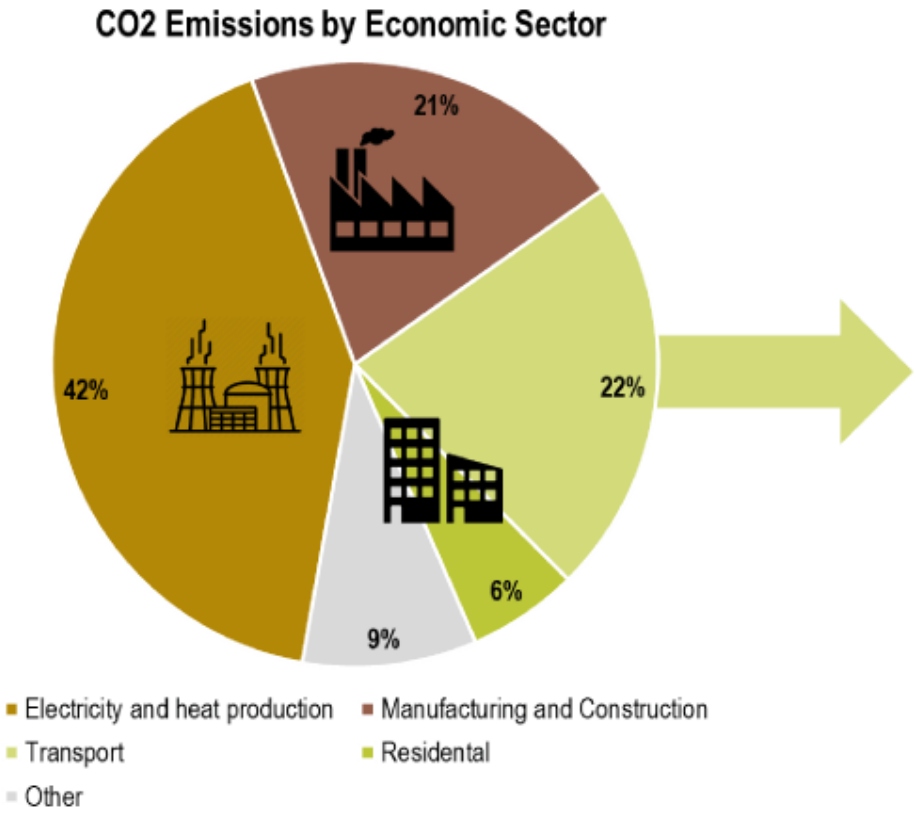
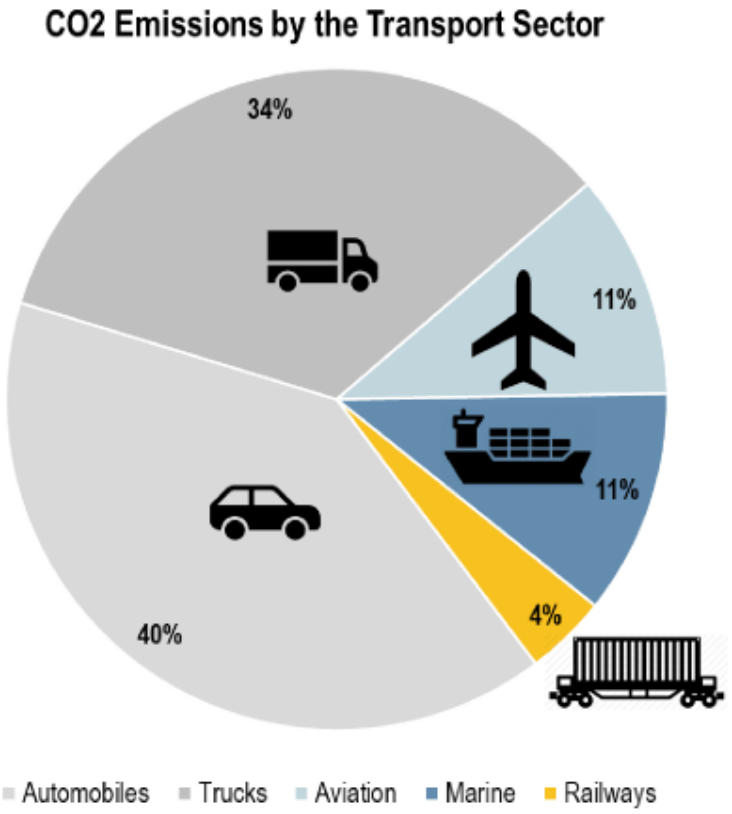
BALLARD
MAERSK

Impact of transportation on the environment



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Urbanization and e-commerce trends are leading to increased number of commercial vehicles on the road.


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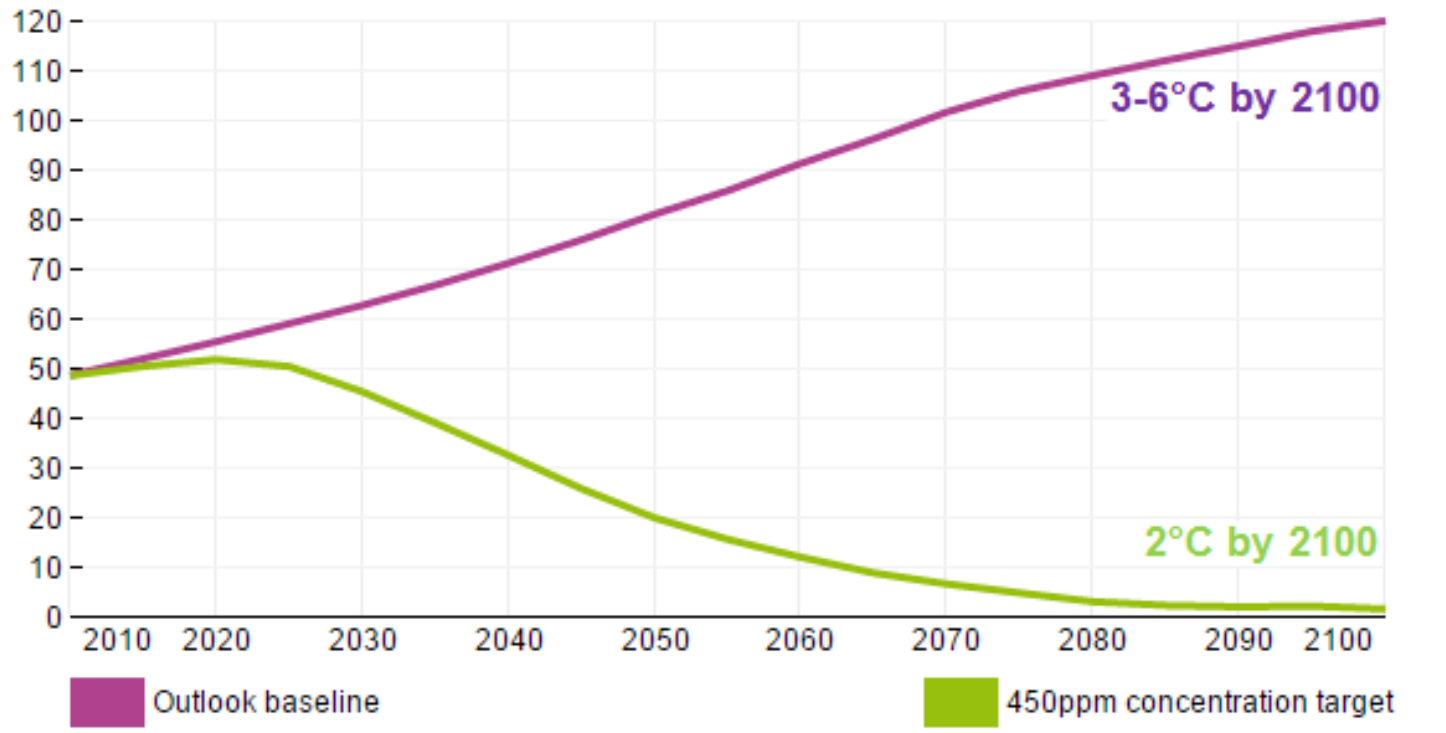
COP21 · CMP11
PARIS 2015
UN CLIMATE CHANGE CONFERENCE

GHG emissions projection, 2010-2050

Baseline scenario (no action) vs targeted concentration level (450ppm)



Source: OECD (2012), OECD Environmental Outlook to 2050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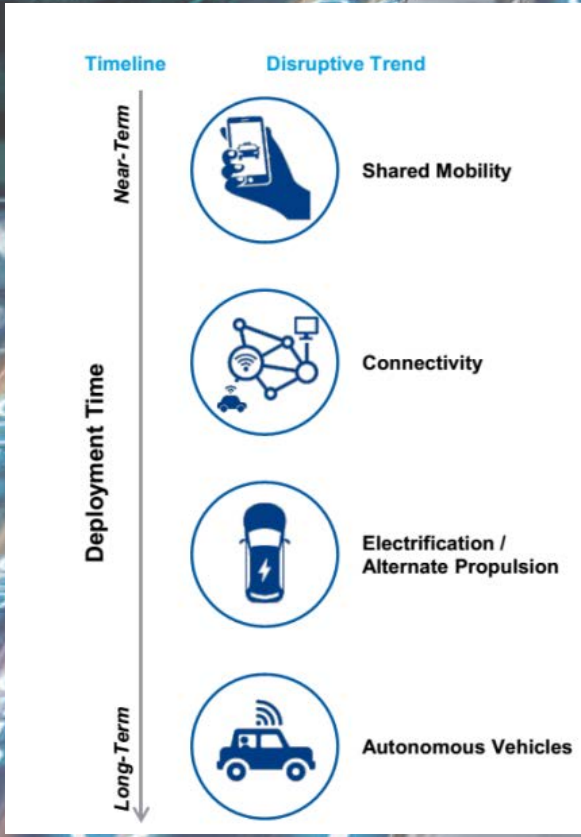
"Mobility's second great inflection point."

(McKinsey)

Technology is reshaping mobility



Mobility as a service; increased asset utilization

Improve data collection and optimization of hybrid powertrain performance and routing

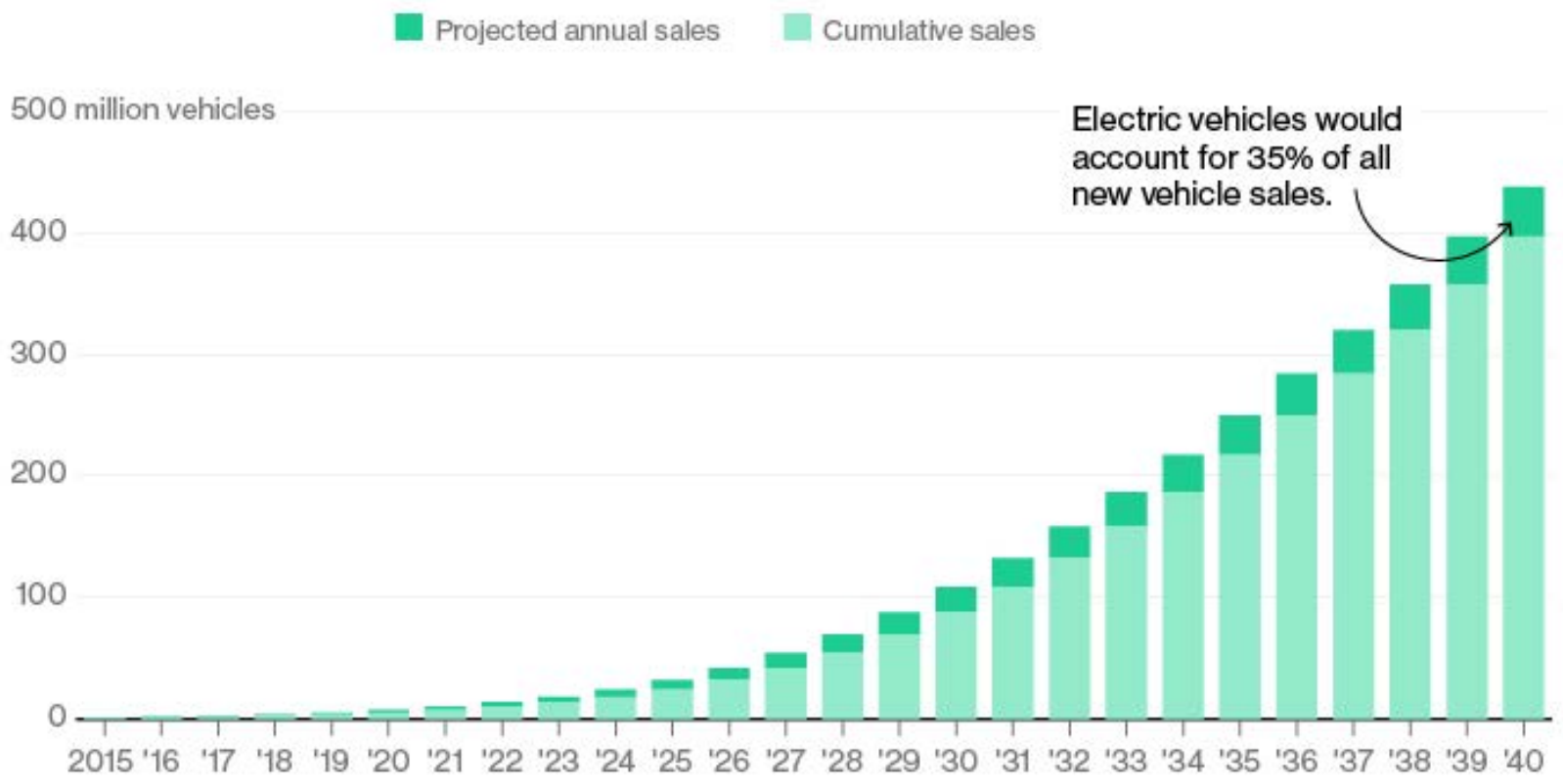
Battery and fuel cells are the only zero-emission alternatives today

Increase range requirement


BALLARD®
Electrification of power train is already disrupting the automotive industry

The Rise of Electric Cars

By 2022 electric vehicles will cost the same as their internal-combustion counterparts. That's the point of liftoff for sales.

