Emerging Technologies-Fuel Cells

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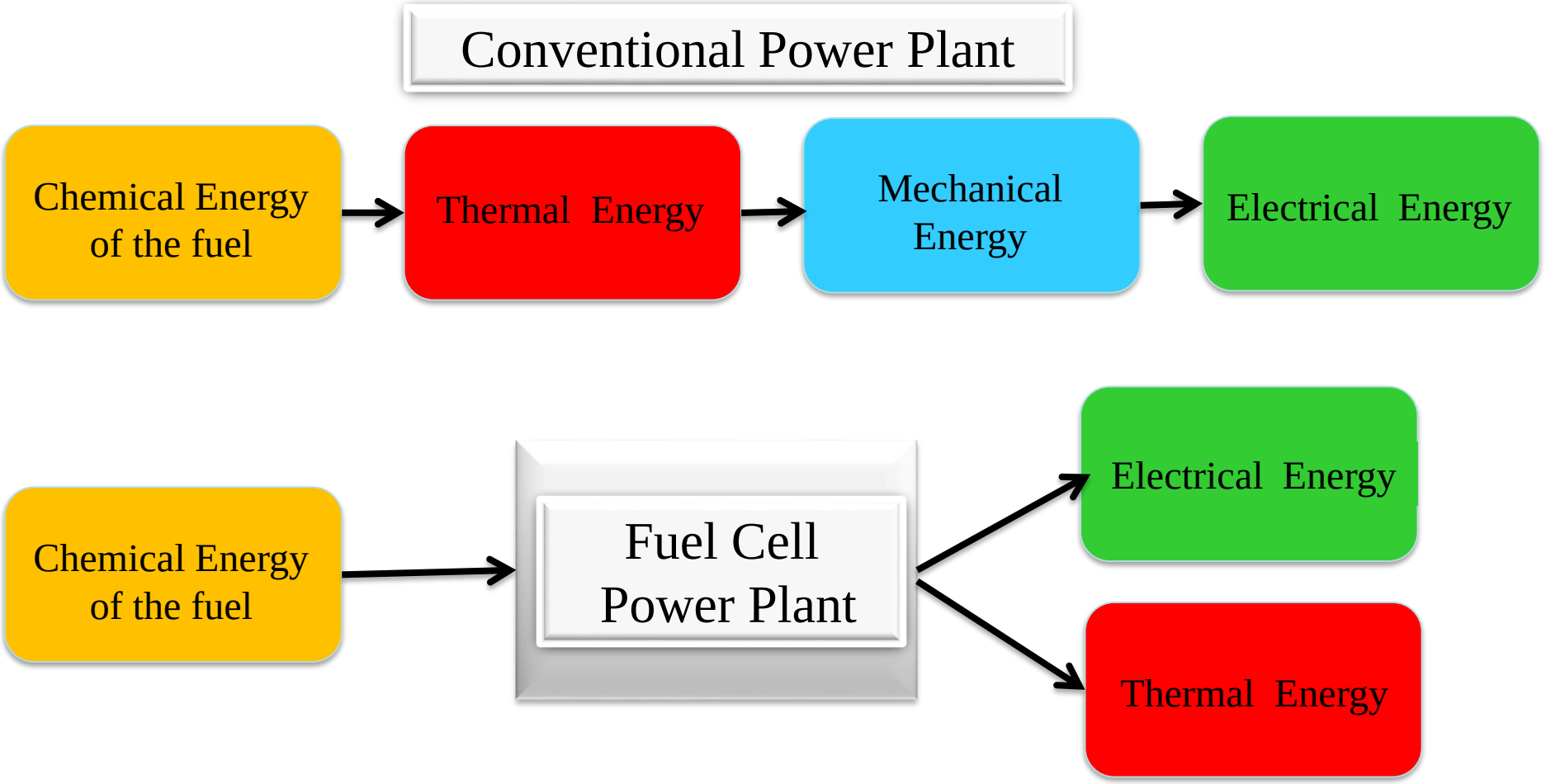
Content

- Grand Challenges
- What is Fuel cell and how it works?
- Types of Fuel Cell
- Benefits of Fuel Cell
- Applications of Fuel Cell
- Global Fuel Cell and Hydrogen initiatives
- Fuel Cell Market