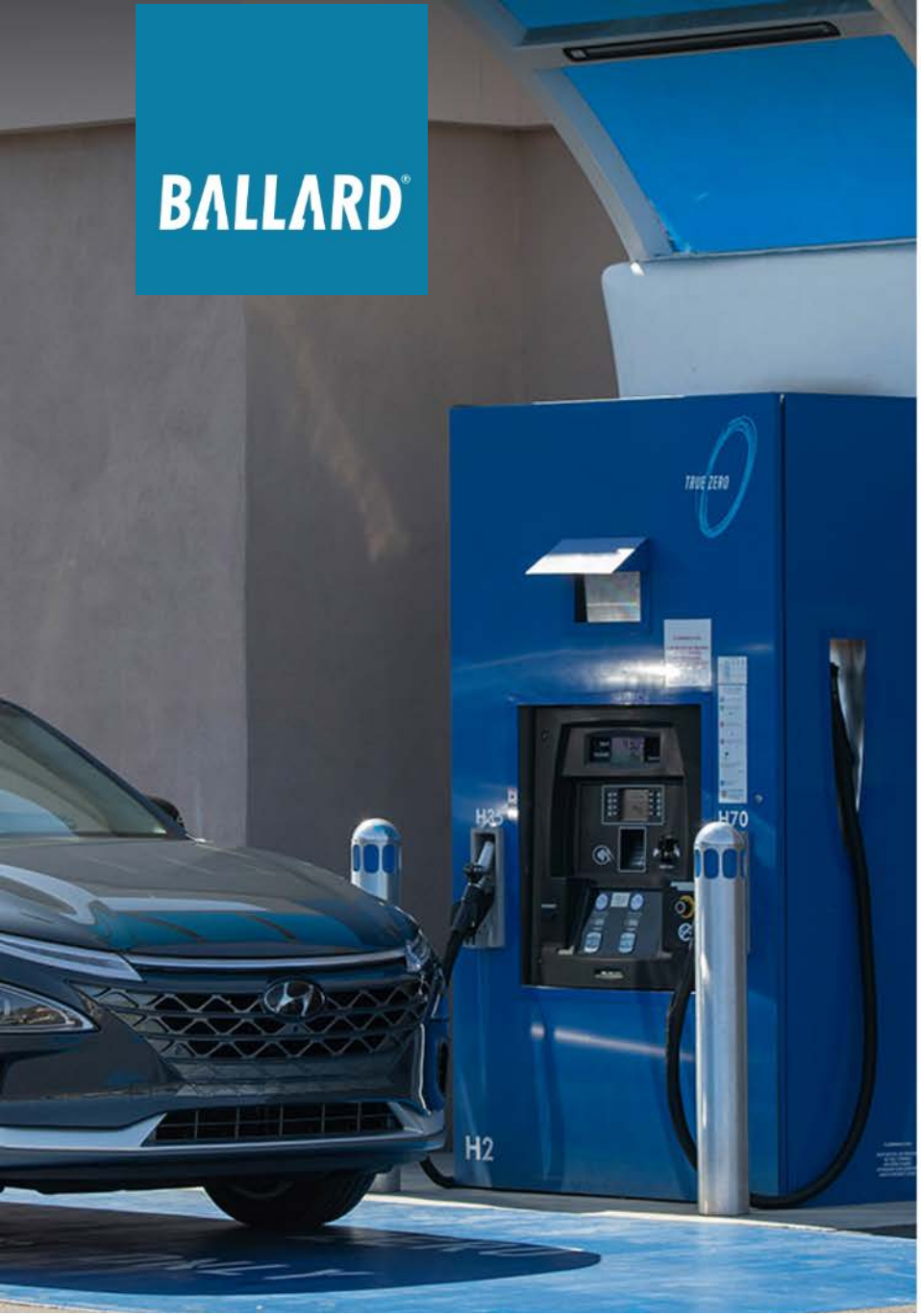


Sources: Data compiled by Bloomberg New Energy Finance, Marklines

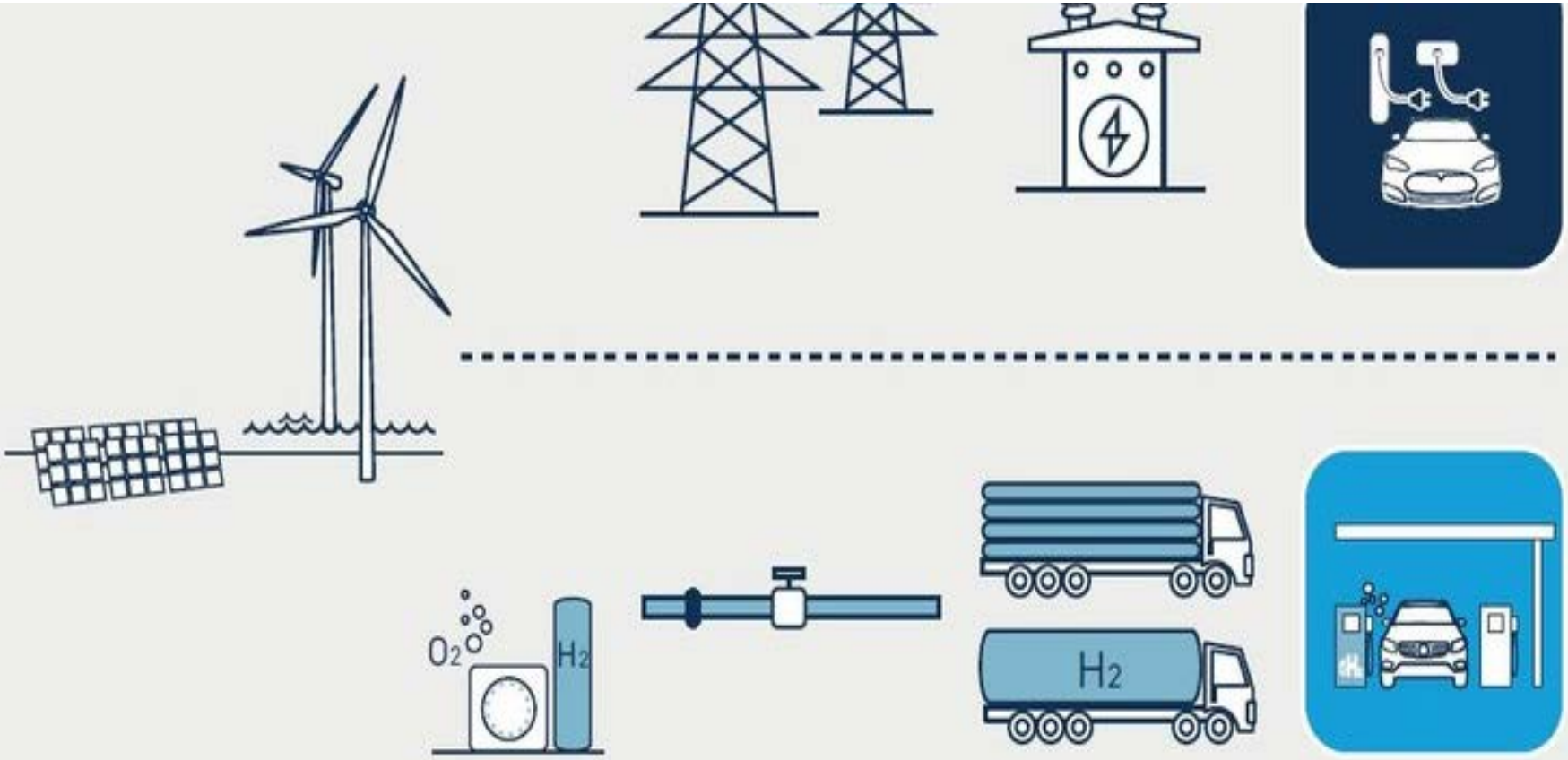
Bloomberg

electric vs hydrogen

The battle to fuel the future of cars


BALLARD
TRUE ZERO
H70
H2


TESLA


O2
H2
H2

In brief

Key messages today

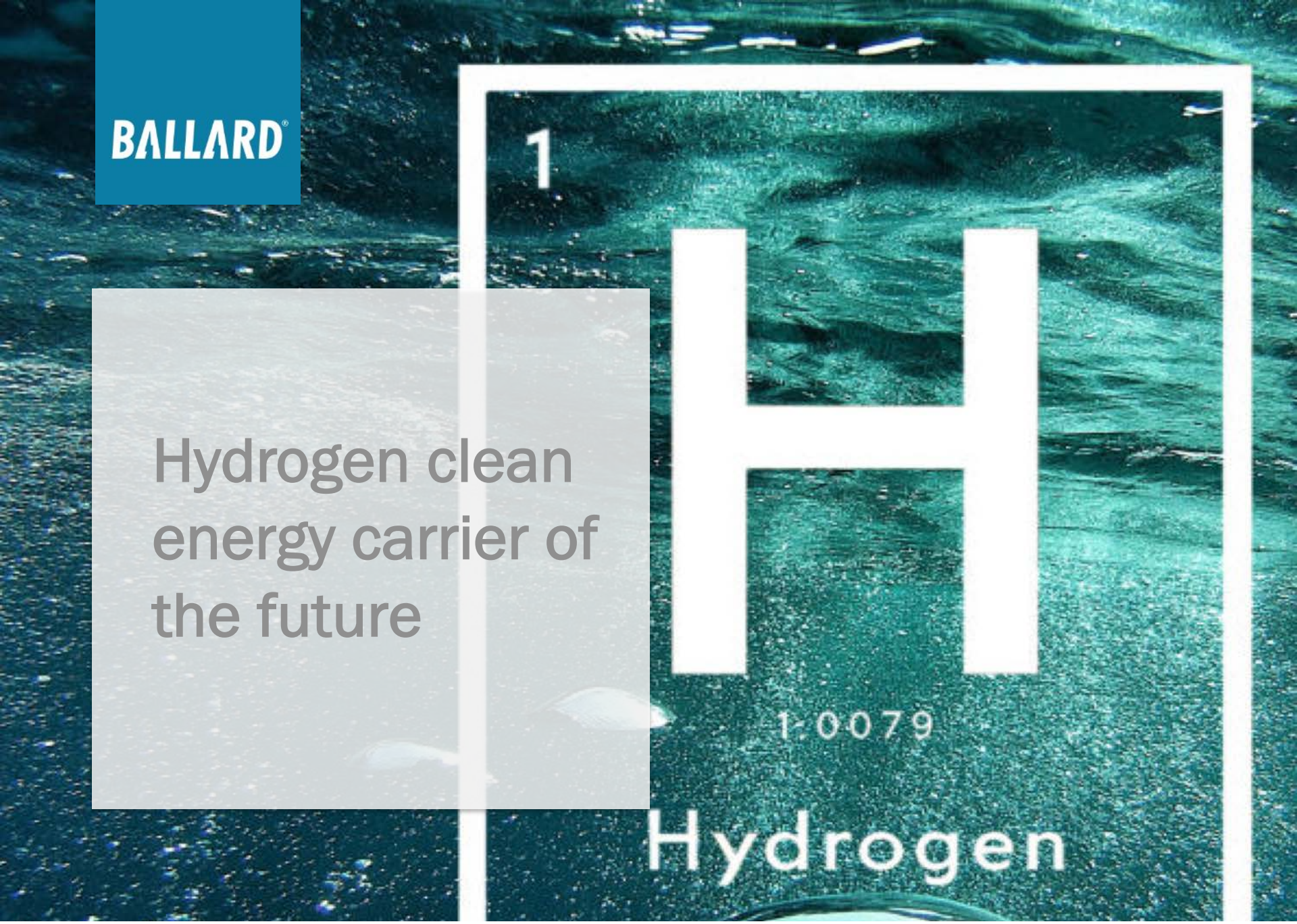
1. **Hydrogen is required to meet our emission reduction objectives**
   if we are serious about decarbonization.

2. **Unprecedented global momentum**

3. **Hydrogen potential 10x until 2050**

4. **Low-carbon hydrogen and fuel cell vehicles can be competitive by 2030**

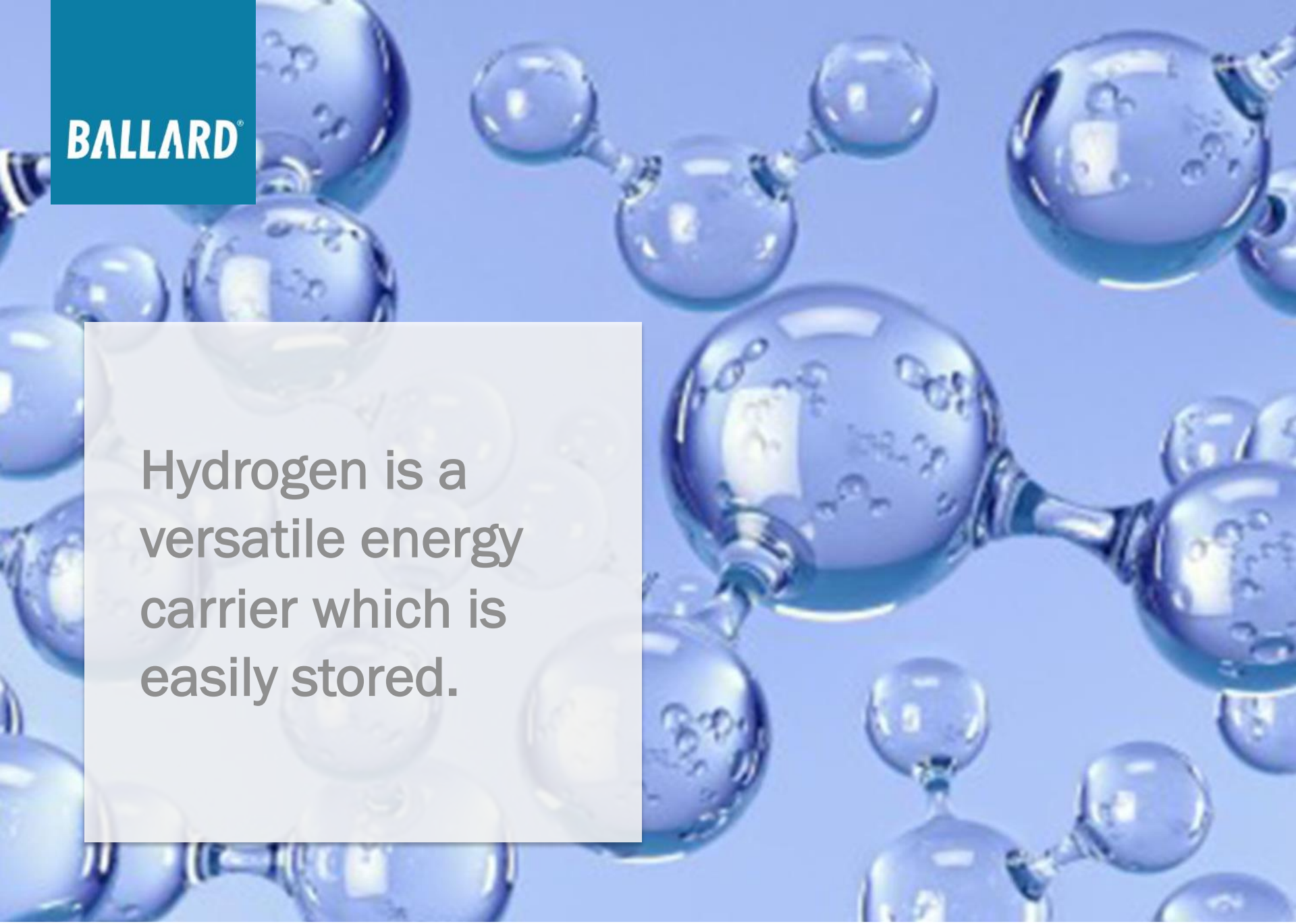
5. **Canada & British Columbia have the opportunity to become global leaders for hydrogen and fuel cells**



Hydrogen clean energy carrier of the future

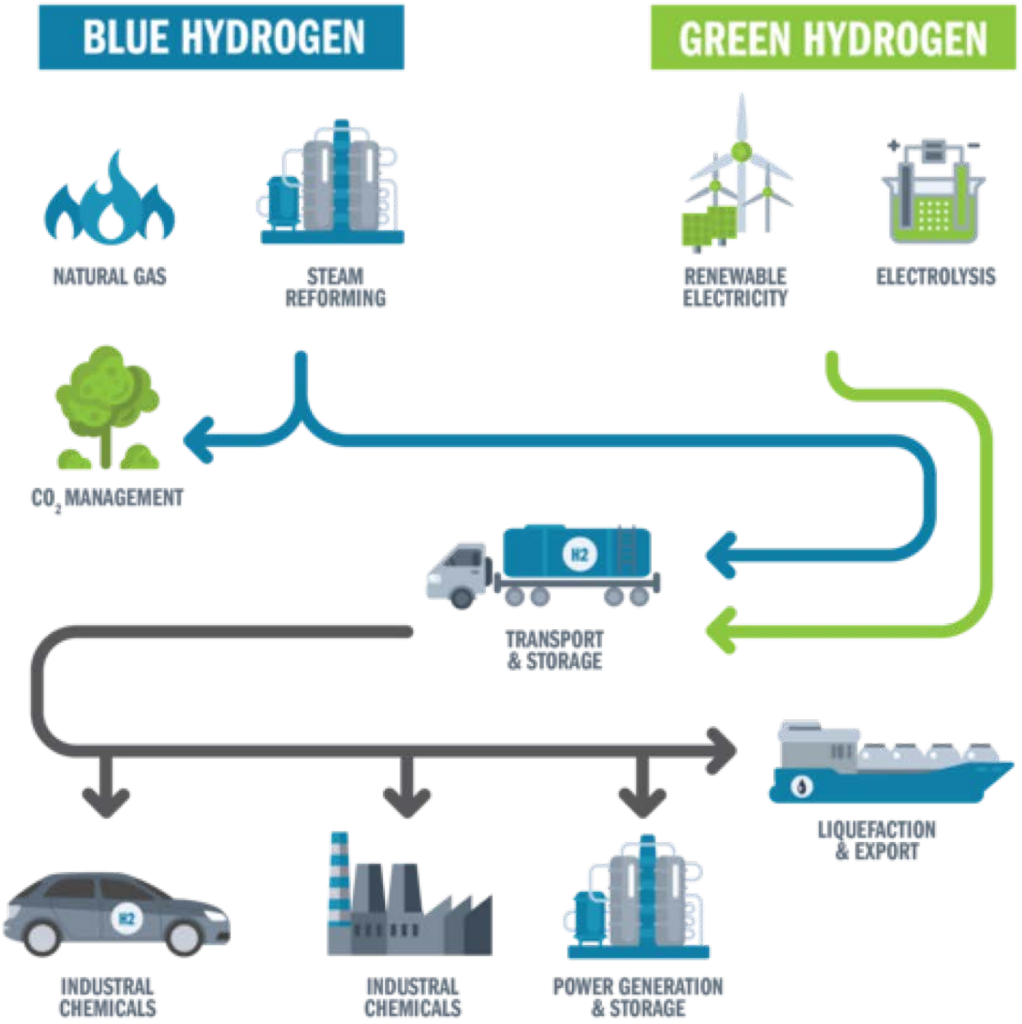
Hydrogen is the most abundant element of the universe

- Exists only on earth combined with other elements (e.g methane, water)
- Lightest of all known elements
- Colorless and odorless
- Non-toxic
- Non-carcinogenic



Hydrogen is a versatile energy carrier which is easily stored.

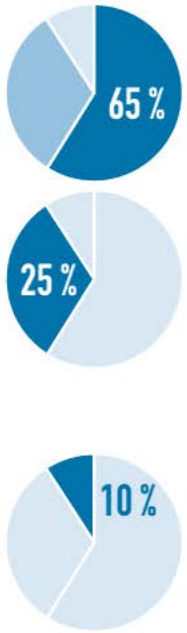
Hydrogen can be generated from various sources



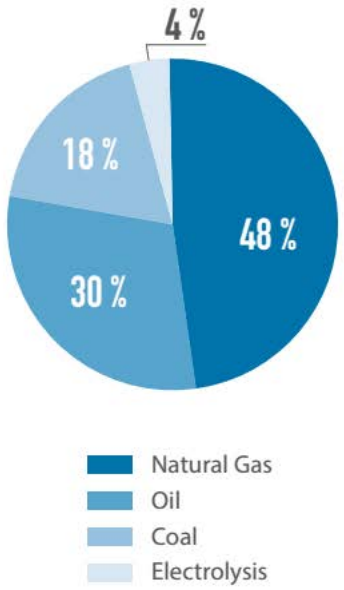
Today 95% of hydrogen is produced from fossil fuel

INDUSTRY SECTOR	KEY APPLICATIONS
CHEMICAL	• Ammonia • Polymers • Resins
REFINING	• Hydrocracking • Hydrotreating
IRON & STEEL	• Annealing • Blanketing gas • Forming gas
GENERAL INDUSTRY	• Semiconductor • Propellant fuel • Glass production • Hydrogenation of fats • Cooling of generators

PERCENTAGE OF GLOBAL H_2 DEMAND



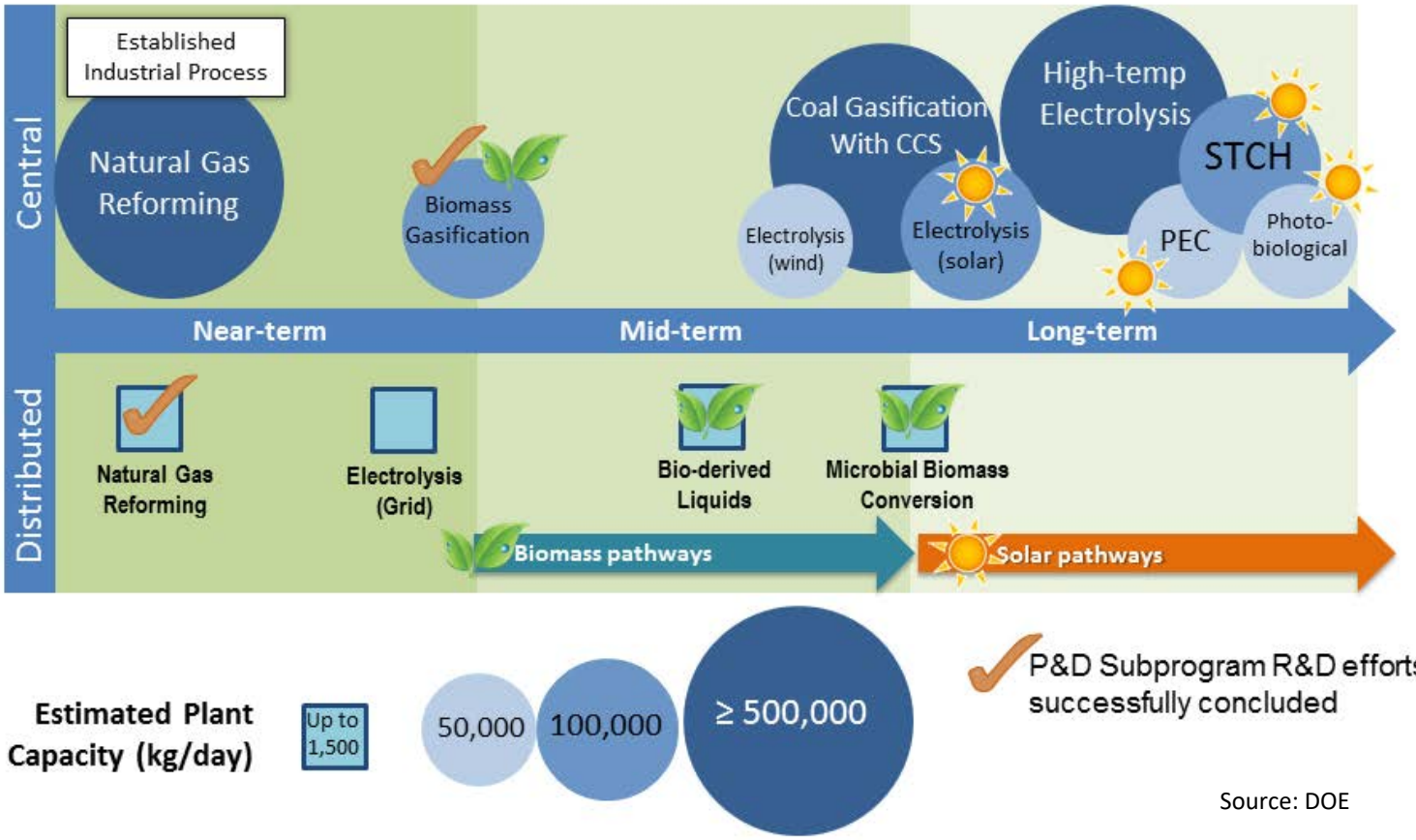
HYDROGEN SOURCES



Hydrogen demand in 2017: 8 exajoules - $115b market

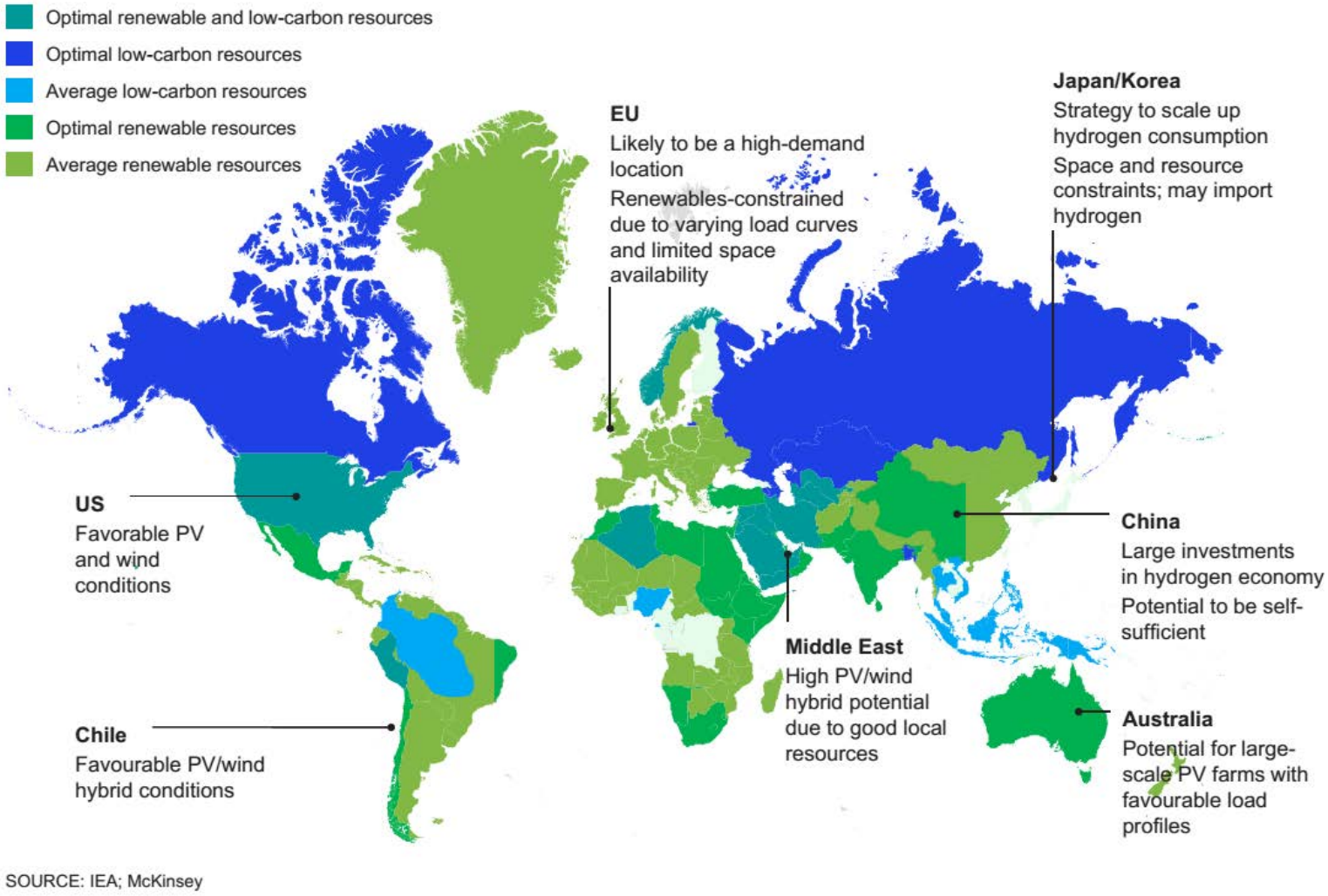
Hydrogen is a clean energy carrier when produced from renewable sources.

There are several paths to green hydrogen production



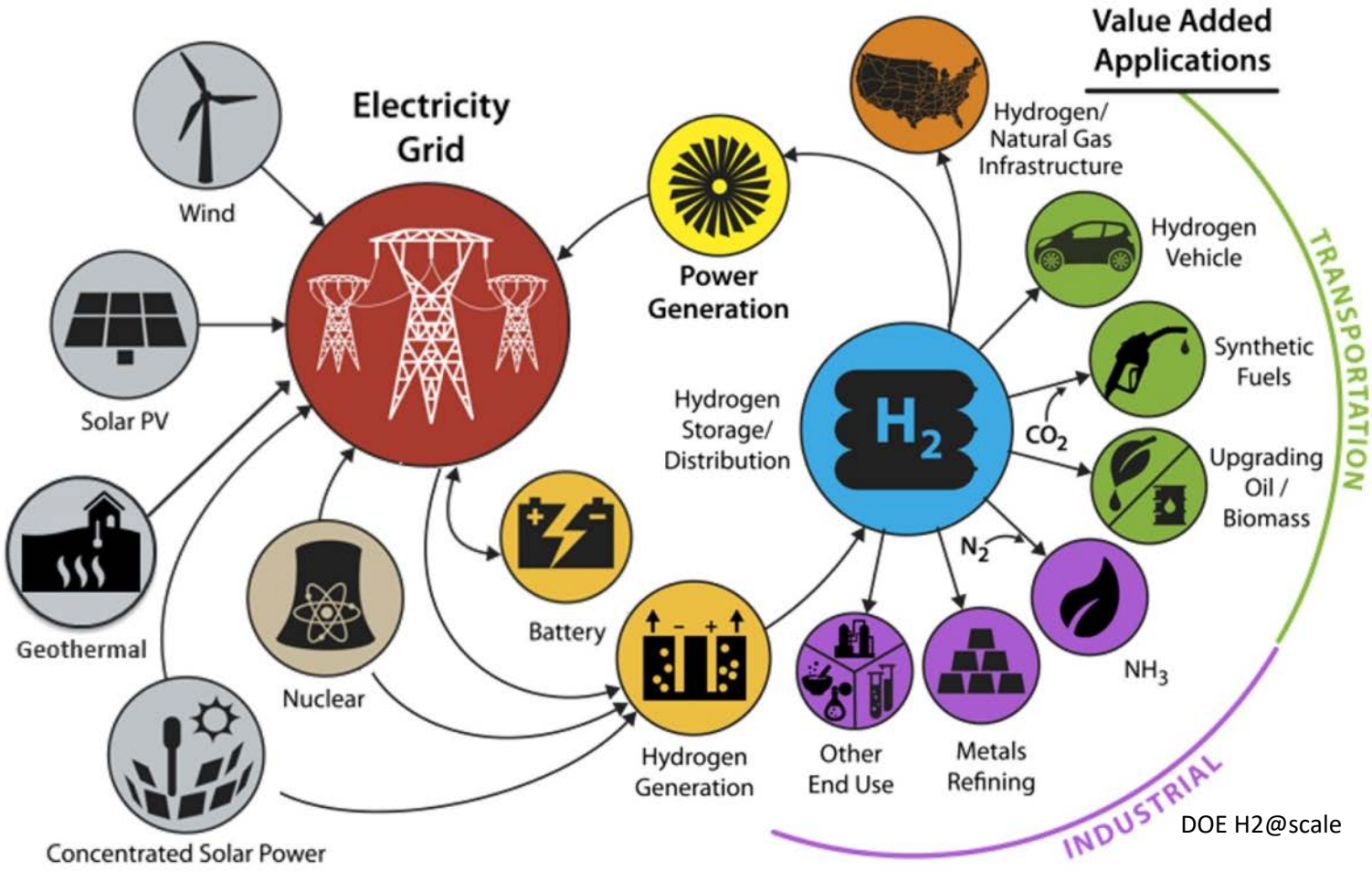
Source: DOE

Best source of low-carbon hydrogen in different regions



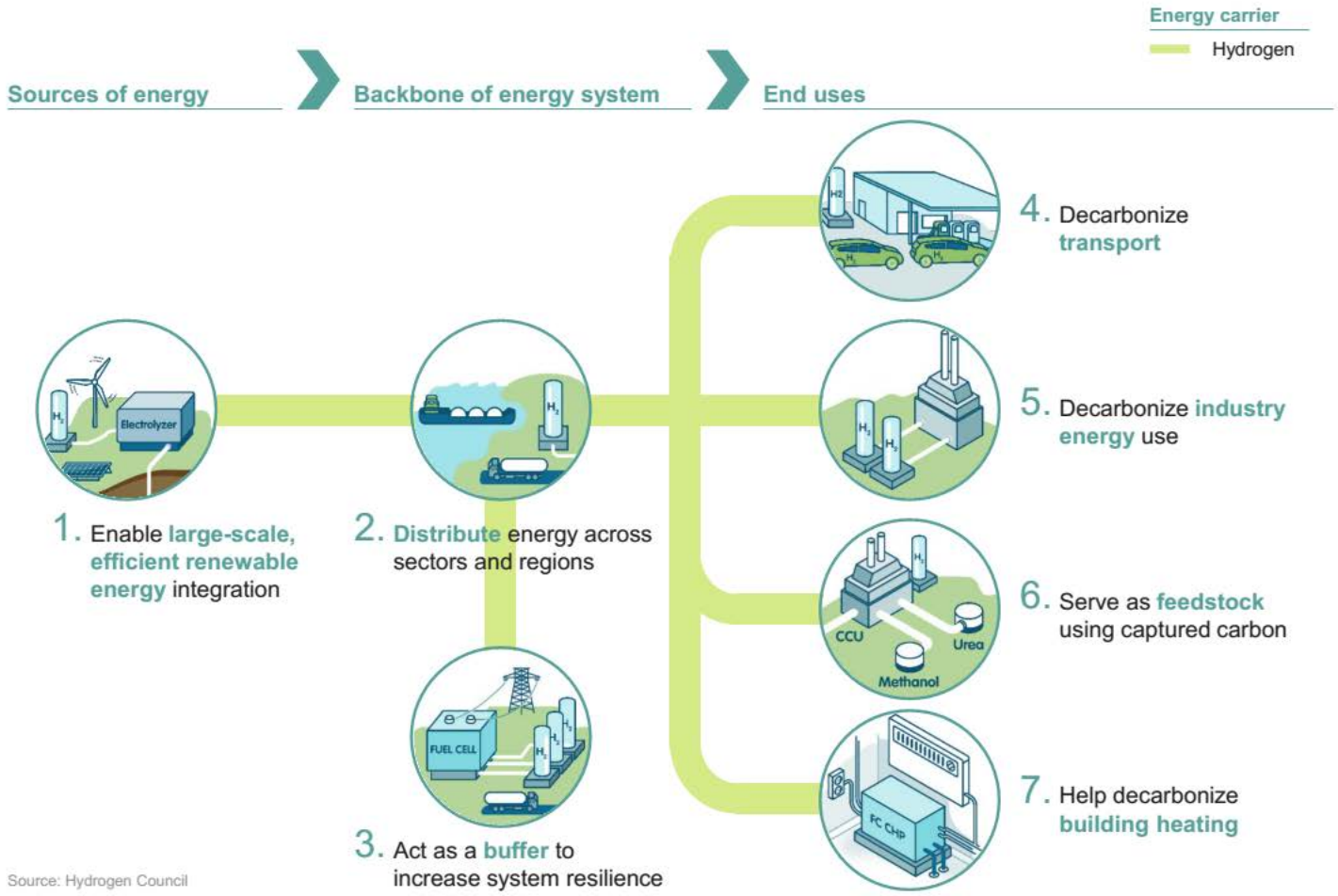
SOURCE: IEA; McKinsey

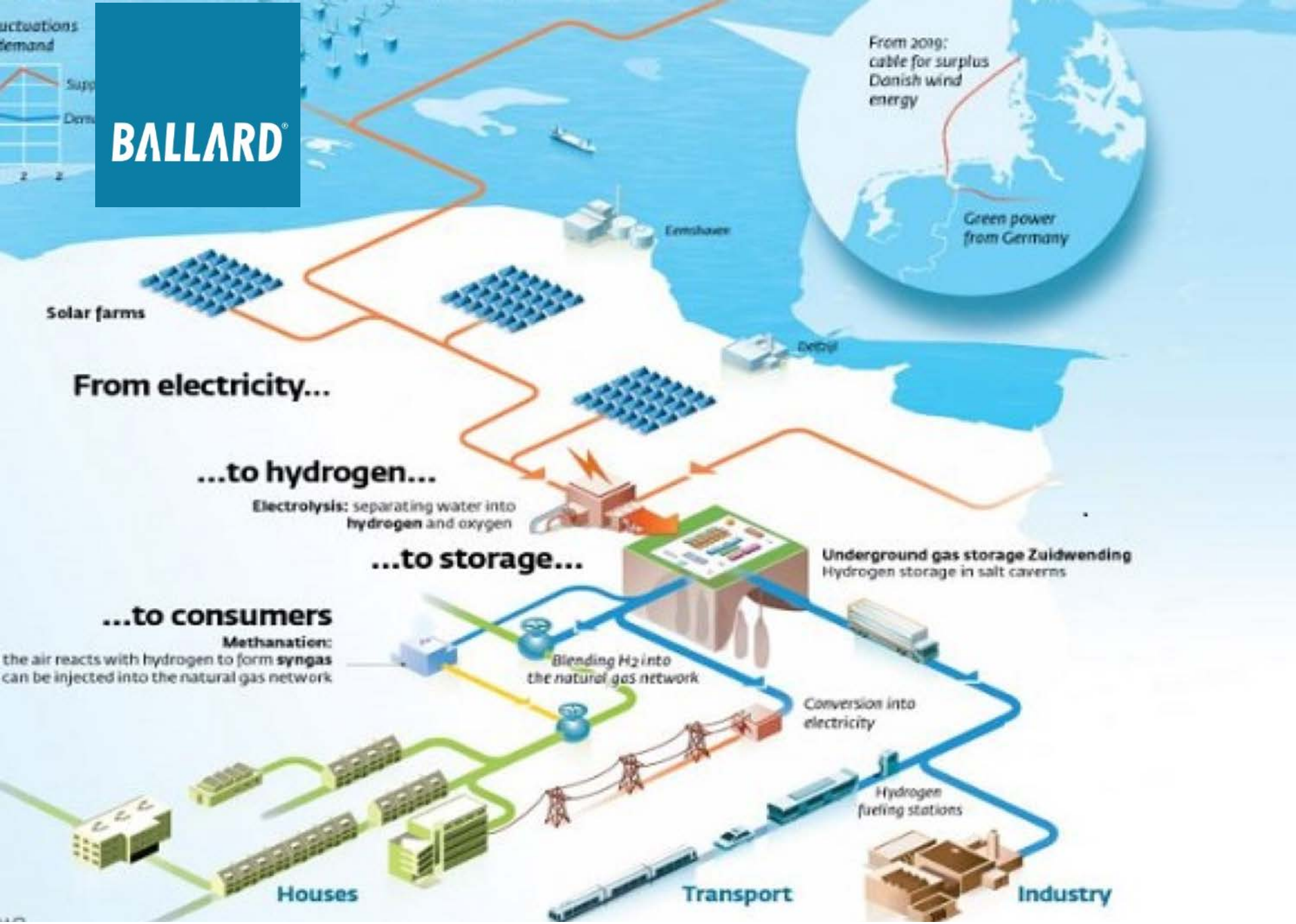
Hydrogen can be used in all sectors of the economy

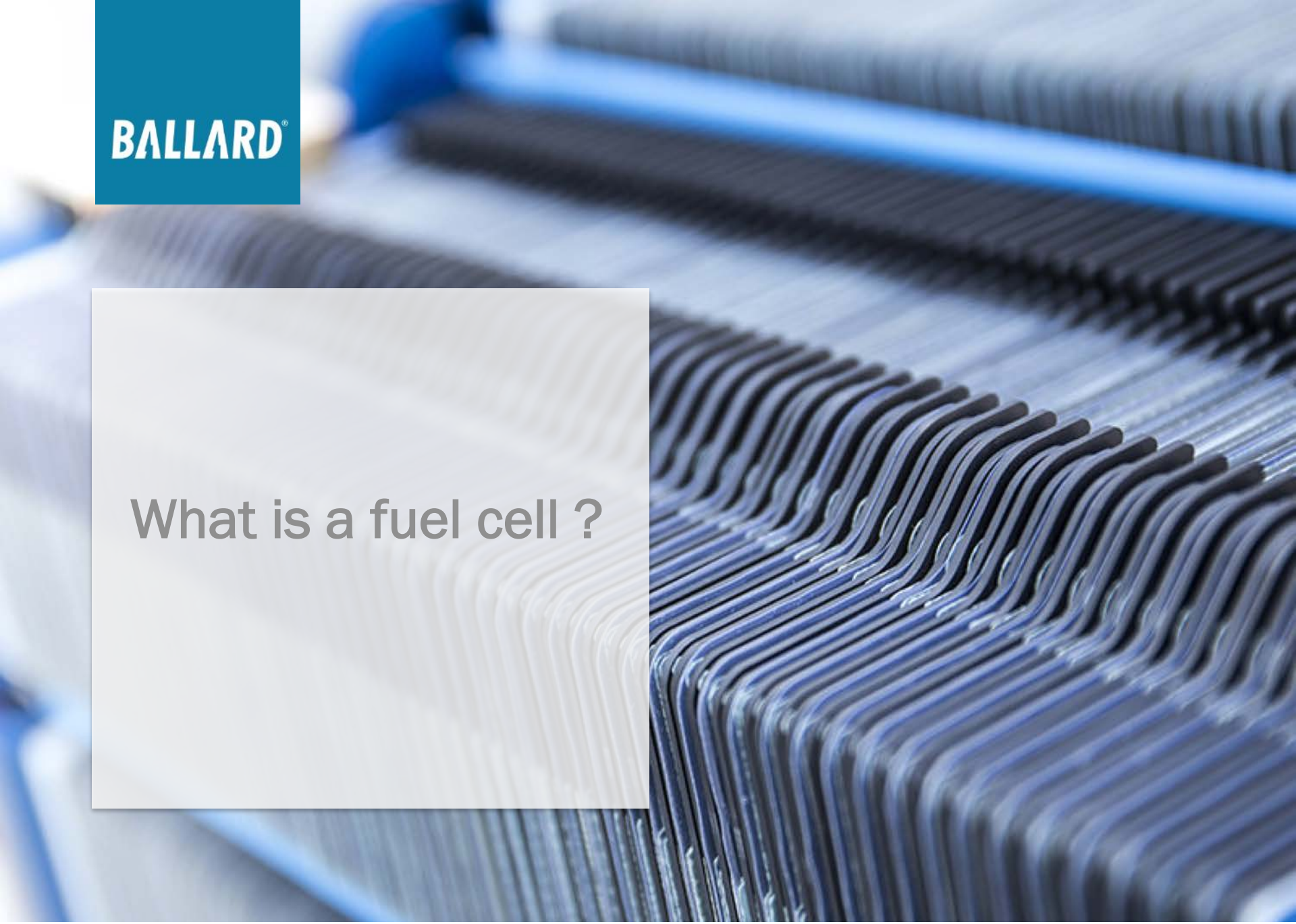


DOE H2@scale

Hydrogen has 7 roles in the decarbonization of the economy



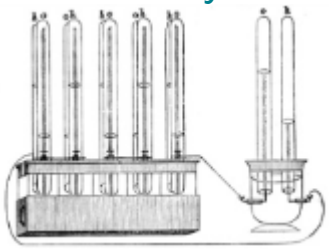

From 2019:
cable for surplus
Danish wind
energy
Green power
from Germany
Eemshaven
Solar farms
From electricity...
...to hydrogen...
Electrolysis: separating water into
hydrogen and oxygen
...to storage...
Underground gas storage Zuidwending
Hydrogen storage in salt caverns
...to consumers
Methanation:
the air reacts with hydrogen to form syngas
can be injected into the natural gas network
Blending H2 into
the natural gas network
Conversion into
electricity
Hydrogen
fueling stations
Houses
Transport
Industry



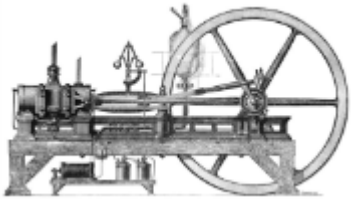
What is a fuel cell ?