Grand Challenges

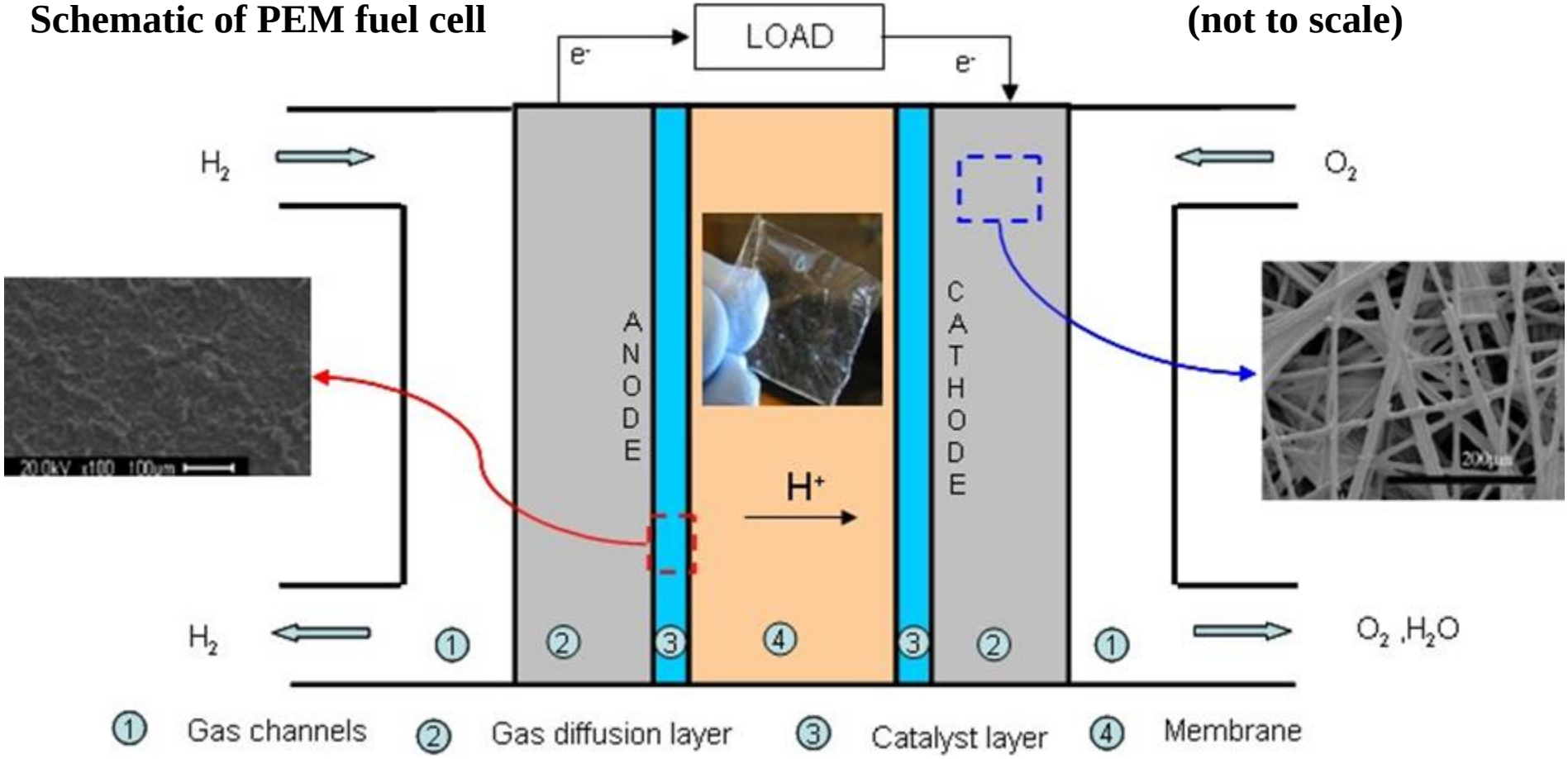
What is Fuel Cell?



A **fuel cell** is an electrochemical device which converts the chemical energy of the fuel directly into electrical and thermal energy.

How Fuel Cell work?