Fuel Cell Technology Pre-dates Internal Combustion Engines

1839 - invention of the fuel cell by William

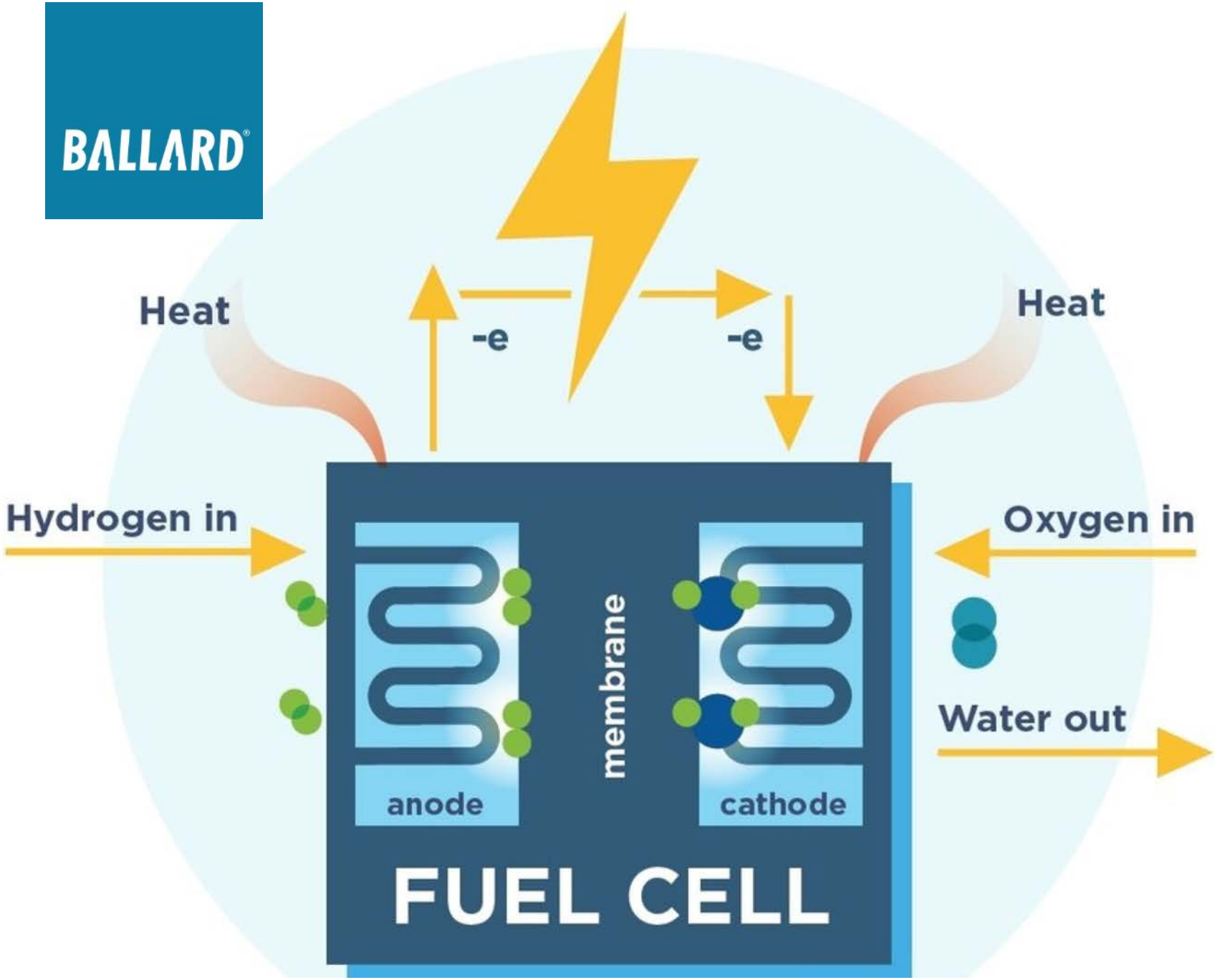


1800 1850 1900

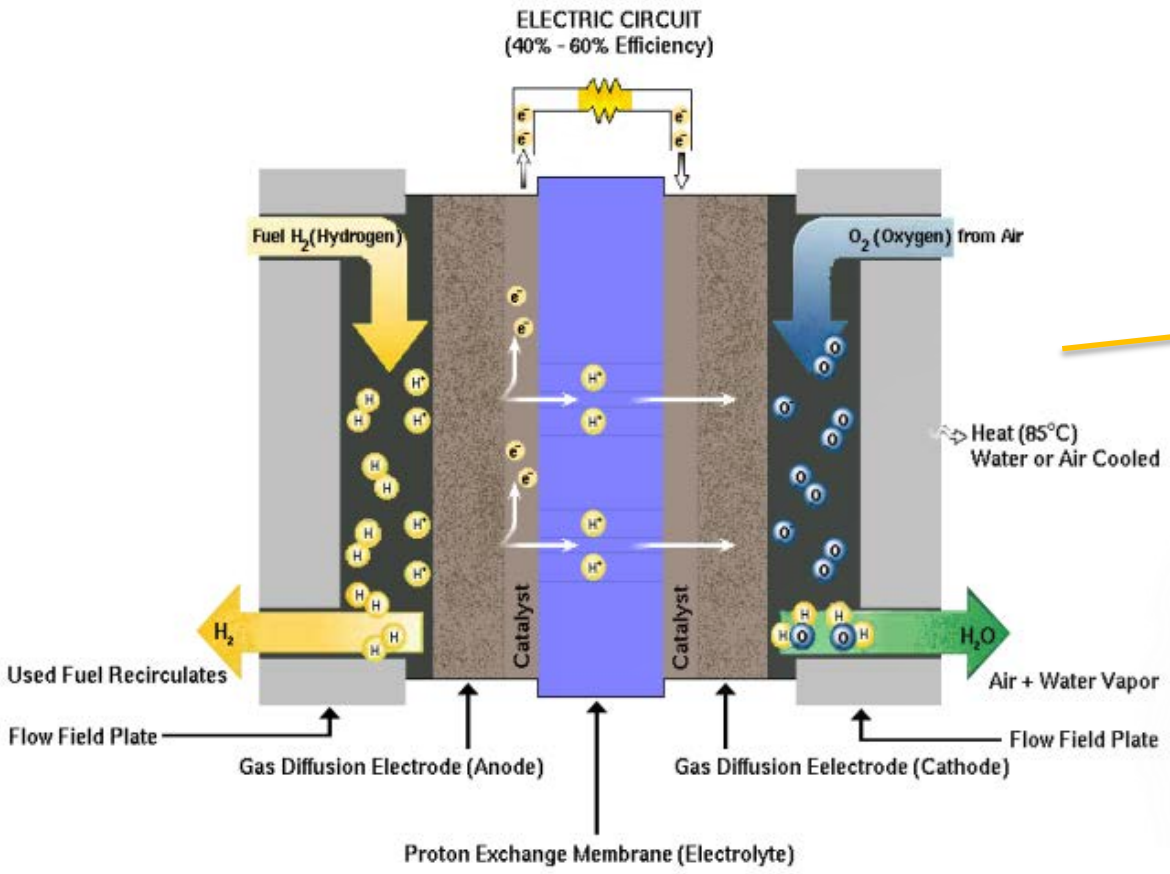


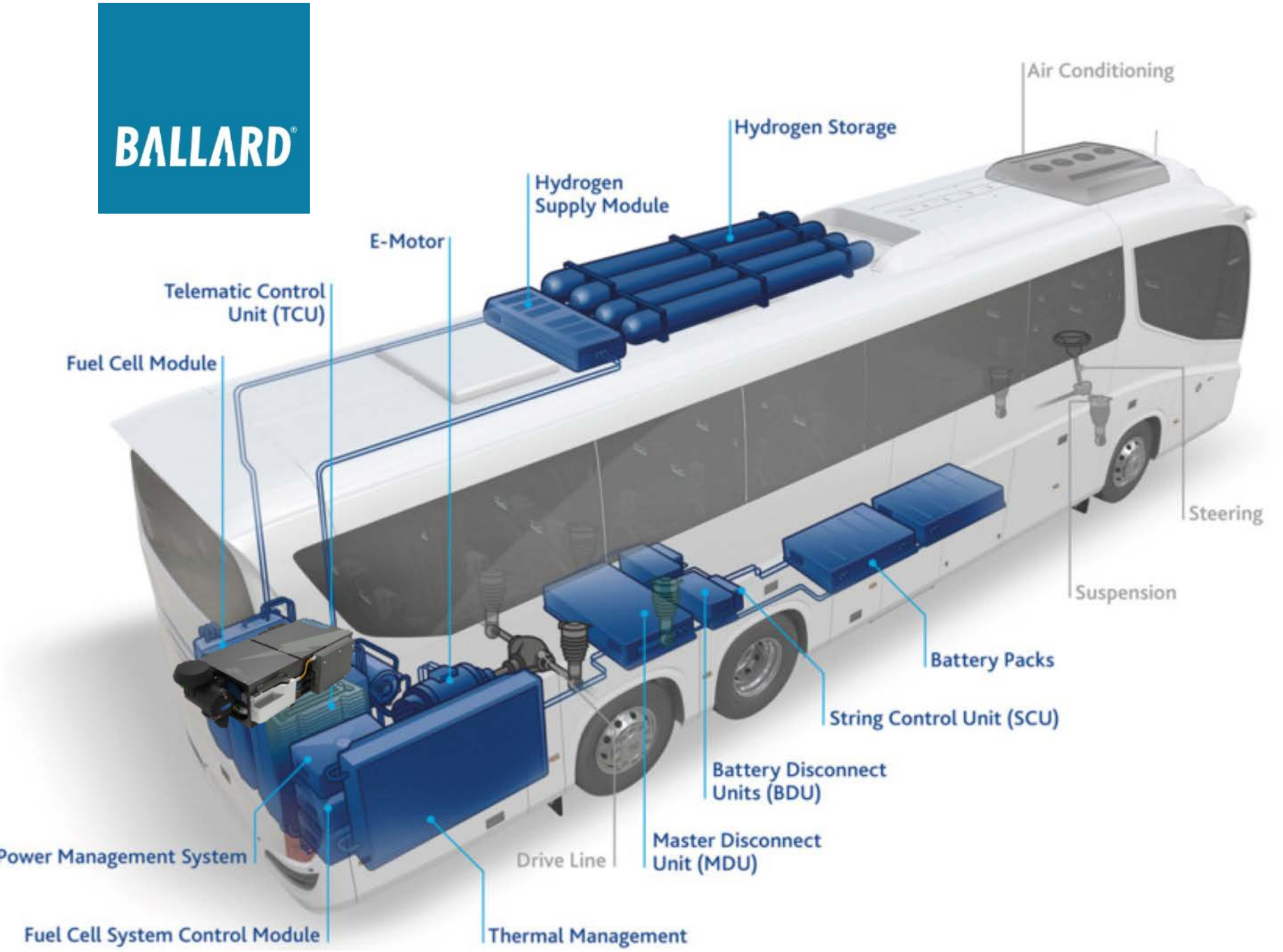
1860 – invention of the internal combustion engine

Yet, internal combustion engines have been the dominate form of propulsion for the last century and this century so far.


Heat
-e
-e
Heat
Hydrogen in
Oxygen in
membrane
anode
cathode
Water out
FUEL CELL

From cell to stack




Air Conditioning
Hydrogen Storage
Hydrogen
Supply Module
E-Motor
Telematic Control
Unit (TCU)
Fuel Cell Module
Steering
Suspension
Battery Packs
String Control Unit (SCU)
Battery Disconnect
Units (BDU)
Master Disconnect
Unit (MDU)
Drive Line
Power Management System
Fuel Cell System Control Module
Thermal Management

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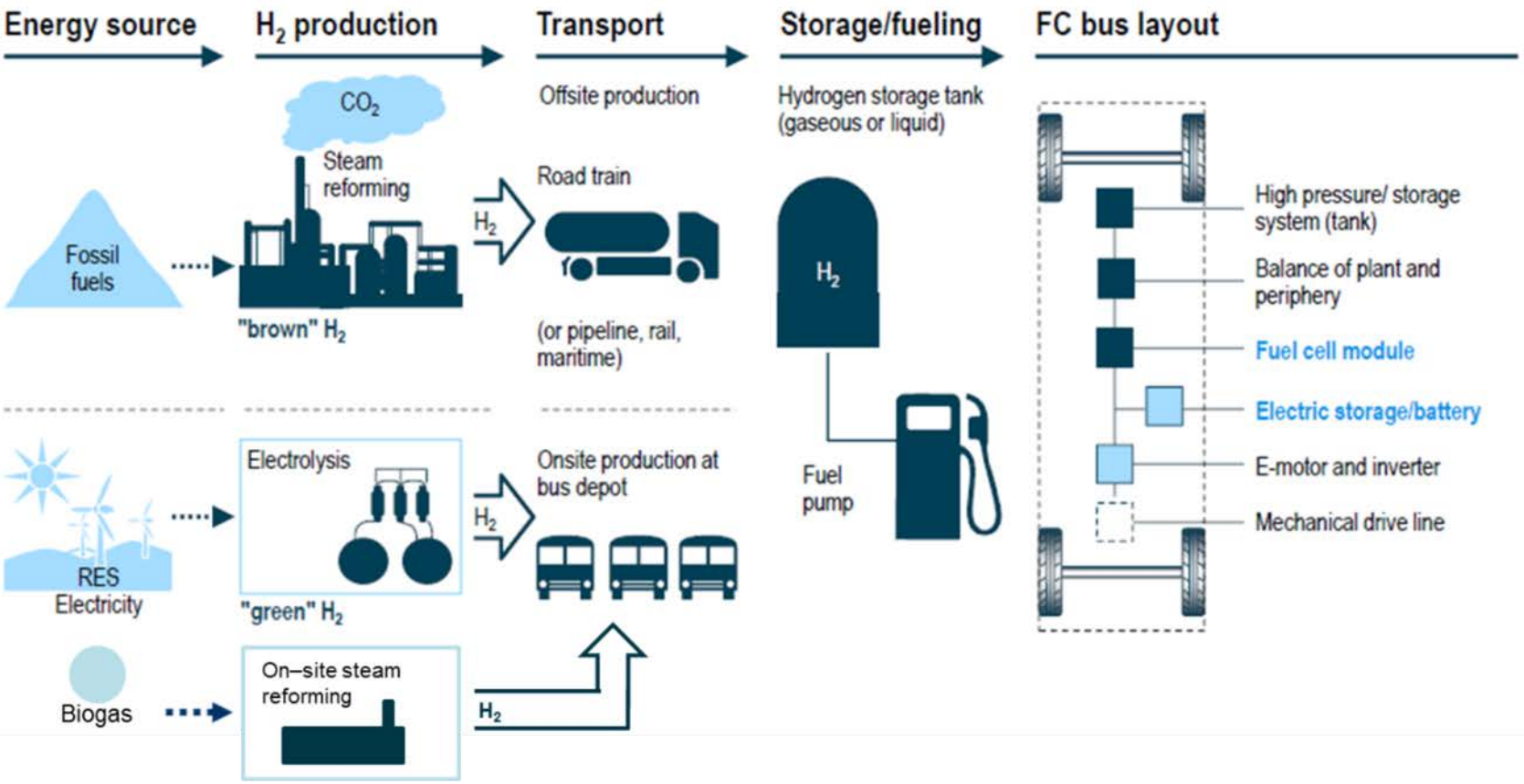
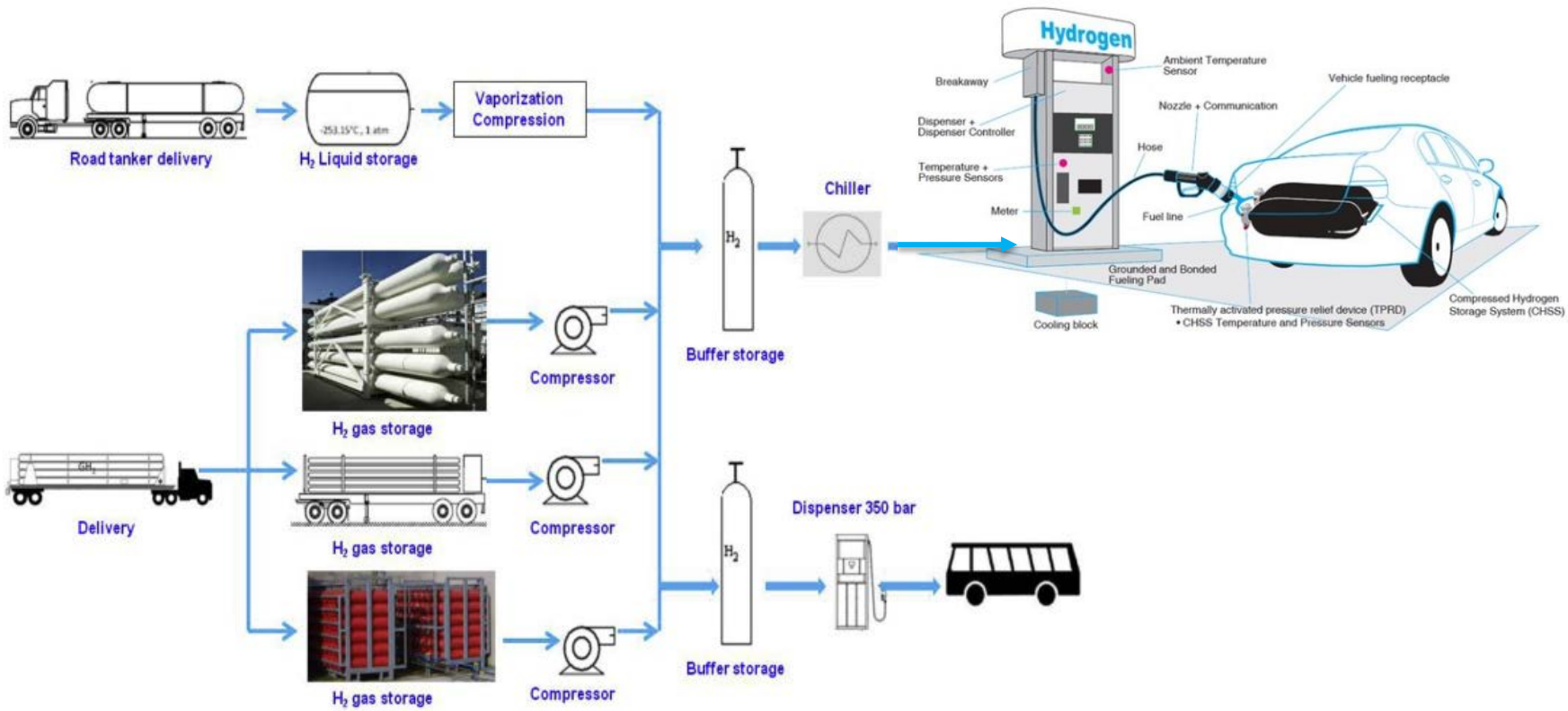
Hydrogen from well to wheel



Hydrogen fueling station

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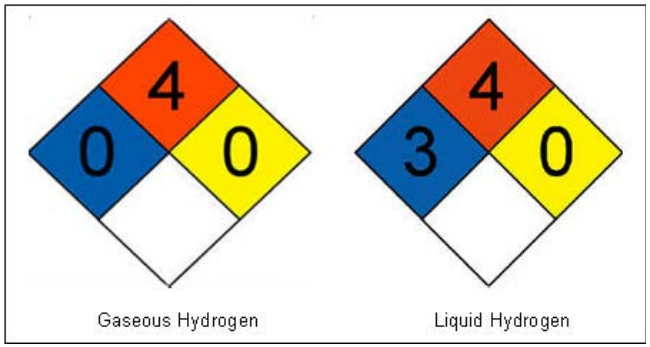
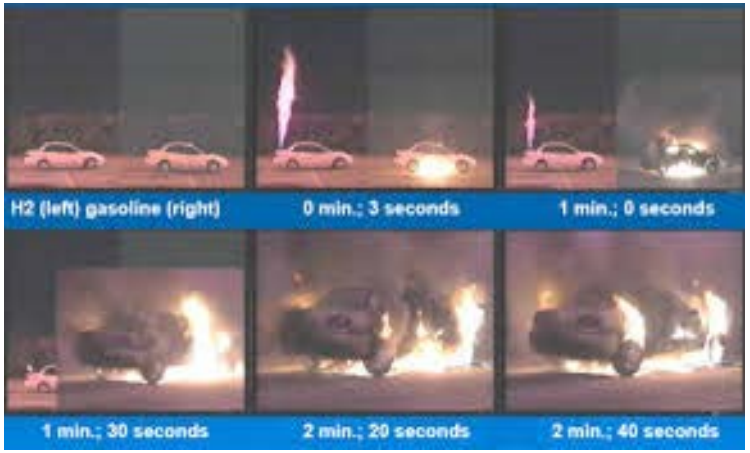
HTEC
HYDROGEN
HYDROGEN
HTEC
Hydrogen Technology & Energy Corporation
htec.ca
2

Hydrogen is no more or less dangerous than other flammable fuel

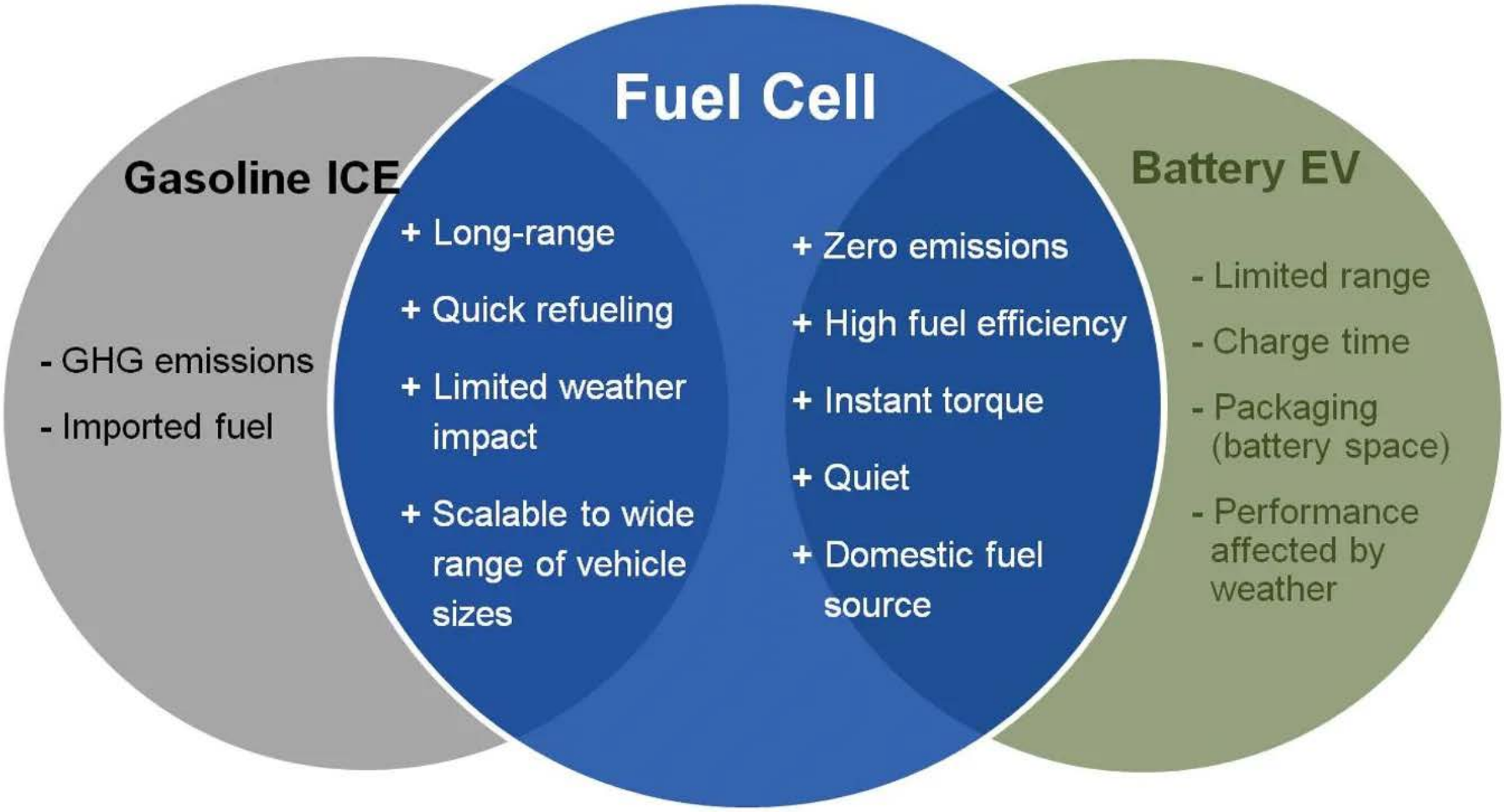
- Hydrogen is lighter than air and diffuses rapidly
- Hydrogen flames have low radiant heat
- Hydrogen is non-toxic and non-poisonous
- Hydrogen gas burns quicker than natural gas or gasoline
- Codes and standards have been developed to ensure safe use of hydrogen





Hydrogen vs gasoline car fire

Why fuel cells?