Schematic of PEM fuel cell **(not to scale)**

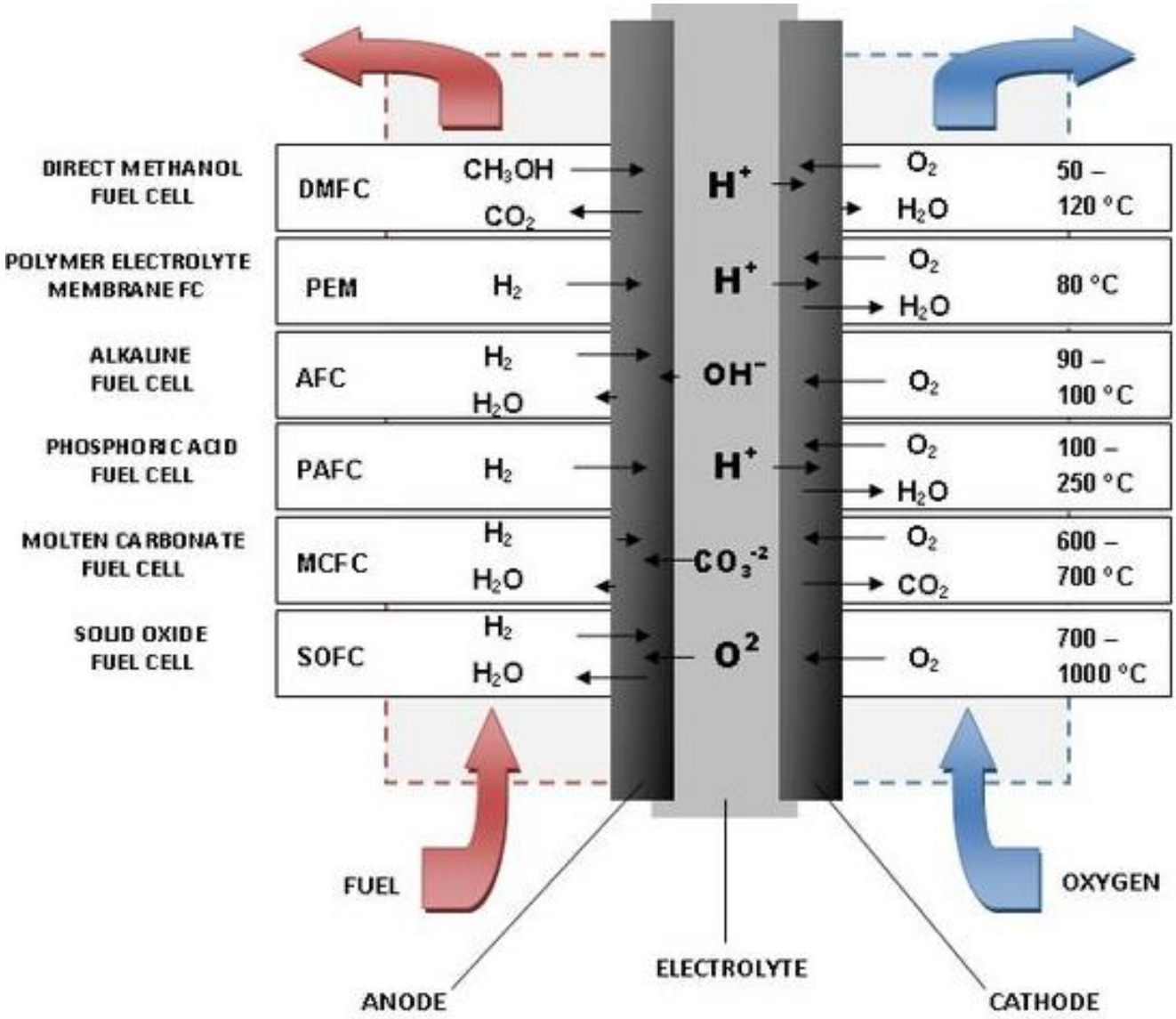


$$H_{2(g)} \rightarrow 2H^{+} + 2e^{-}$$

$$\frac{1}{2}O_{2(g)} + 2H^{+} + 2e^{-} \rightarrow H_2O_{(l)}$$

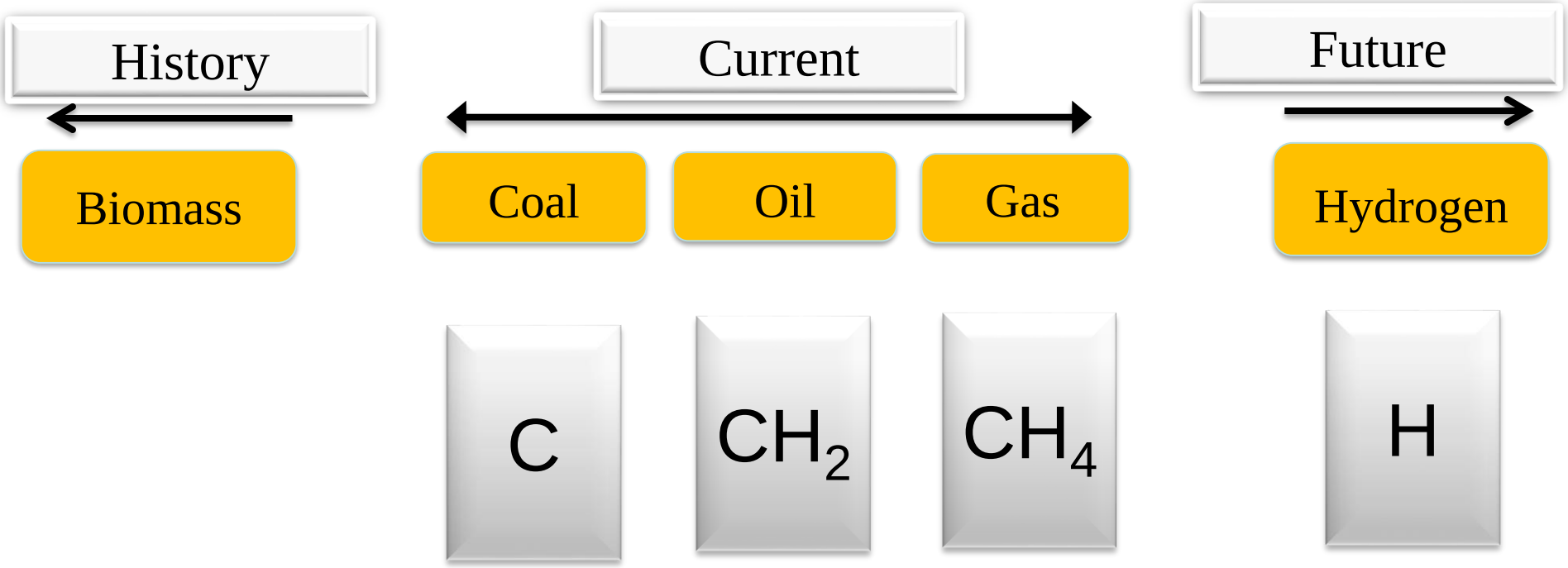
$$H_{2(g)} + \frac{1}{2}O_{2(g)} \rightarrow H_2O_{(l)}$$