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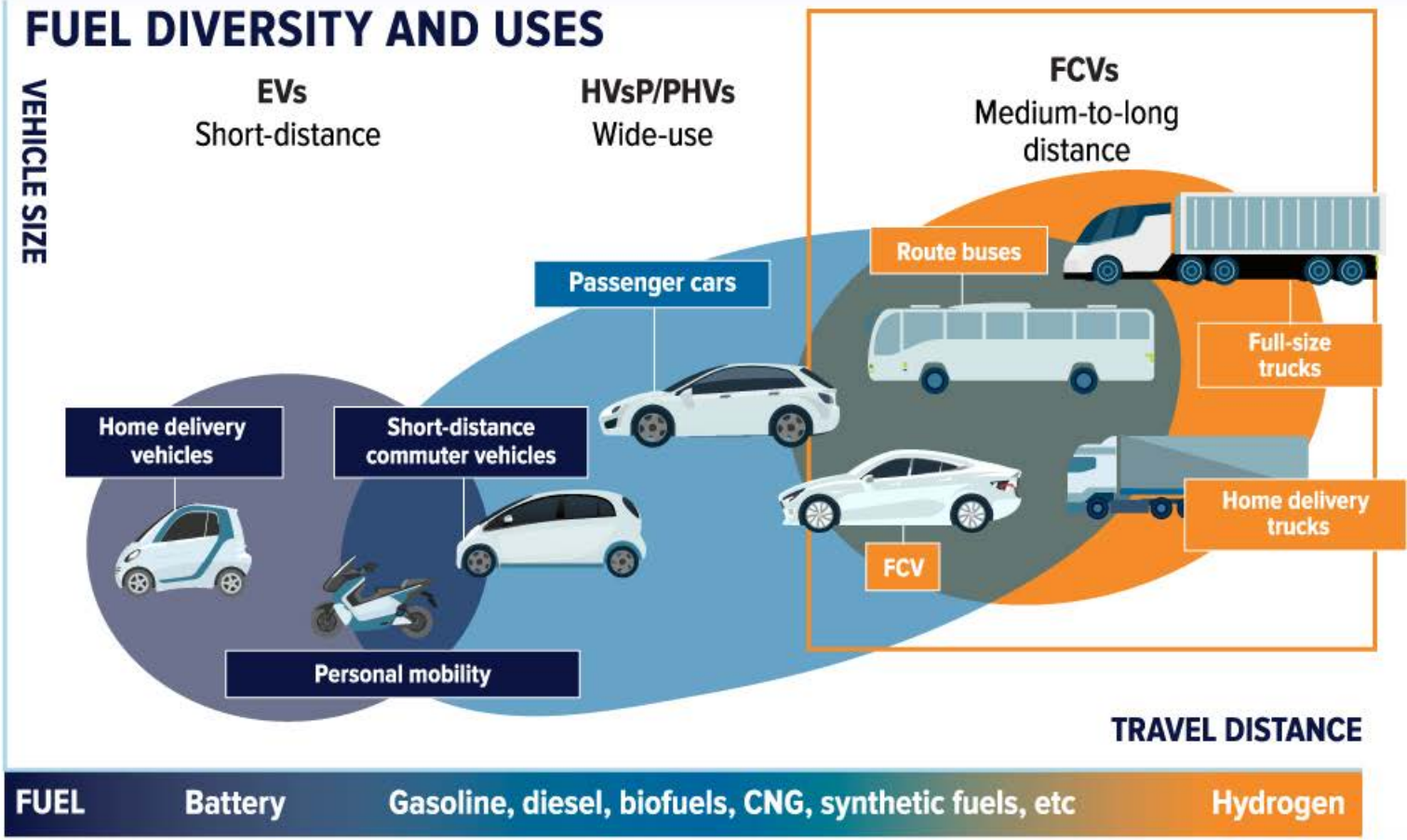
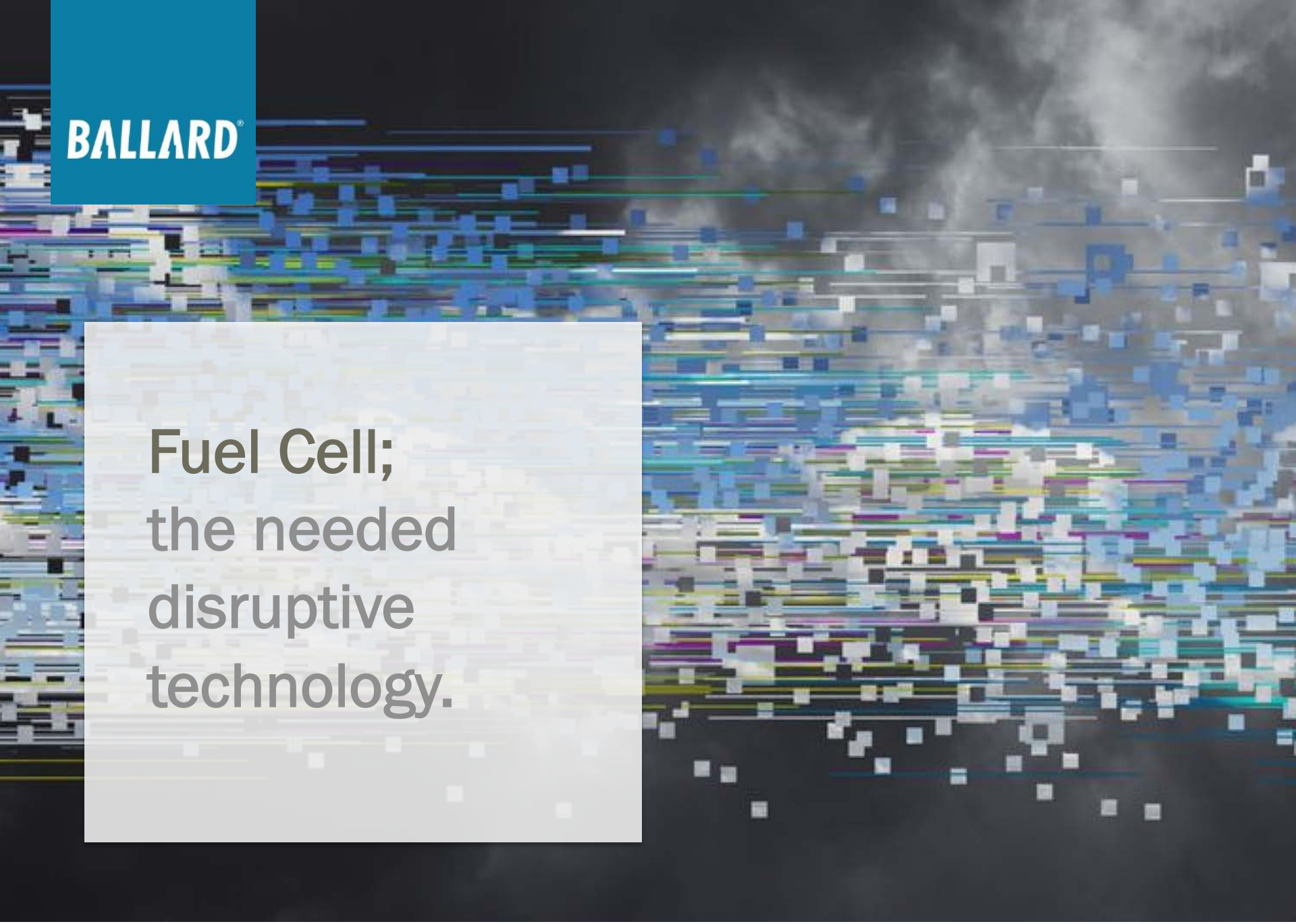
Fuel Cell Vehicles (FCVs)

powered by hydrogen, are no-compromise and emission-free, offering long operating range and fast refueling.

FUEL DIVERSITY AND USES

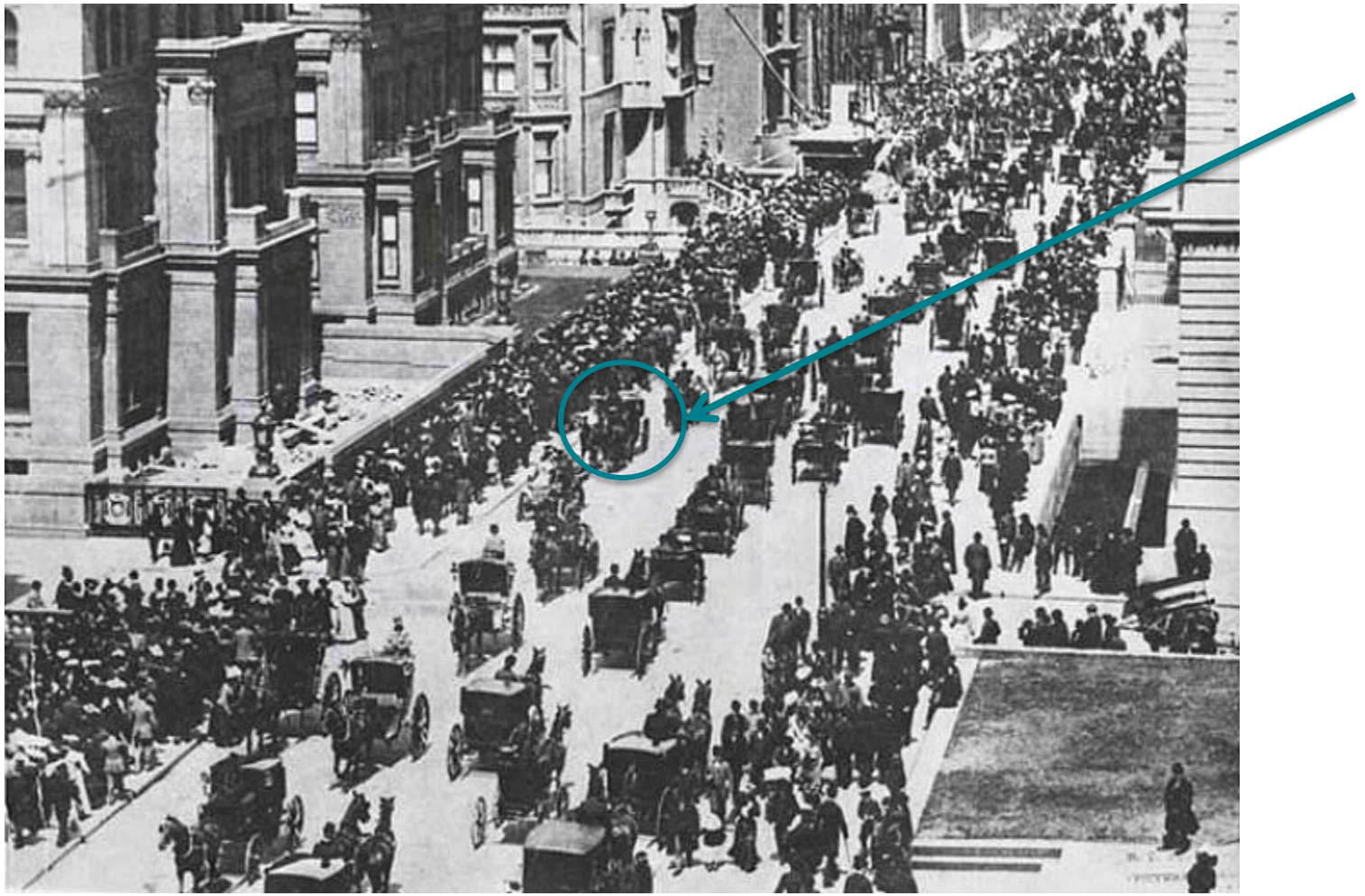


SOURCE: Green Car Reports


BALLARD®
Fuel Cell;
the needed
disruptive
technology.

5th Av, New York City, April 15th 1900

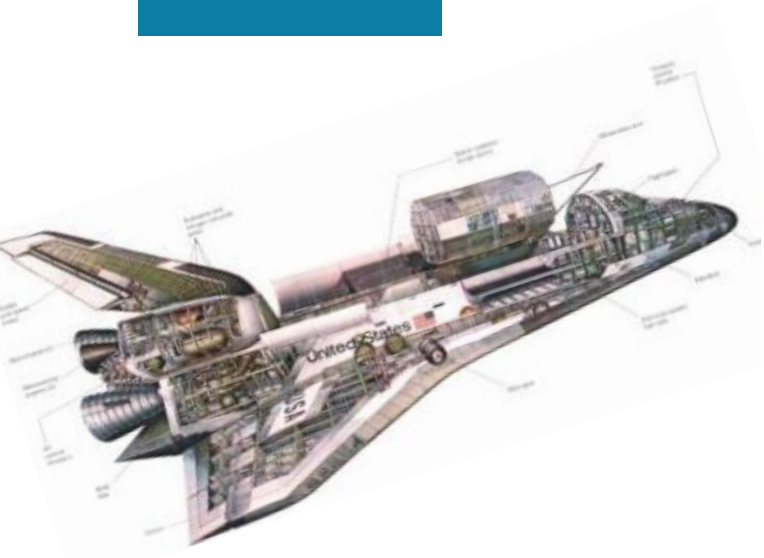
Where is the car ?



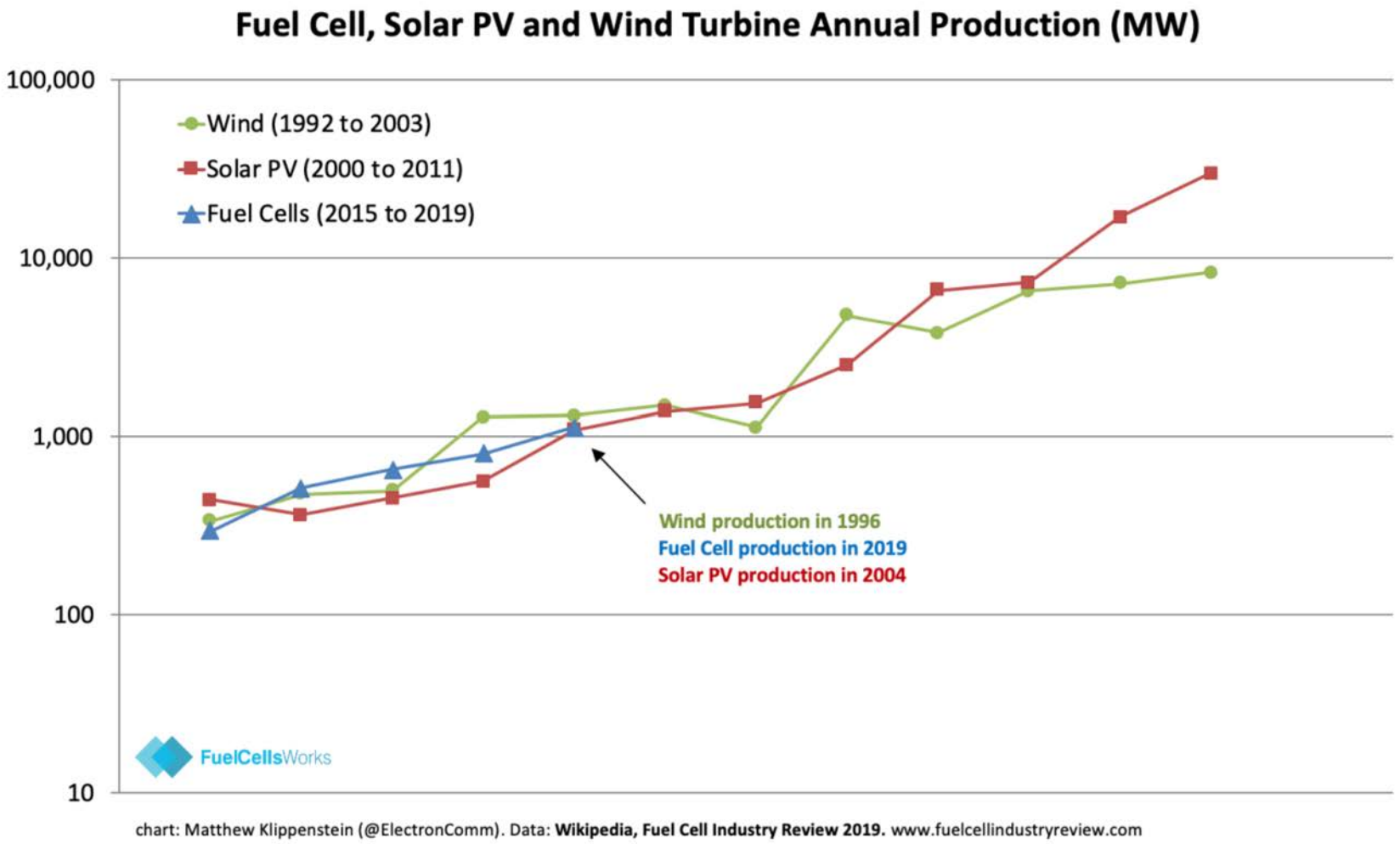
5th Av, New York City; Easter 1913

Can you spot the horse ?

Early Motive Fuel Cell Applications



Growth similar to PV and wind



Why hydrogen now ?

Drivers of renewed interest in hydrogen

Stronger push to limit carbon emissions

10
Years remaining in the global carbon budget to achieve the 1.5°C goal

66
Countries that have announced net-zero emissions as a target by 2050

Falling costs of renewables and hydrogen technologies

80%
Decrease in global average renewable energy prices since 2010

55x
Growth in electrolysis capacity by 2025 vs. 2015

Indicators of hydrogen's growing momentum

Strategic push in national roadmaps

70%
Share of global GDP linked to hydrogen country roadmaps to date[1]

10 m
2030 target deployment of FCEVs announced at the Energy Ministerial in Japan

Industry alliances and momentum growing

60
Members of the Hydrogen Council today, up from 13 members in 2017

30+
Major investments announced[2] globally since 2017, in new segments, e.g. heavy duty and rail

1. Based on 18 country roadmaps announced as of publication
2. Not exhaustive

There are now > 13,000 FC cars on the road and more than 2,500 buses and trucks on the road with over 300 HRS


654 101

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10 million Fuel Cell Vehicles

5,000 FC vehicles on the road in China by 2020

200 fuel stations in California by 2025

50,000 FCVs in service, in China, among which 10,000 units are FC commercial vehicles, and 40,000 units FC passenger cars by 2025
China road map 2018

40,000 vehicles on the road in Japan by 2021
Japan roadmap

6 million FC car produced by 2040
Korea road map 2019

1 million FC vehicles on the road in China by 2030
China road map 2018

800,000 FCEV in Japan by 2030

2019 | 2020 | 2025 | 2030

30,000 fuel cell forklifts in daily operation

12,000 fuel cell cars on the road

2,500+ fuel cell buses and trucks in service

>350 FCEBs on the road in Europe (JIVE)

100 FCEBs at Tokyo 2020 Olympics

1,600 FC trucks in Switzerland

+600 FCEBs on the road in Europe
H2Bus Project

2,000 fuel cell buses in Shandong Province
Weichai

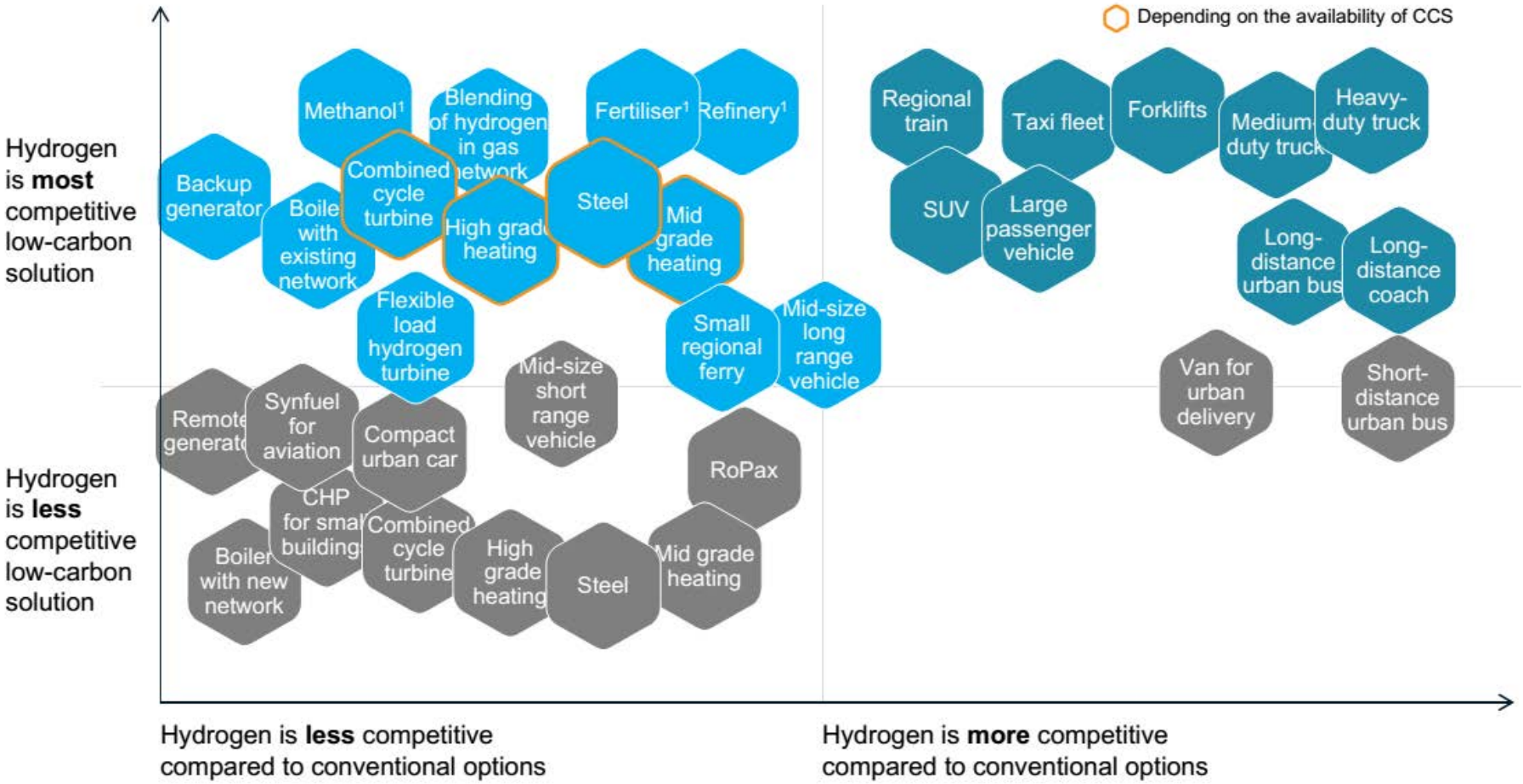
10 to 15 million fuel cell cars and 500,000 trucks on the road
1 in 10 trains on non-electrified tracks
Hydrogen Council vision

15,000 Fuel Cell Vehicles


BALLARD®
Fuel cell technology is needed to achieve deep decarbonization of transportation.