Types of Fuel Cell



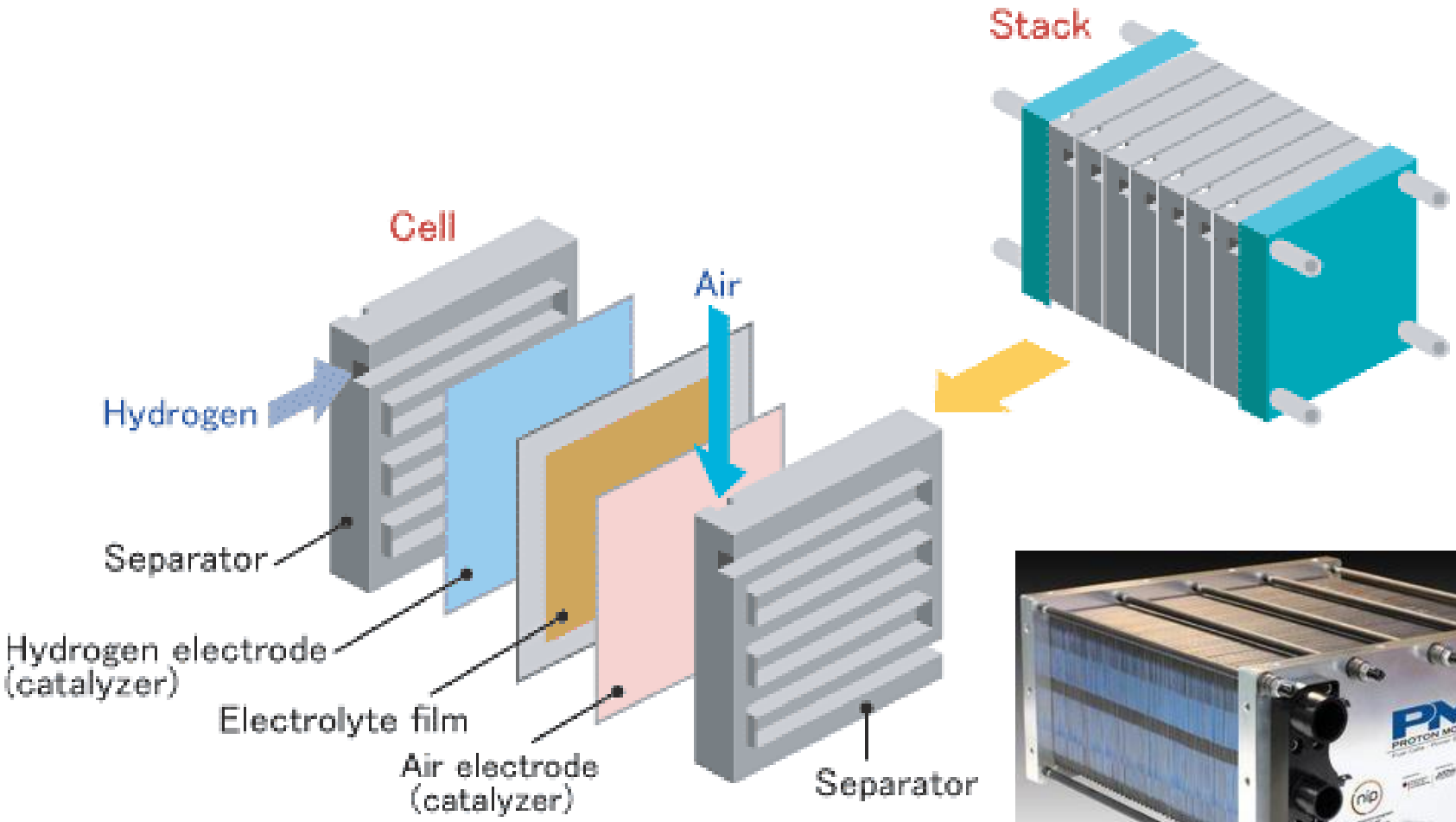
Early market applications	
Transportation, portable power, distributed generation	
Space and Military applications	
Distributed generation	
Electricity utility and distributed generation	
Electricity utility and distributed generation, APU's	

Fuels



Hydrogen is the cleanest fuel.