Fuel cells offer superior zero-emission performance for medium and heavy duty vehicles.

Best applications for fuel cells



Source – Hydrogen Council Report – "Path to Hydrogen Competitiveness: A Cost Perspective", January 2020

All current market drivers for electrification are fueling unprecedented fuel cell activity for mobility.

ICE vehicle ban

Country	Current government proposals to ban ICE only vehicle sales
China	Actively considering and studying a ban
France	2040
Germany	2030
India	2030
Ireland	2030
Israel	2030
Netherlands	2030
Norway	2025
Scotland	2032
UK	~~2040~~ 2035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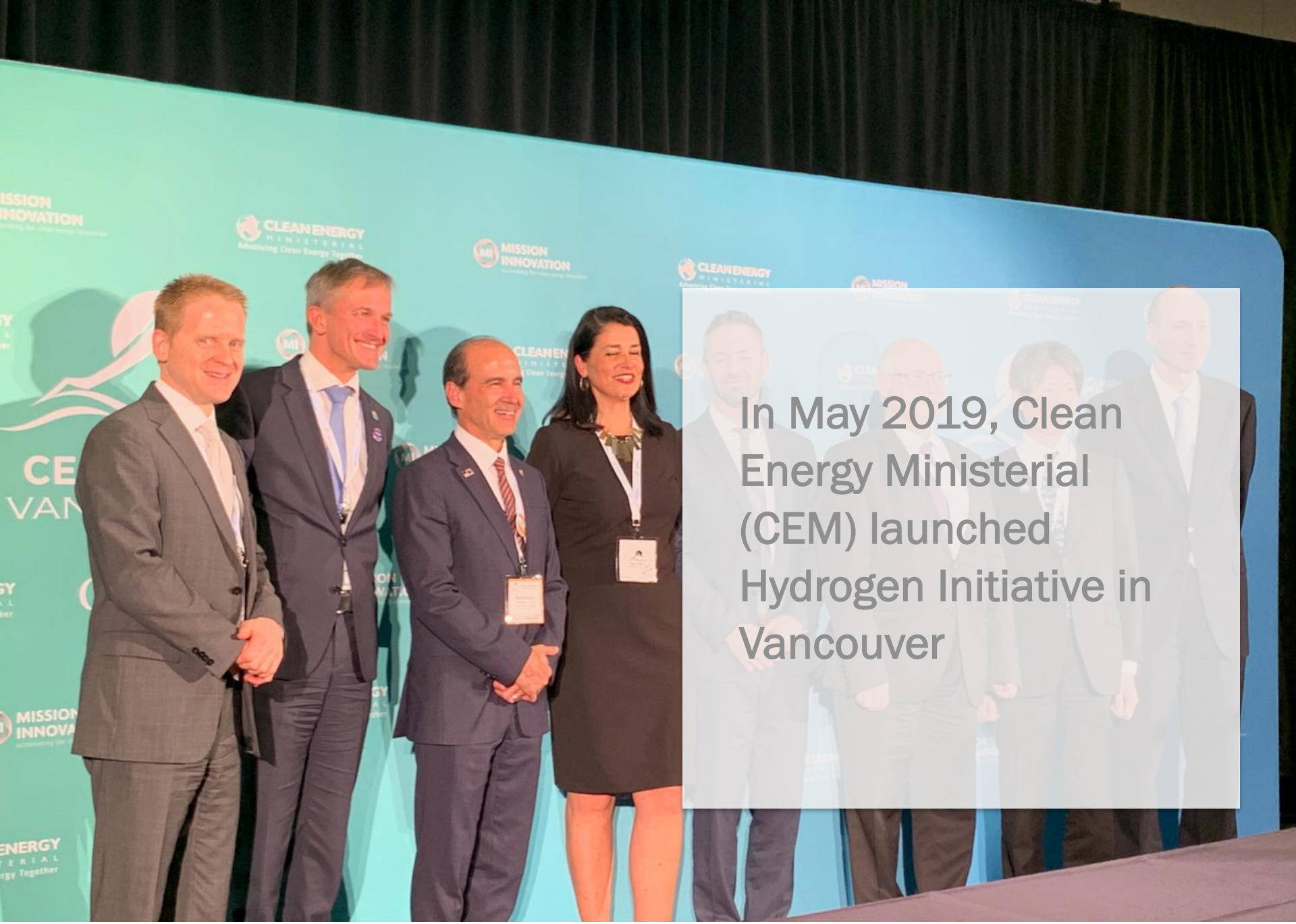
In Feb 2019, EU set emission reductions for Class 8 trucks, requiring reductions of 30% by 2030

IEA Report: The Future of Hydrogen

- **The time is right** to tap into hydrogen's potential to play a key role in a clean, secure and affordable energy future.
- Hydrogen can help tackle various **critical energy challenges.**
- Hydrogen is versatile.
- **Hydrogen can enable renewables** to provide an even greater contribution
- There have been false starts for hydrogen in the past; this time could be different.
- Hydrogen can be used much more widely
- However, **clean, widespread use of hydrogen in global energy transitions faces several challenges.** (Currently mostly carbon based, infrastructure needed, ongoing regulatory effort…)



In May 2019, Clean Energy Ministerial (CEM) launched Hydrogen Initiative in Vancouver

Major Investments and Partnerships Now Accelerating

BALLARD®

Hydrogen Council

3M · AIRBUS · Air Liquide · AIR PRODUCTS · ALSTOM · AngloAmerican · aramco · BMW GROUP · BOSCH · BP

国家能源集团 CHN ENERGY · CNH INDUSTRIAL · Cummins · DAIMLER · EDF · ENGIE · equinor · faurecia · GM · Great Wall · HONDA

HYUNDAI · Iwatani · JM Johnson Matthey · JXTG Nippon Oil & Energy · Kawasaki · KOGAS · Linde · MICHELIN

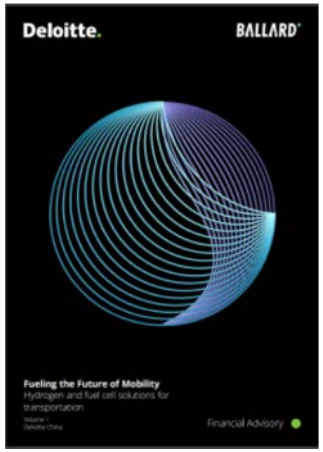
SCHAEFFLER · SIEMENS · SINOPEC · thyssenkrupp · TOTAL · TOYOTA · WEICHAI

AFCEnergy · AVL · BALLARD · CHART · Chevron · elringklinger · Faber CYLINDERS · Fortescue · galp · GORE · HEXAGON · ILJIN · ITOCHU · LIEBHERR

MANN+HUMMEL · Marubeni · MCDERMOTT · McPhy · Mitsubishi Corporation · MITSUBISHI HEAVY INDUSTRIES · MITSUI&CO. · nel · NGK NTK · NIKOLA · PLUG POWER

REFIRE · 中自催化 SINOCAT · 亿华通 · SMBC · snam · SoCalGas · Sumitomo Corporation · TOYOTA TSUSHO · TRUEZERO · Vopak · Woodside

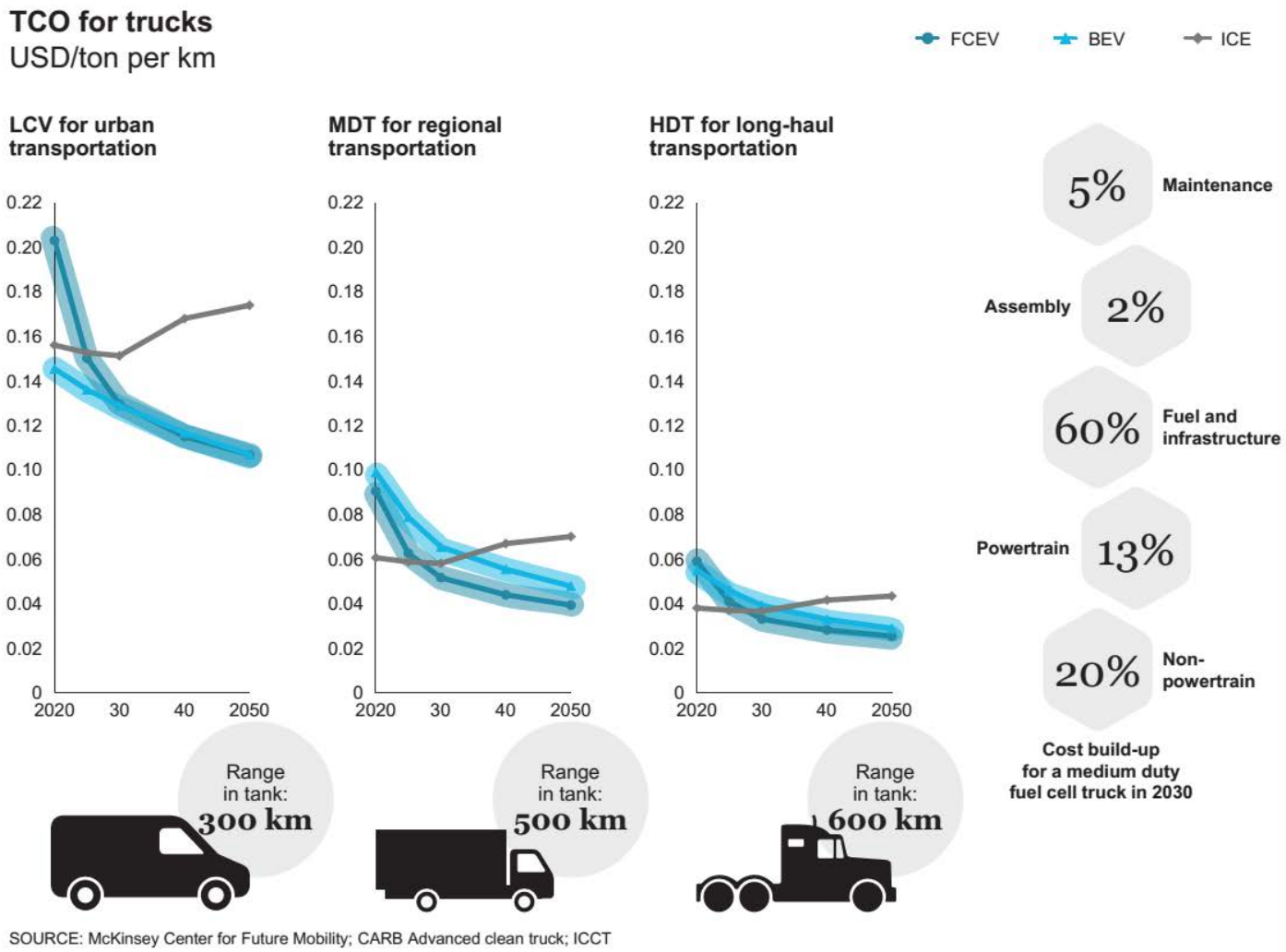
ANTIN · BNP PARIBAS · CRÉDIT AGRICOLE · John laing · SOCIETE GENERALE



> “In less than 10 years, it will become cheaper to run a fuel cell electric vehicle (FCEV) than it is to run a battery electric vehicle (BEV) or an internal combustion engine (ICE) vehicle for certain commercial applications.”

Deloitte- Ballard report 2020

Exhibit 20 | TCO trajectory of trucks



SOURCE: McKinsey Center for Future Mobility; CARB Advanced clean truck; ICCT

BALLARD

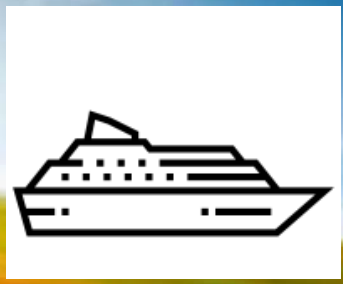
2030

100% decarbonized hydrogen fuel for transport

Thousand's of fuel cell buses will be on the road.

500,000 trucks will be powered by hydrogen .

1-10 trains sold for currently non electrified railways could be powered by hydrogen.



The first hydrogen powered cruise ships will be in service .

The vision of the Hydrogen Council is achievable

Hydrogen and fuel cells in Canada

https://youtu.be/RxwcGduXq74

40 years

BALLARD®

"It will take a combined effort of academia, government, and industry to bring about the change from a gasoline economy to a hydrogen economy"

Geoffrey Ballard (1932-2008)