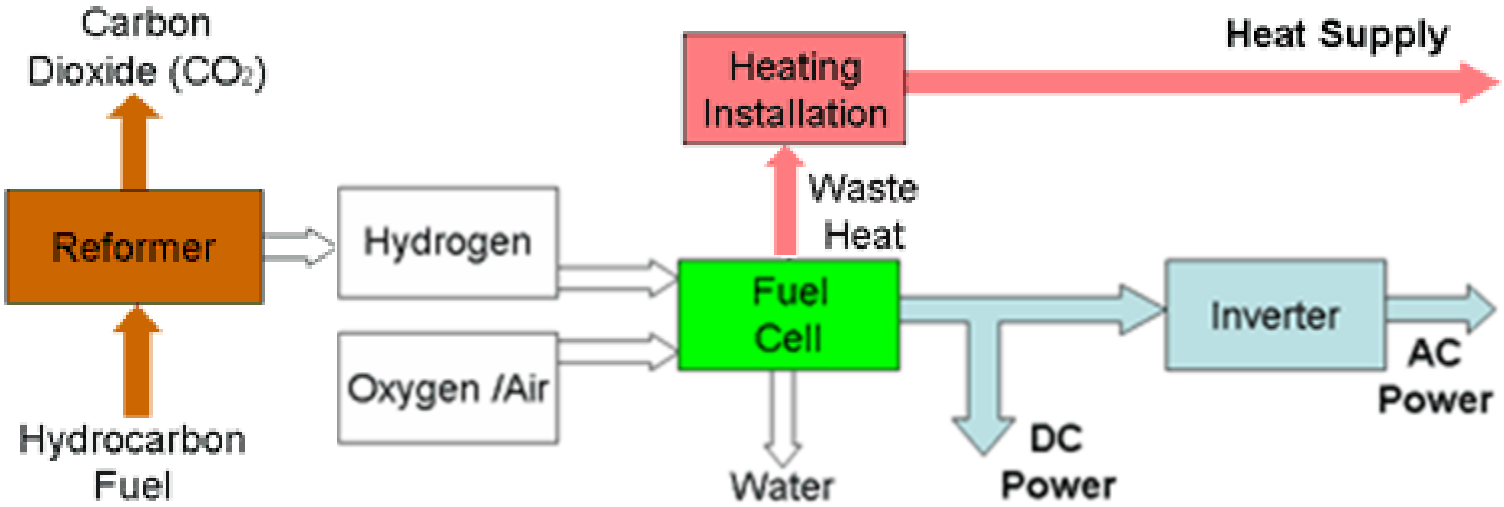
Fuel Cell Stack

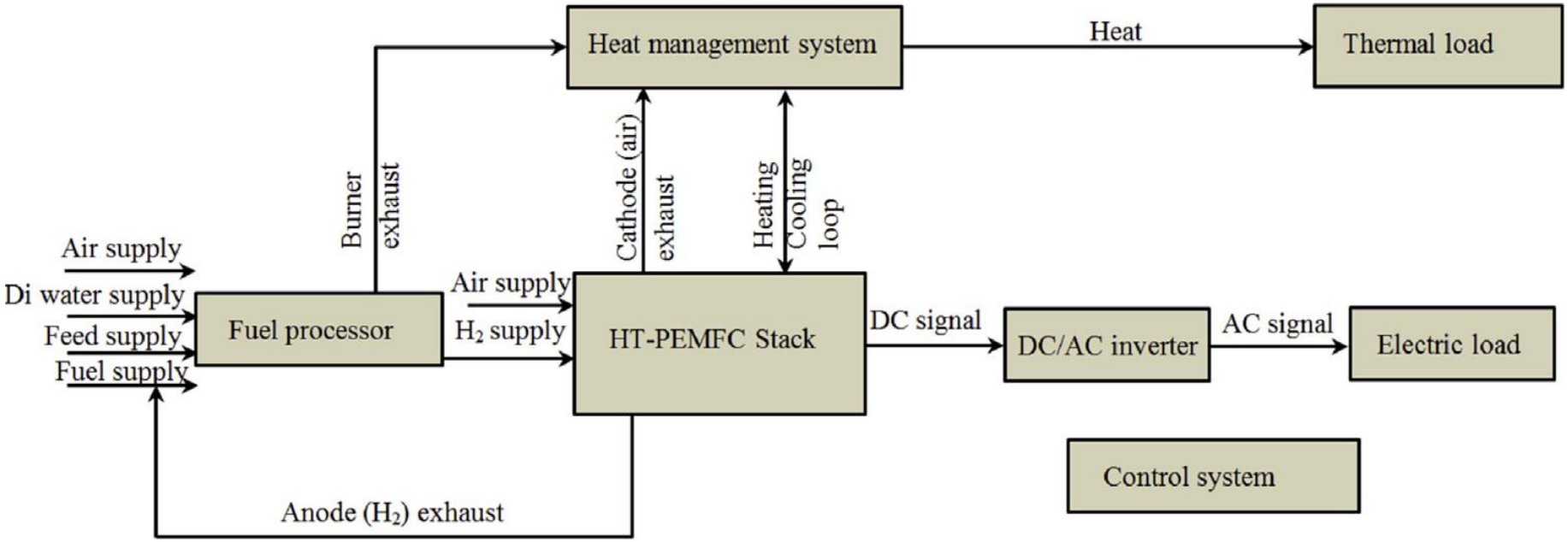


A30 kW fuel cell stack of Proton Motor Fuel Cell GmbH

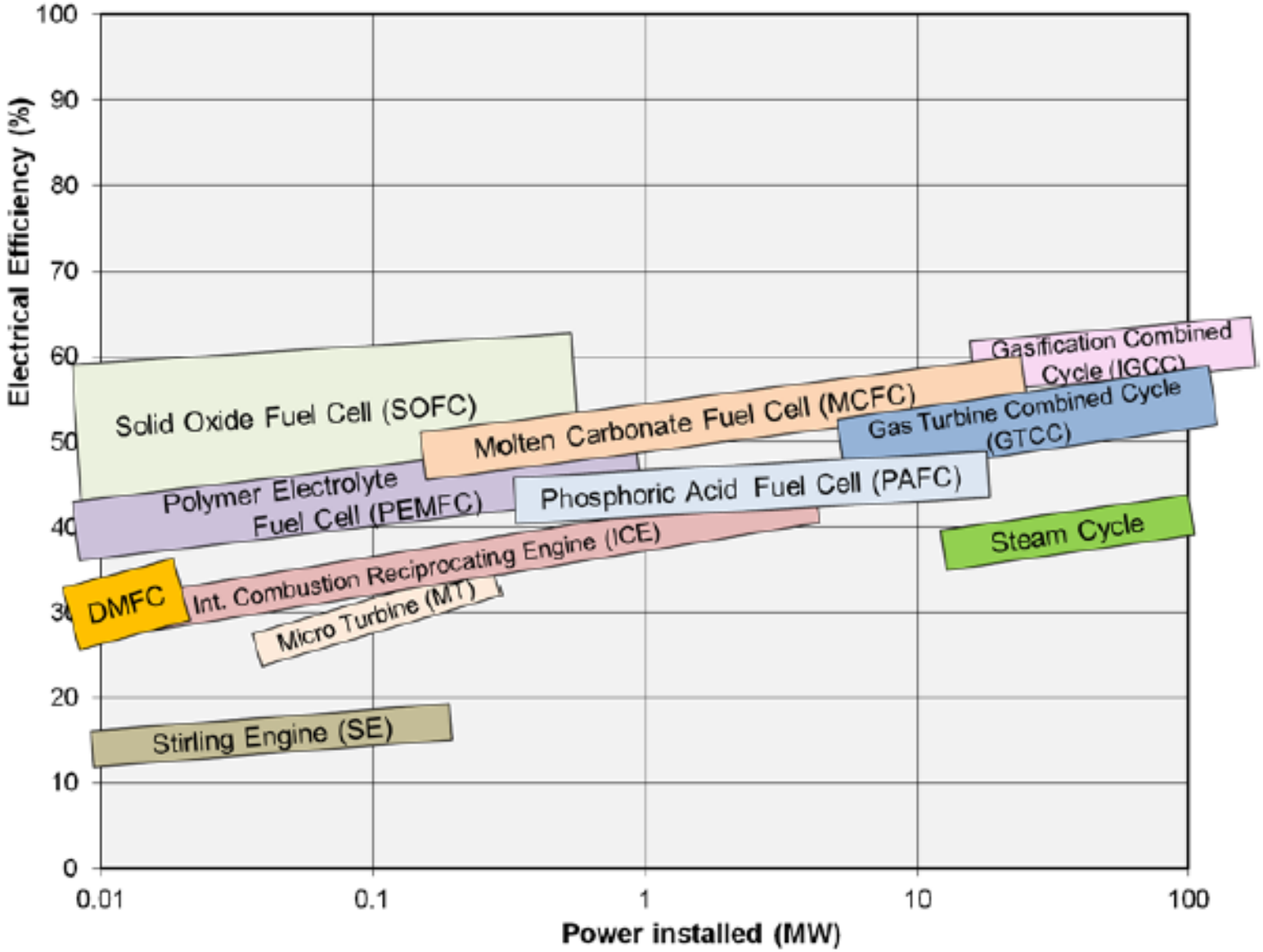
Source: http://www.jari.or.jp/Portals/0/jhfc/e/beginner/about_fc/index.html