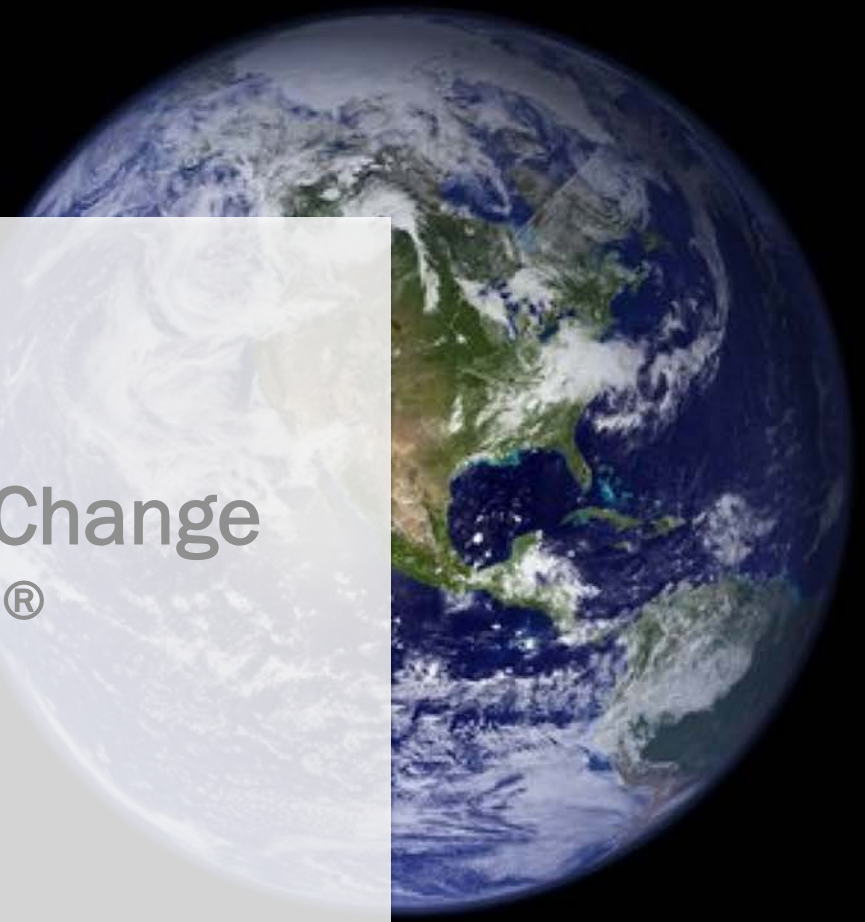

BALLARD FUEL CELL POWER
Zero Emission Waste
SCIENCE


BALLARD
43 TO VILLAGE
1010
BCTransit
BCTransit


VANHOOL
PAU - 9 - 2019


BALLARD

BALLARD®



Power to Change the World®

BALLARD BY THE NUMBERS

40
YEARS
1979-2019

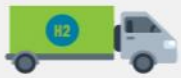

900
employees

1,400
patents & applications

25 years Nasdaq
27 years TSX
publicly listed Company

WEICHAI
AngloAmerican
NISSHINBO
大洋电机 BROAD-OCEAN
4
strategic shareholders


570+
transit buses in service



2,000+
trucks delivering goods


4 TRAIN
projects on track

5 SHIPS
in development


12,000
forklifts in operation


$80 million
automobile stack development program

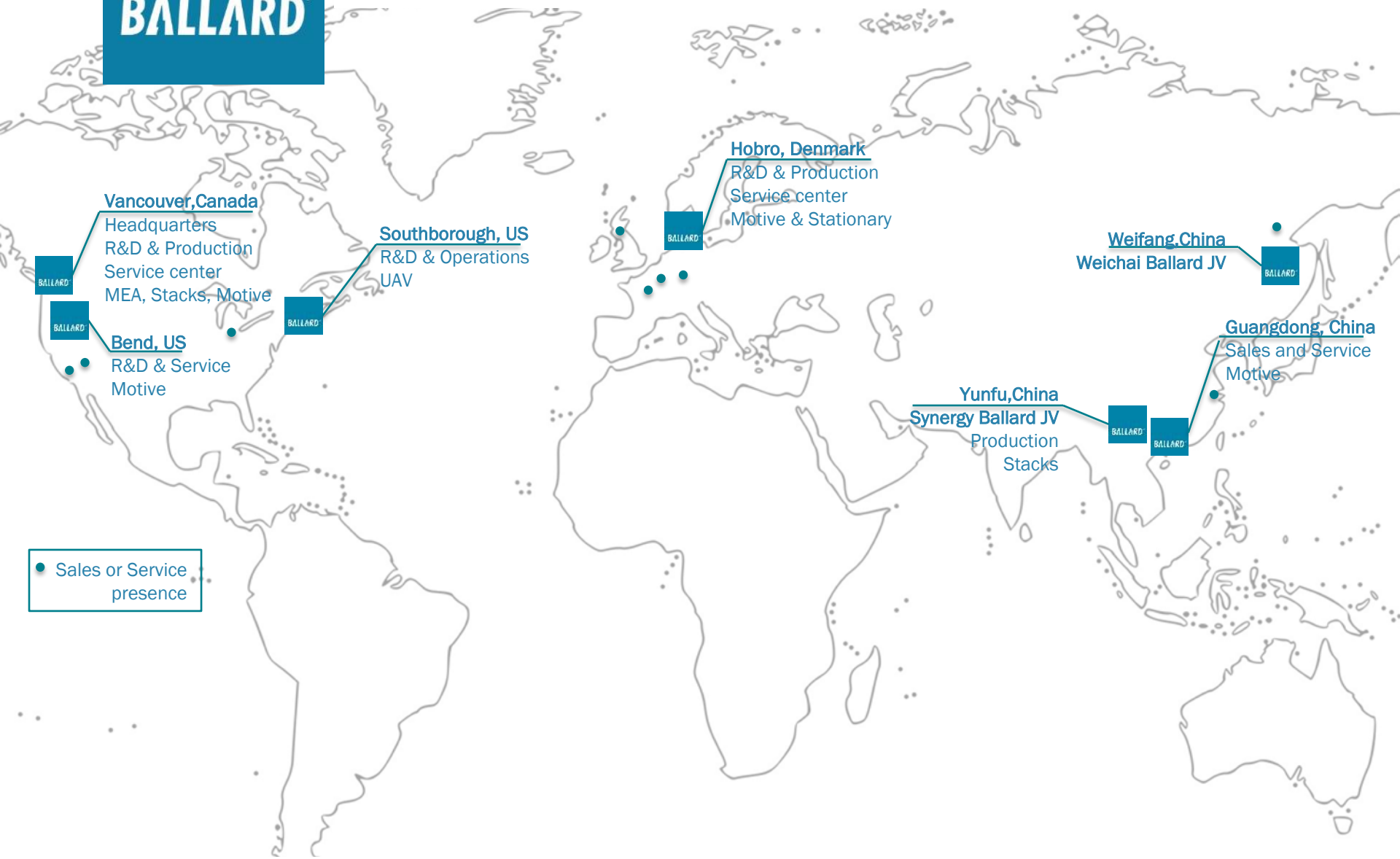

670 MW
of fuel cell products delivered


>5.5 million MEAs
produced


>30 million
kilometers of vehicle experience

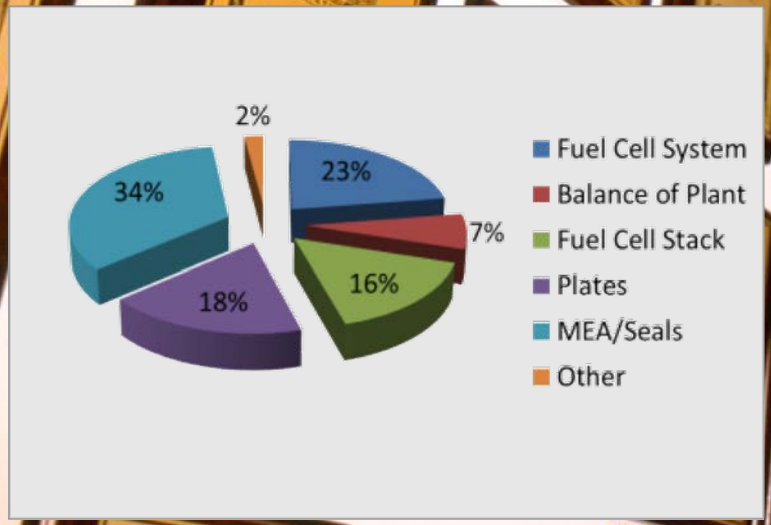

>30,000 hours
operation of fuel cell stack in London buses

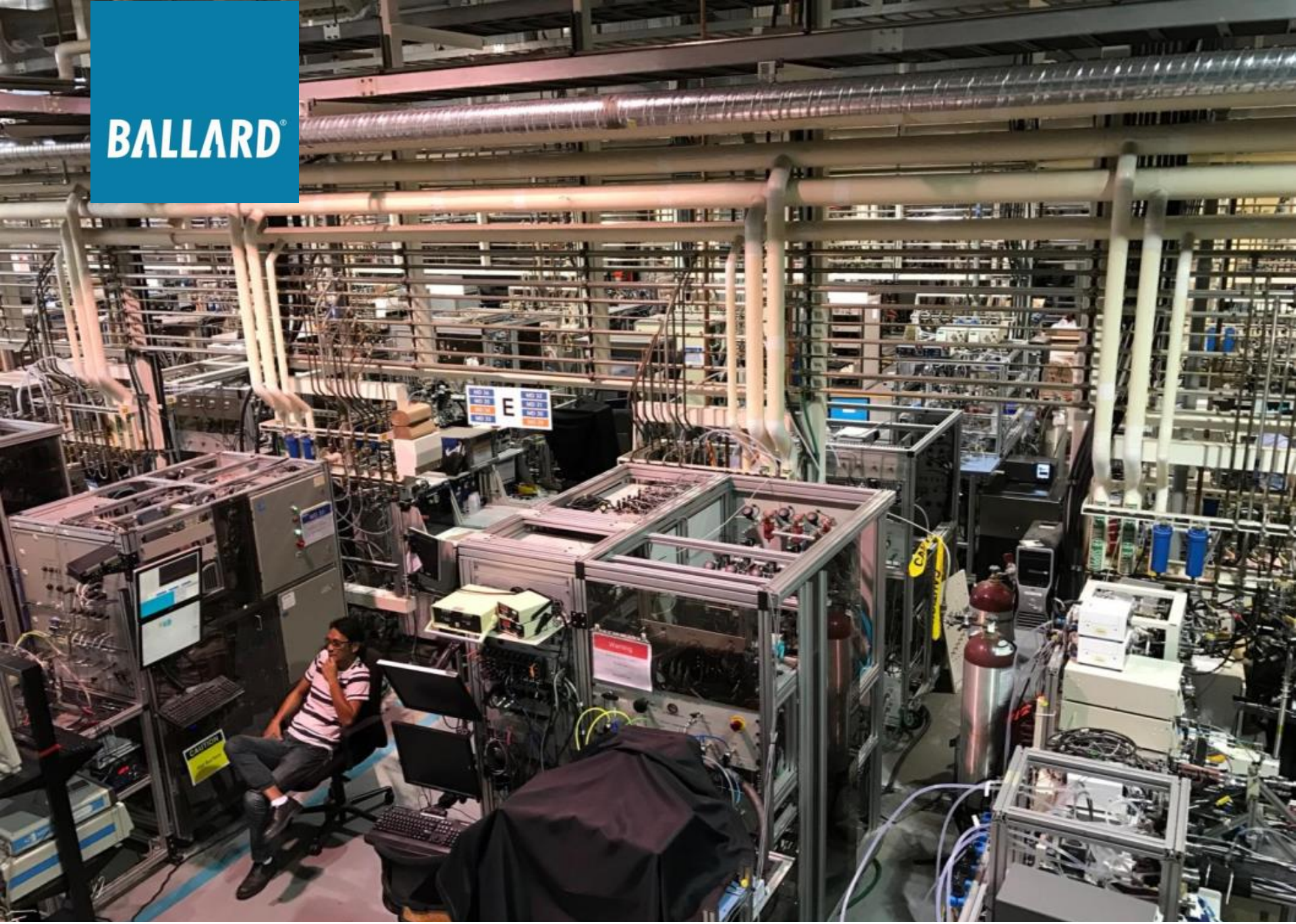
We are a global company



BALLARD®

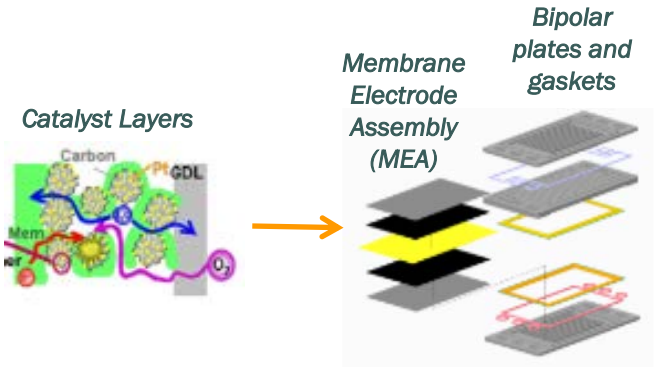
Strong intellectual capital and IP with over 1,400 patents and applications




BALLARD

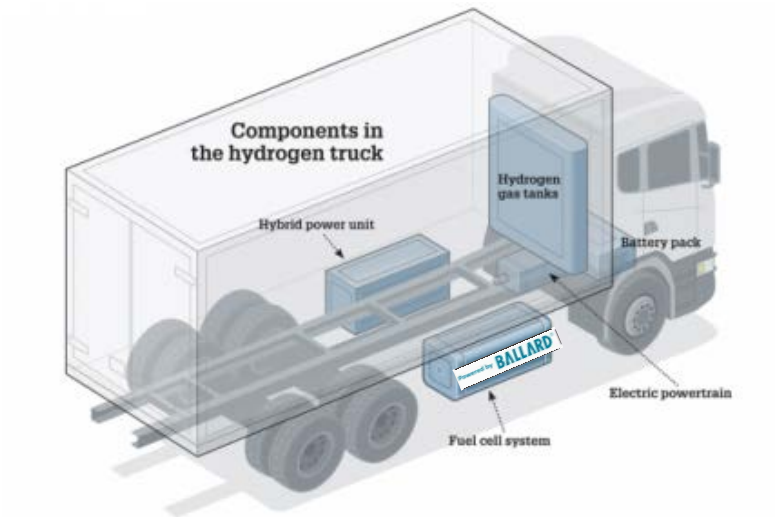
Ballard-Powered Fuel Cell Vehicles

Unit cell stack components



Fuel cell stack

Fuel cell module



Powered by Ballard









BALLARD
Mireo Plus

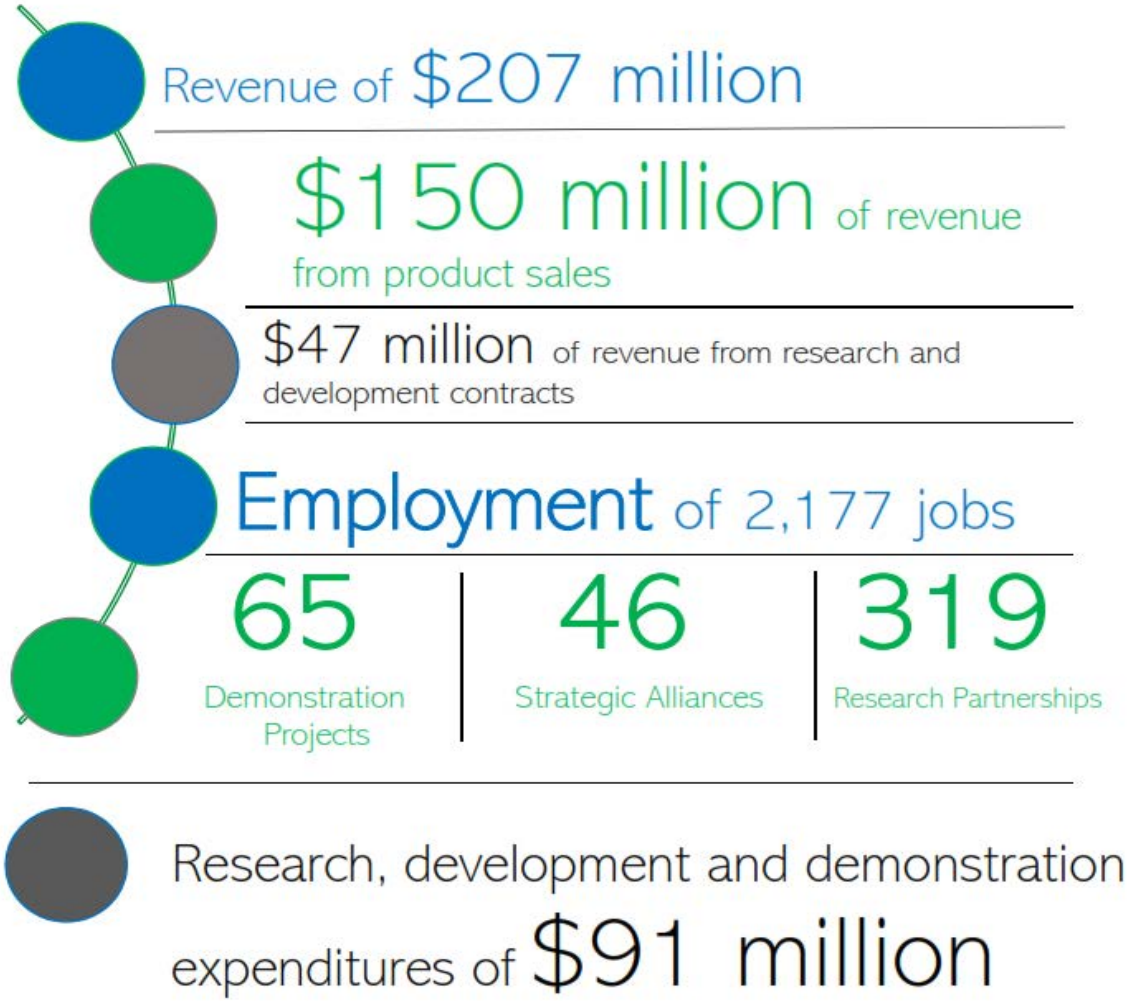

BALLARD
NORLED


BALLARD
STNE

Fuel cell truck for Alberta


BALLARD
BALLARD
Powered by hydrogen
TOYOTA MIRAI | Zero CO_2 Emissions

Canadian Hydrogen and Fuel Cell Sector



Canada hydrogen and fuel cell industry

Hydrogen and Fuel Cells

BALLARD
HYDROGENICS
SHIFT POWER | ENERGIZE YOUR WORLD
LOOP
ITM POWER
Energy Storage | Clean Fuel
dynaCERT Inc.
QUADROGEN
NU:IONIC TECHNOLOGIES
Hydrogen In Motion

Test Equipment and Services

GREENLIGHT INNOVATION
Powertech
The Power of Trust. The Future of Energy.
Intertek
CSA Group

OEMs and Energy

HYUNDAI
TOYOTA
ENBRIDGE
FORTIS BC

Components

DANA
dpoint technologies
TANDEM TECHNOLOGIES
IONMR
Terrella Energy Systems Ltd.
Blue-O

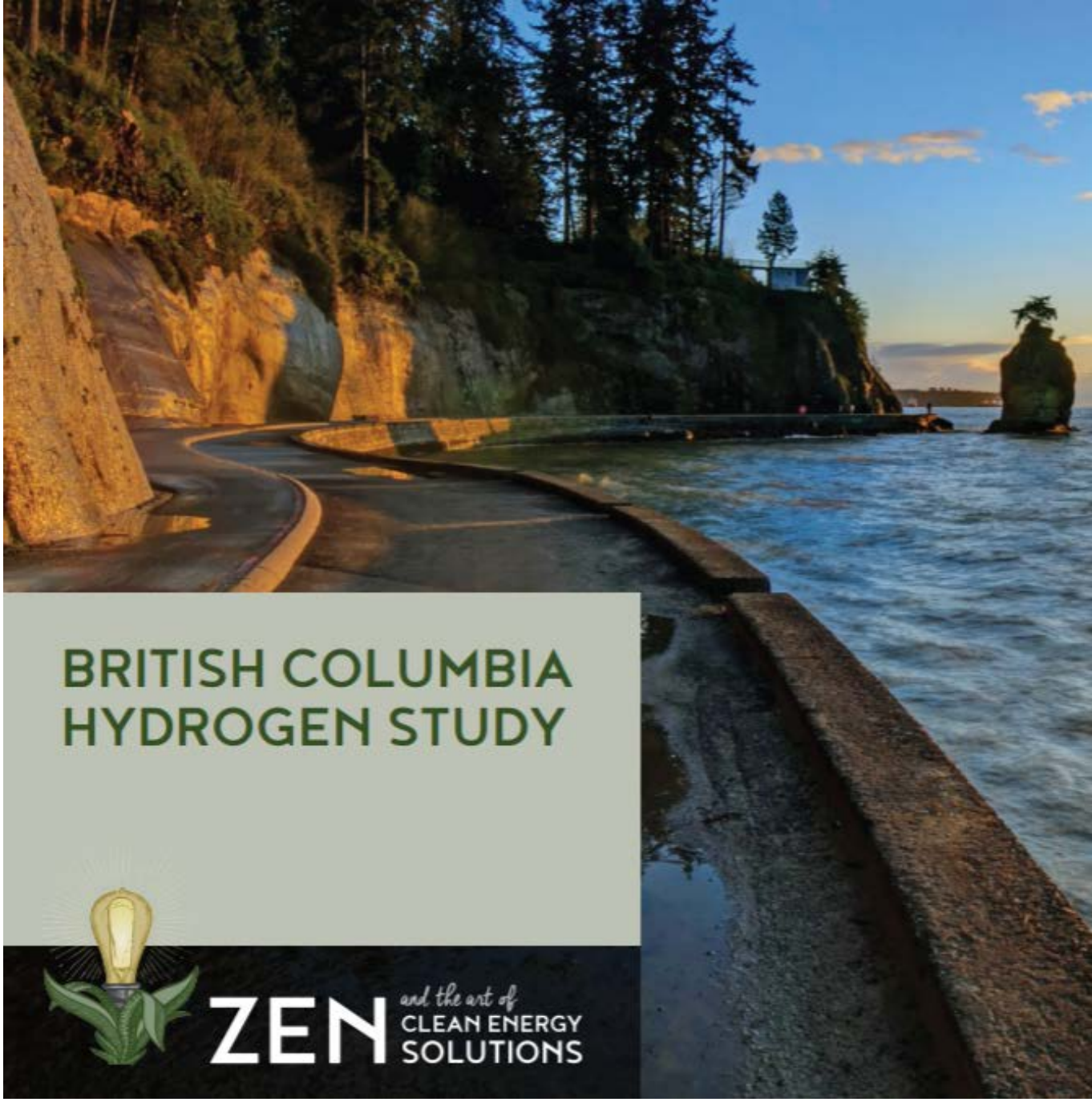
Engineering and Consulting

Sacré-Davey ENGINEERING
NORAM
HTEC
Hydrogen Technology & Energy Corporation
ZEN CLEAN ENERGY SOLUTIONS
OVERDRIVE
FUEL CELL ENGINEERING
G&S Budd Consulting
PACIFIC WELLFARE

Academia

UQTR
UBC
SFU
CERC Clean Energy Research Centre
Lambton College
UNIVERSITY OF TORONTO
NRC·CNRC
RED RIVER COLLEGE
Canadian Nuclear Laboratories
Laboratoires Nucléaires Canadiens

CHFCA
clean energy now™


BRITISH COLUMBIA
HYDROGEN STUDY
ZEN
and the art of
CLEAN ENERGY
SOLUTIONS

Vision for 2050

BC can be a global leader by adopting policies that promote and support all sides of an emerging hydrogen economy including demand, supply and technology development. Through a combination of policy and investment, hydrogen can play a major role in the Province by 2050.

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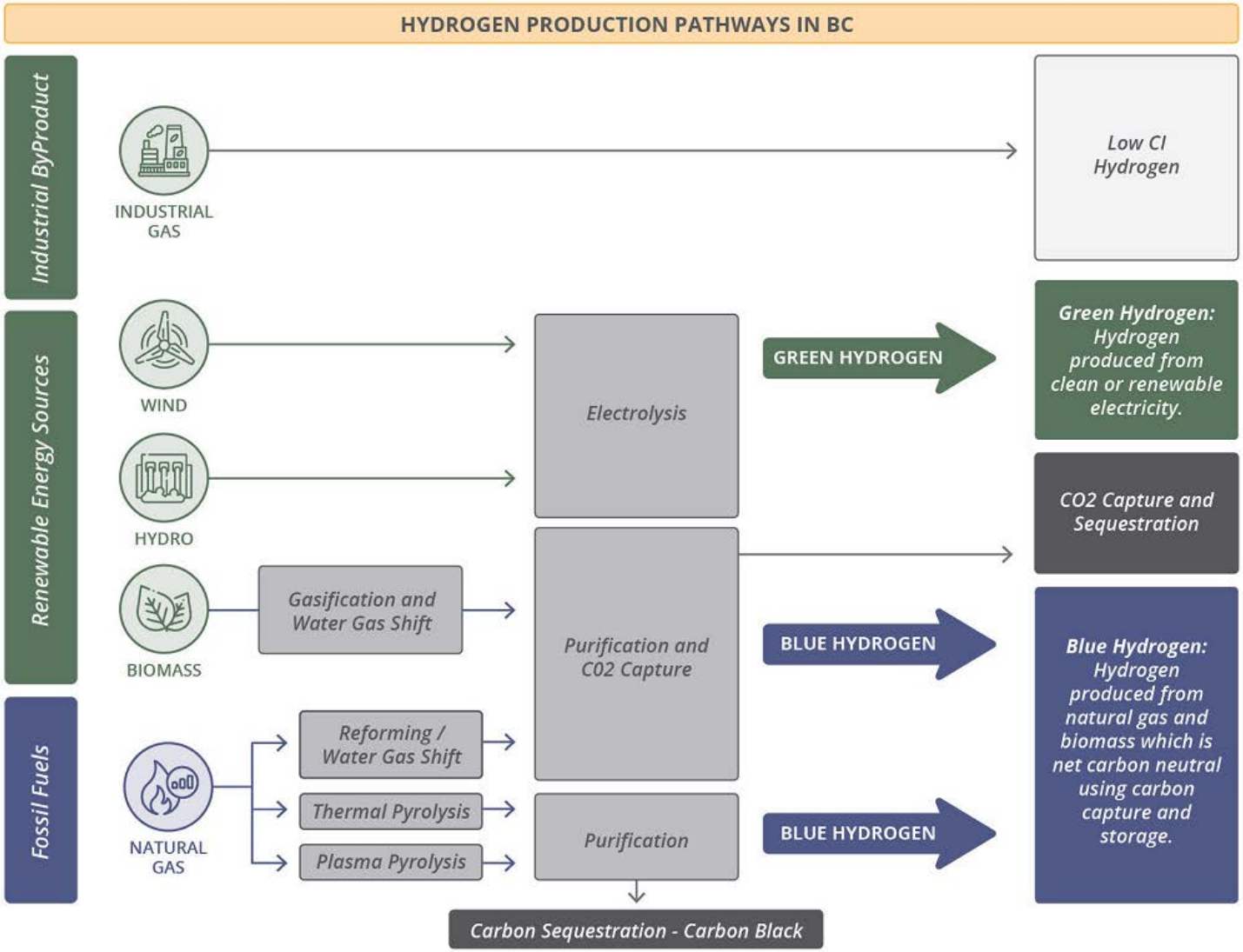
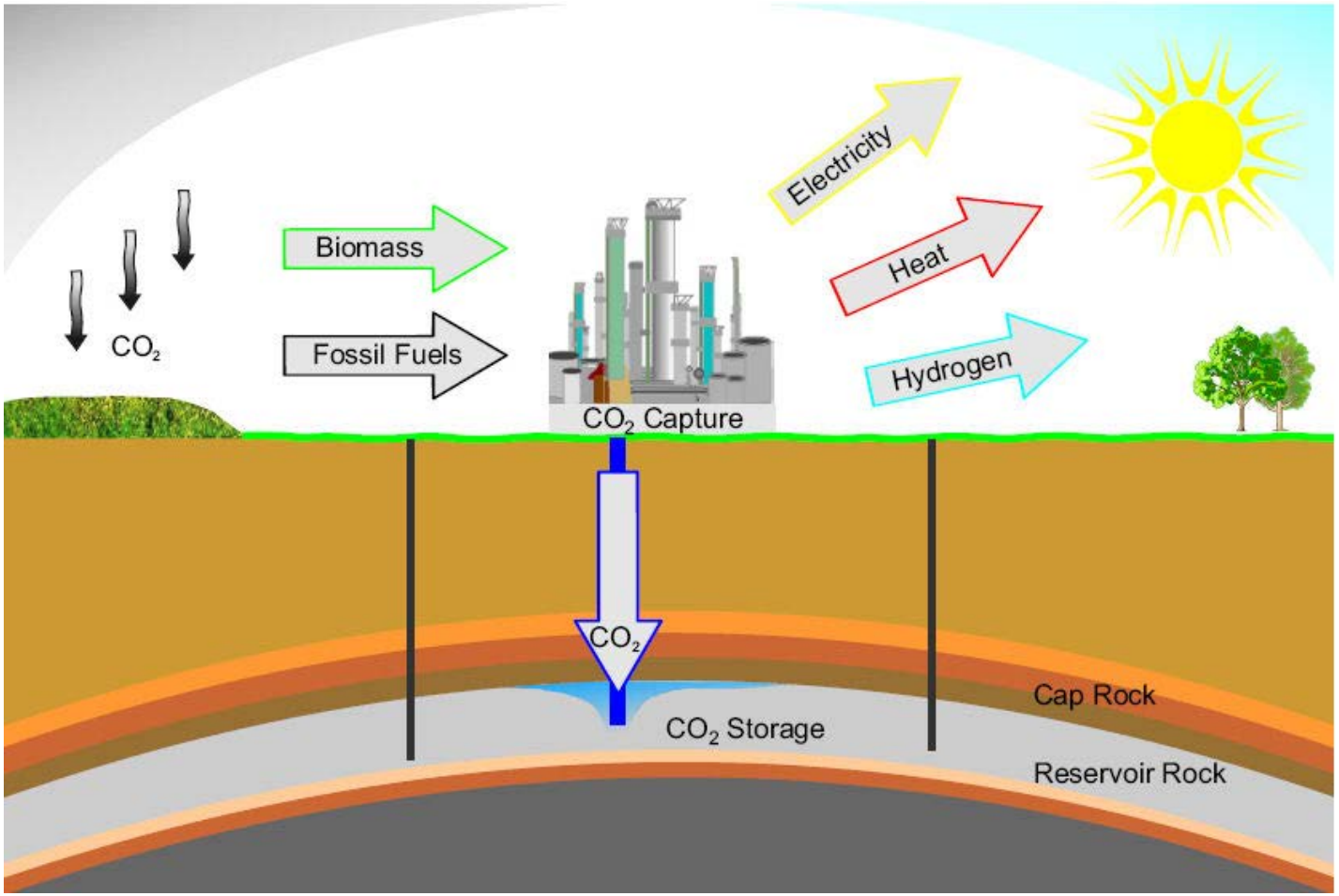

HYDROGEN PRODUCTION PATHWAYS IN BC
Industrial ByProduct
Renewable Energy Sources
Fossil Fuels
INDUSTRIAL GAS
WIND
HYDRO
BIOMASS
NATURAL GAS
Gasification and Water Gas Shift
Reforming / Water Gas Shift
Thermal Pyrolysis
Plasma Pyrolysis
Electrolysis
Purification and C02 Capture
Purification
GREEN HYDROGEN
BLUE HYDROGEN
BLUE HYDROGEN
Carbon Sequestration - Carbon Black
Low CI Hydrogen
Green Hydrogen: Hydrogen produced from clean or renewable electricity.
CO2 Capture and Sequestration
Blue Hydrogen: Hydrogen produced from natural gas and biomass which is net carbon neutral using carbon capture and storage.

Recommendations

The top ten recommendation themes for the 2020 – 2025 timeframe are to:

1. Identify and communicate hydrogen as priority sector for the Province.
2. Priorities development of large-scale, low carbon intensity hydrogen supply infrastructure and strategic hydrogen liquefaction and distribution assets in the Province.
3. Adopt policy that specifies the carbon intensity of hydrogen, rather than limiting to renewable only. This includes updating the defining of renewable natural gas in BC's Greenhouse Gas Reduction Regulation to include low carbon intensity hydrogen.
4. Set longer-term objectives for transition to renewable hydrogen supplies through establishing tired thresholds of required renewable content over tie.
5. Develop flexible, lower cost electricity rate schedule to encourage production of Green Hydrogen.
6. Support lighthouse projects that will demonstrate the potential of hydrogen in critical end use applications.
7. Adopt recommended policies and regulatory framework for light and heavy-duty FCEVs and support the build out of hydrogen refueling infrastructure.
8. Support research, development and deployment in the Province to ensure the local hydrogen cluster maintains competitive global advantages and remains an important economic sector within the Province.
9. Support initiatives related to developing an export market for hydrogen, particularly those that can leverage international investment to develop local supply of hydrogen.
10. Priorities a strategic investment fund to support the above recommendations.

Opportunity for BC and AB with production of low carbon H2

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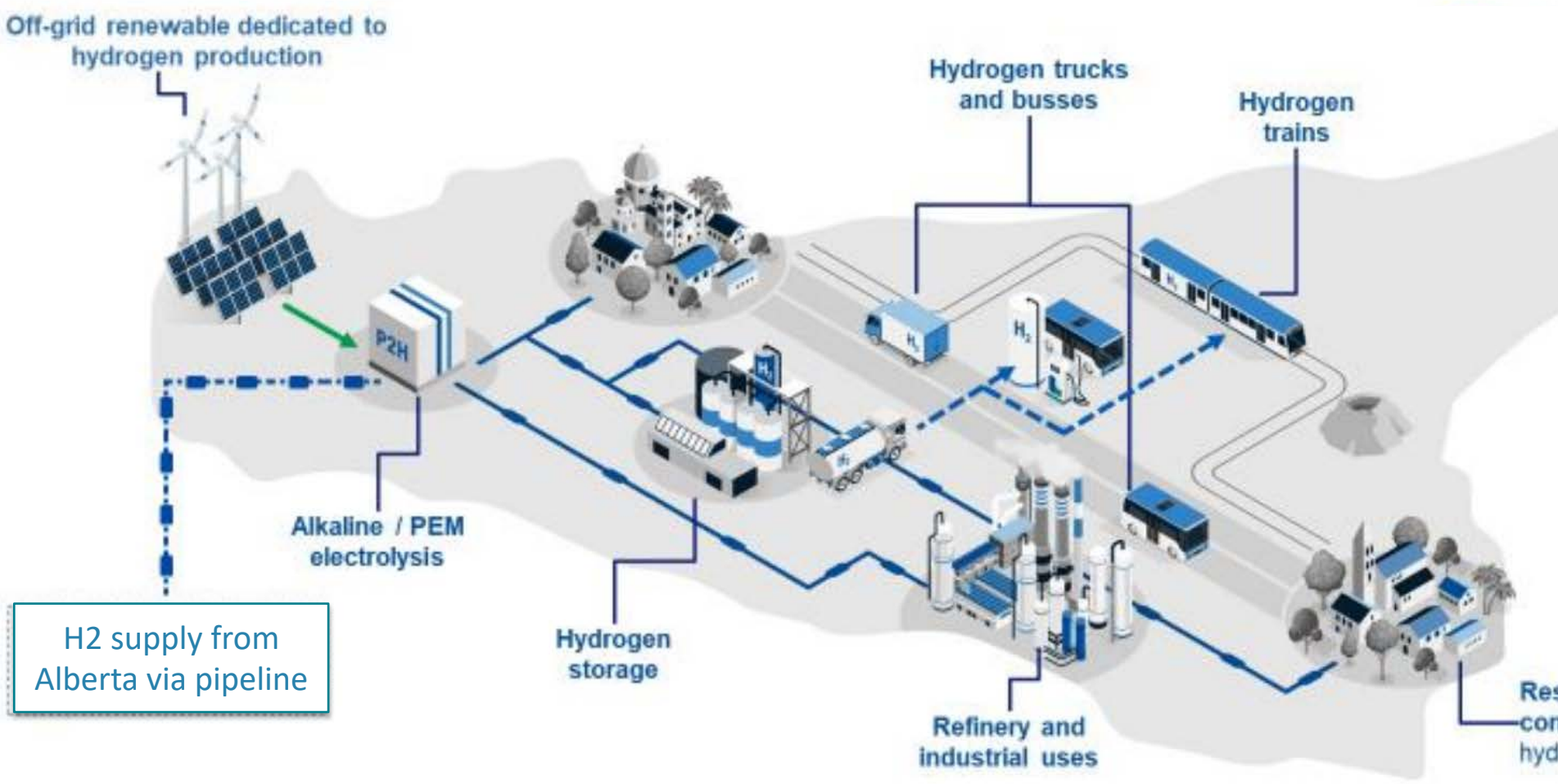
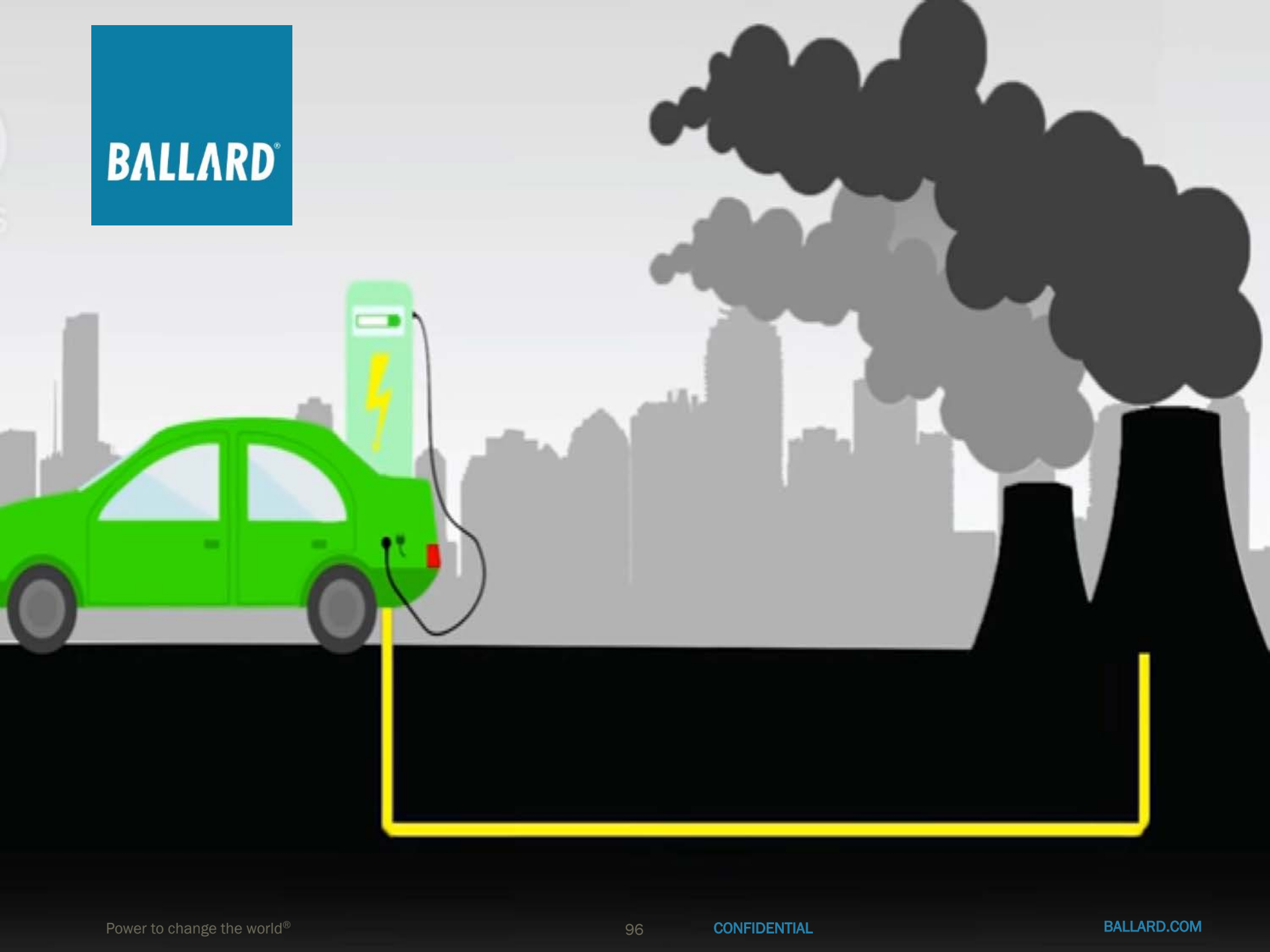
In the future…




BALLARD®
Complete and long-term environmental impact must also be addressed.

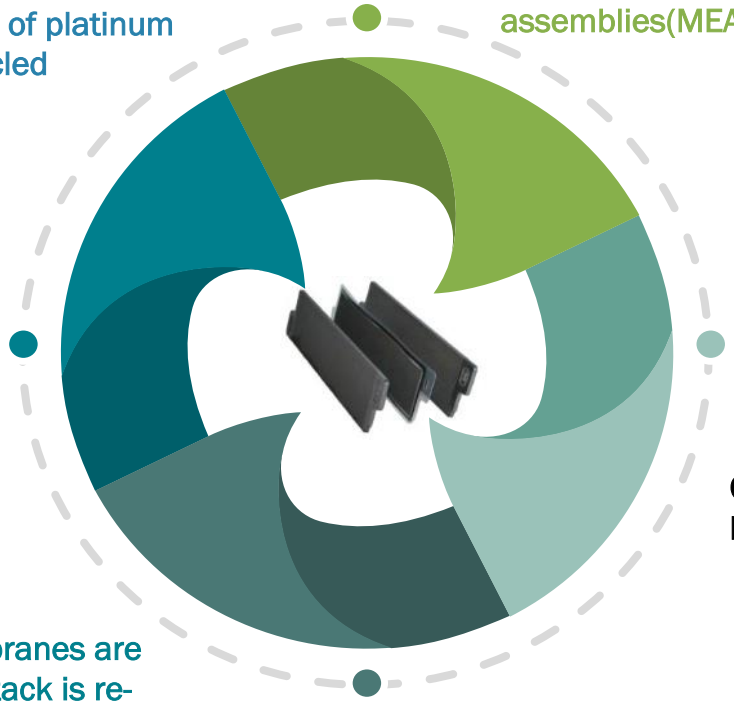



BALLARD®
Supply chain risk must be part of the technology assessment when choosing a path to electrification.

Fuel cell have a lower environmental impact

More than 95% of platinum catalyst is recycled

Fuel cell stacks are refurbished by replacing the membrane electrode assemblies(MEA)



Carbon bipolar plates & compression hardware are re-used indefinitely

Fuel cell membranes are recycled and stack is re-conditioned

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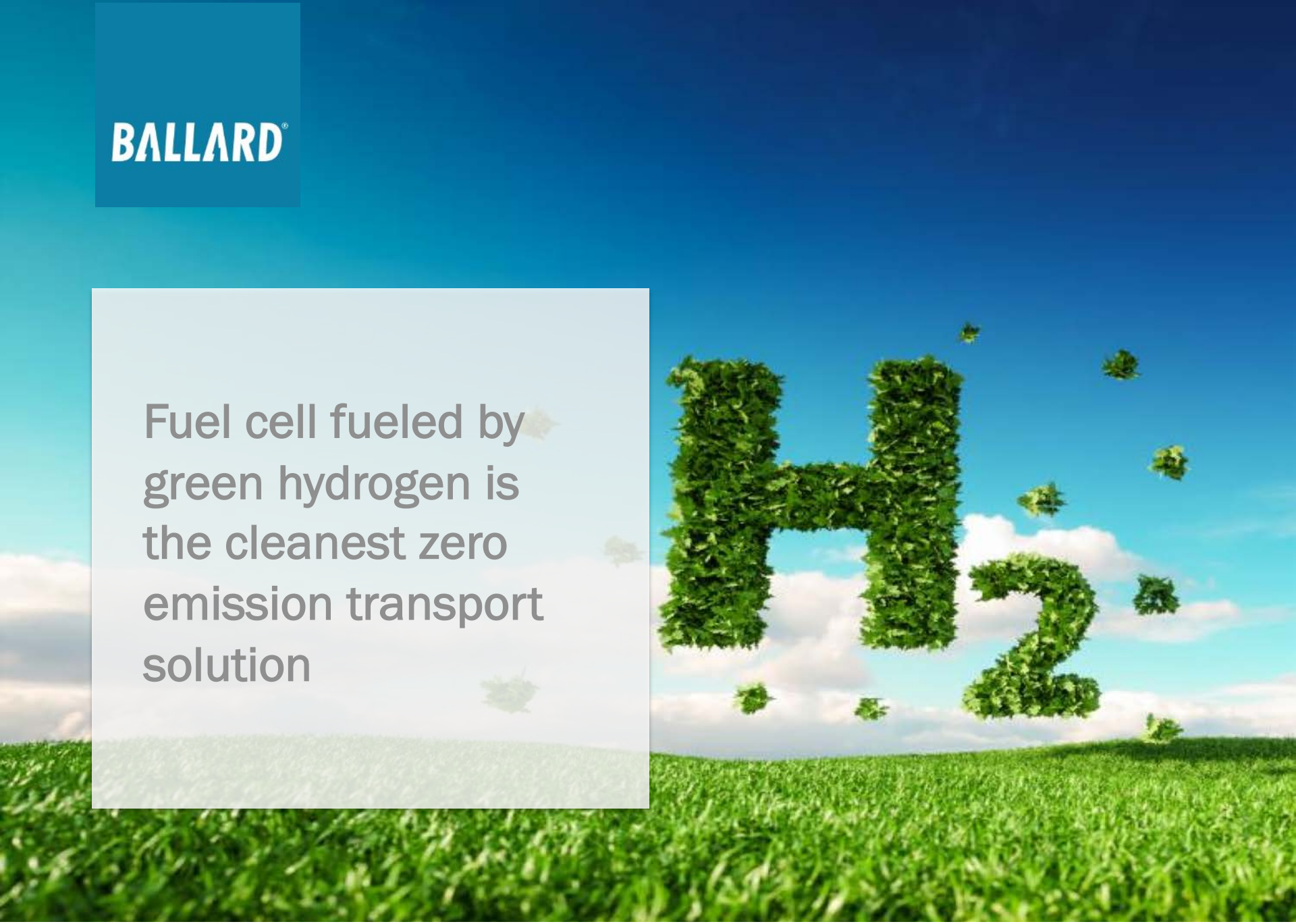
Fuel cell fueled by green hydrogen is the cleanest zero emission transport solution



Take away

1 Hydrogen is required to meet our emission reduction objectives
if we are serious about decarbonization.

2 Unprecedented global momentum
driven by 4 underlying trends – decarbonization, falling renewable costs, strategic government push and industry coordination.

3 Hydrogen potential 10x until 2050
Growth in feedstock, transport, buildings, industrial heat, and electricity.

4 Low-carbon hydrogen can be competitive by 2030
Green and blue hydrogen can beat grey hydrogen by 2030.
Step-change in scale would unlock trucks, cars, steel and others.

5 Canada & British Columbia have the opportunity to become global leaders for hydrogen and fuel cells


SUPPORT
HYDROGEN FUEL CELLS
SOLAR + WIND
POWER!
RAW


f-cell HFC
VANCOUVER
SAVE THE
DATE
Vancouver
Convention
Centre
April 1+2
2020


BALLARD®
At Ballard,
We deliver fuel cell power for a sustainable planet.