Fuel Cell systems





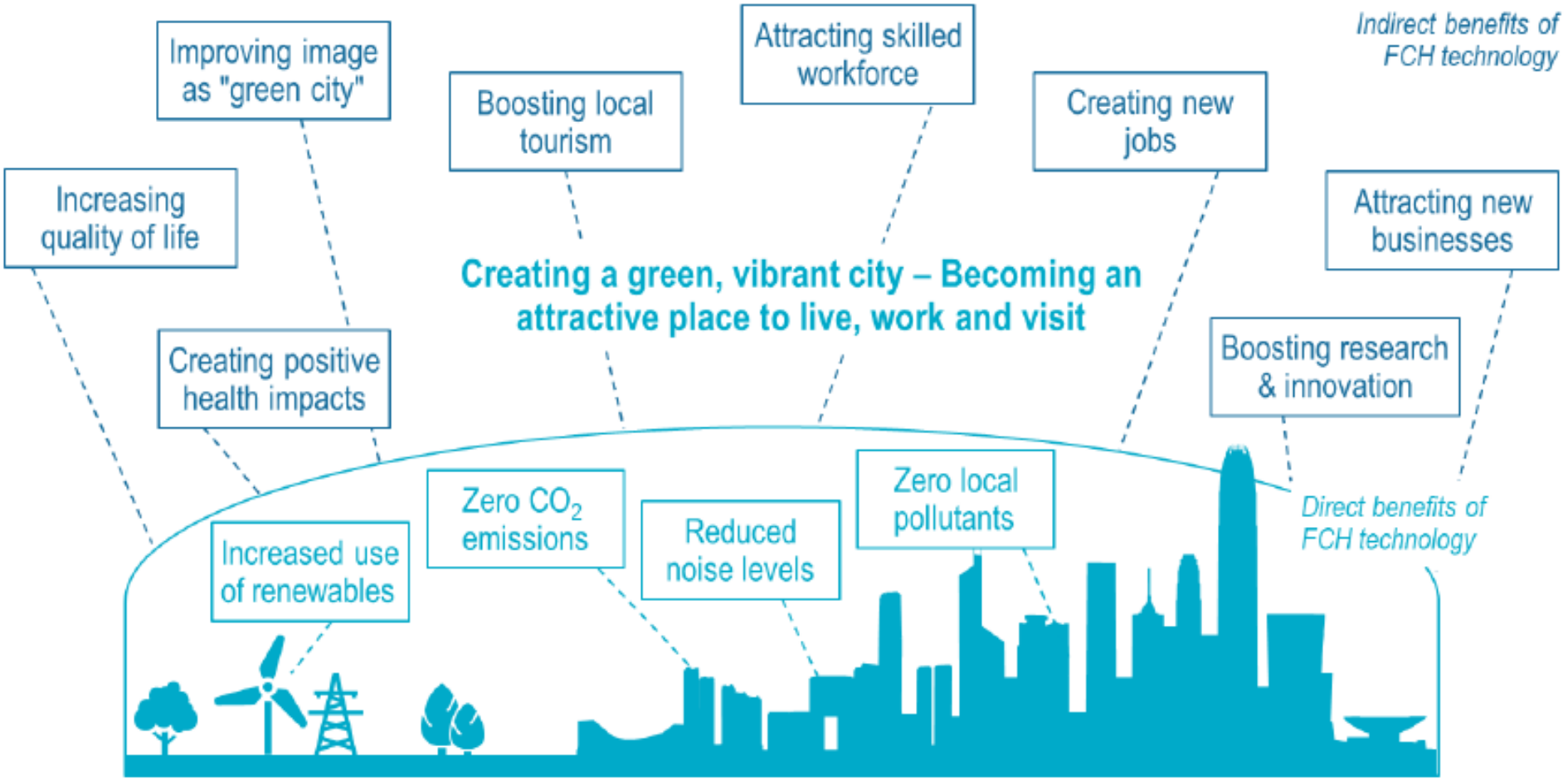
Comparison of efficiency Vs Power installed



Key Benefits of Fuel Cell Technology

- Low or zero emissions
- High quality reliable power
- Durable, Rugged and Modular
- Efficiency – 50% (electrical) 90% (CHP)
- Quiet operation- Less moving parts
- Fuel flexible – can use conventional or renewable fuels

Benefits of Hydrogen and Fuel cell-European Venture



Source: Fuel Cells and Hydrogen for Green Energy in European Cities and Regions- A Study for the Fuel Cells and Hydrogen Joint Undertaking

Applications of Fuel Cell Technology

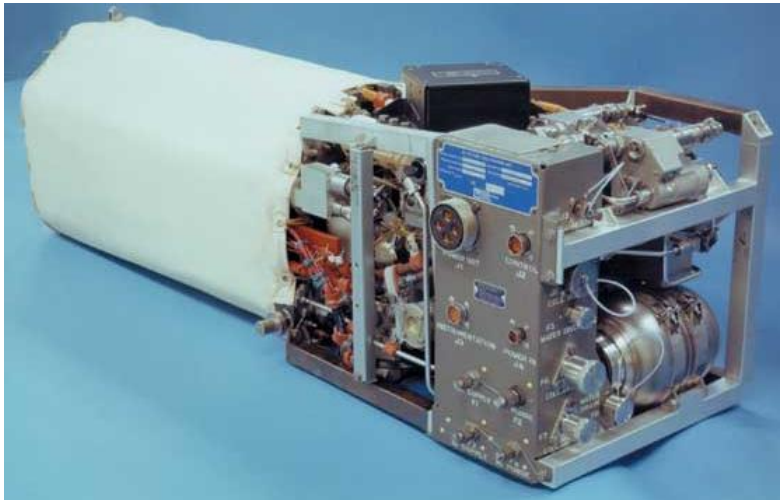
Low Power Applications

Medium Power Applications

High Power Applications

Fuel cell power plants applications

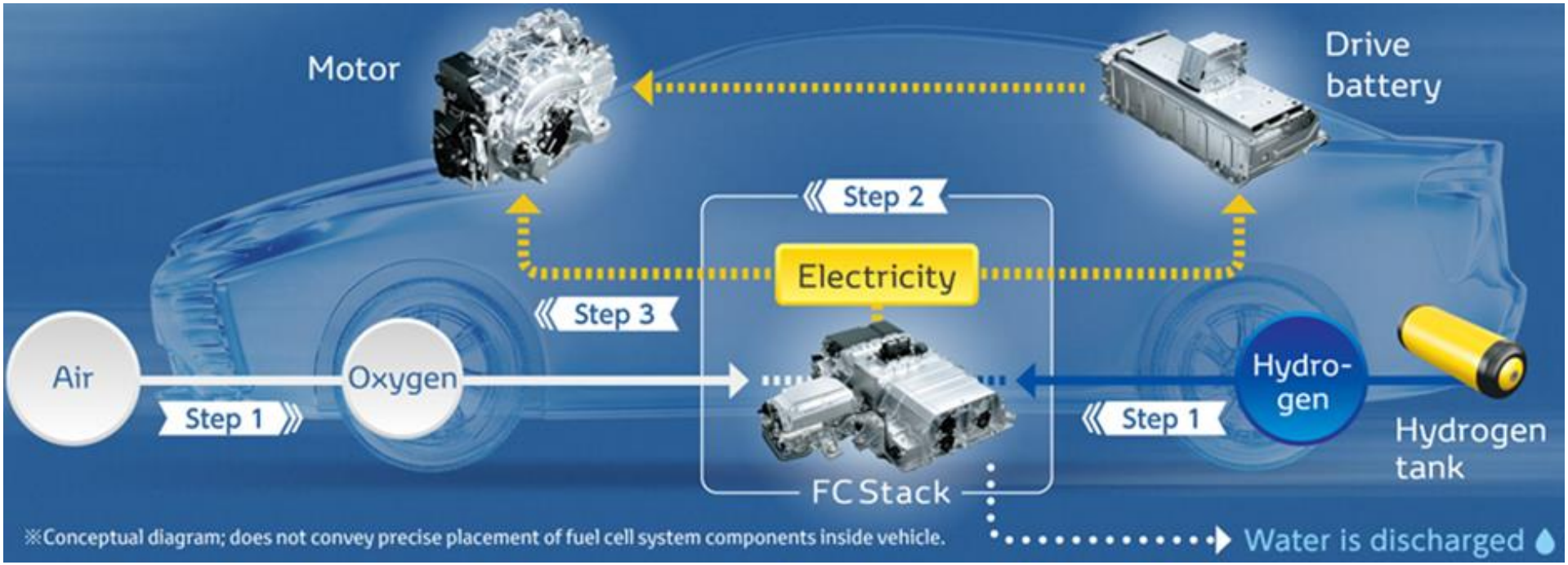
DMFC fuel cell plant, 110 W,
Suitable for house needs



AFC module used by NASA for the space shuttle Apollo

London bus on the RV1 line, powered by Ballard FC Velocity-HD6 PEMFC modules delivering 150 kWe

Fuel Cell Vehicle



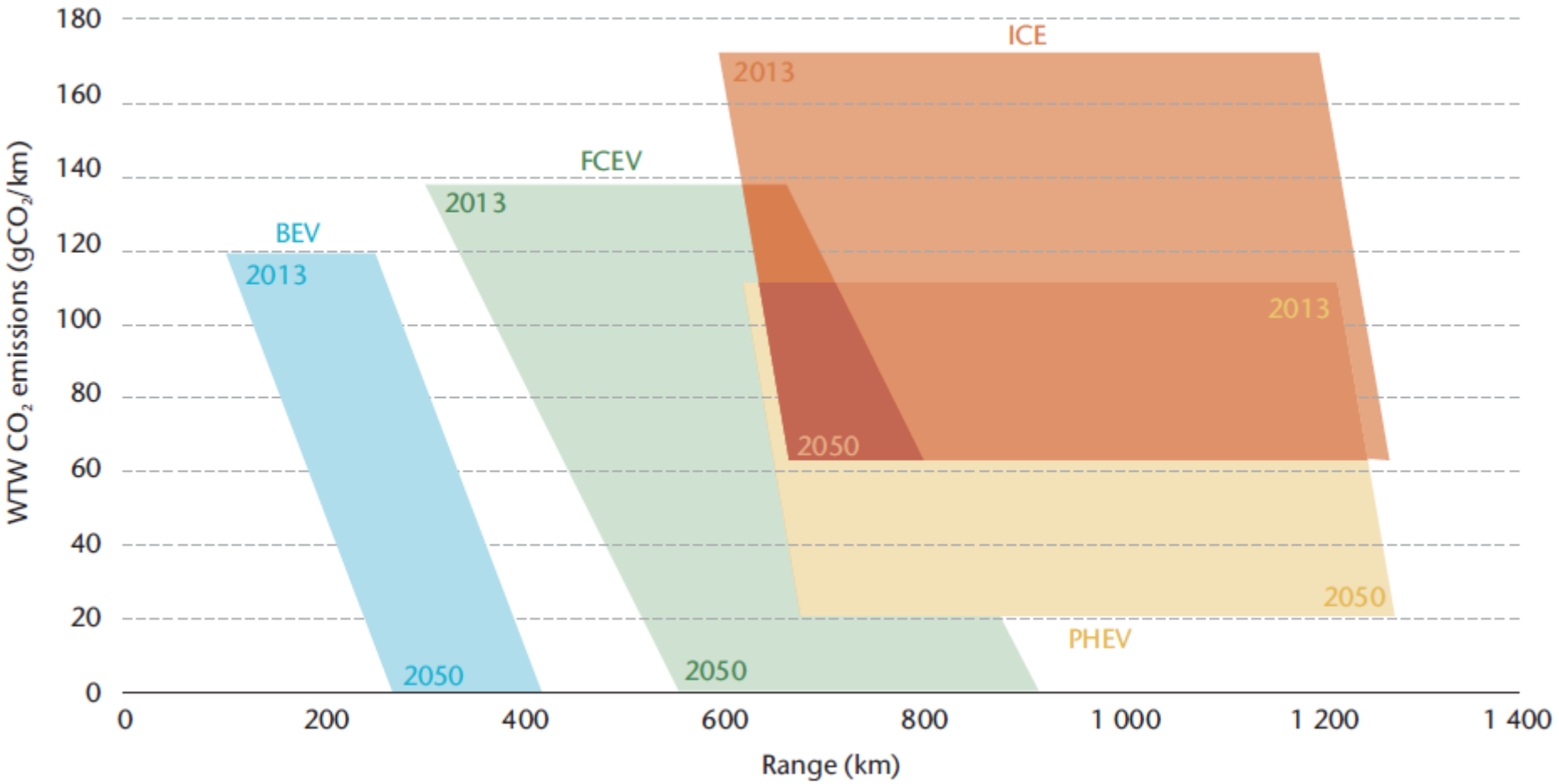
Source: http://www.toyota-global.com/innovation/environmental_technology/fuelcell_vehicle/

Comparison of fuel economy expressed in MPGe for hydrogen fuel cell vehicles available for leasing in California and rated by the U.S. Environmental Protection Agency as of October 2016[25][26]

Vehicle	Model year	Combined fuel economy	City fuel economy	Highway fuel economy	Range	Annual fuel cost
Hyundai Tucson Fuel Cell	2017	49 mpg-e	48 mpg-e	50 mpg-e	265 mi (426 km)	US$1,700
Toyota Mirai	2016	66 mpg-e	66 mpg-e	66 mpg-e	312 mi (502 km)	US$1,250
Honda Clarity Fuel Cell	2017	67 mpg-e	68 mpg-e	66 mpg-e	366 mi (589 km)	-

Notes: One kg of hydrogen is roughly equivalent to one U.S. gallon of gasoline.

Well-to-Wheel (WTW) emissions Vs. Vehicle range



FCEVs can achieve a mobility service compared to today's conventional cars at potentially very low WTW carbon emissions. Source: Technology roadmap 2015 by IEA.

Applications areas of Hydrogen and Fuel cell - FCH JU

1 Heavy-duty transport

- Trains
- Buses
- Heavy-duty trucks

2 Light & medium-duty transport

- Cars
- Delivery vans
- Garbage trucks
- Sweepers
- Mobile construction equipment
- Material handling
- Bikes
- Scooters

3 Maritime & aviation

- Ferries
- Boats
- Ships
- Port operations equipment
- Aircraft
- Airport ground operations

4 Stationary

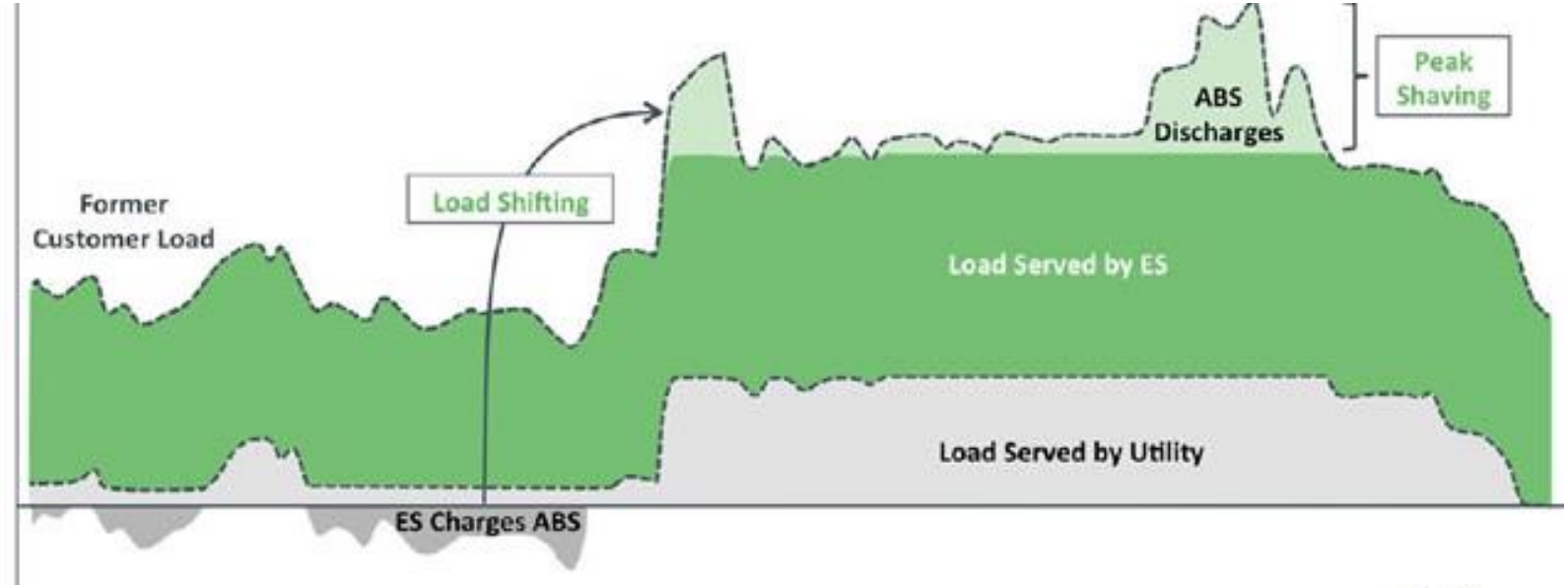
- Residual use/ FC micro-CHP
- Commercial buildings
- Industrial use cases
- Back-up power
- Off-grid power
- Gensets

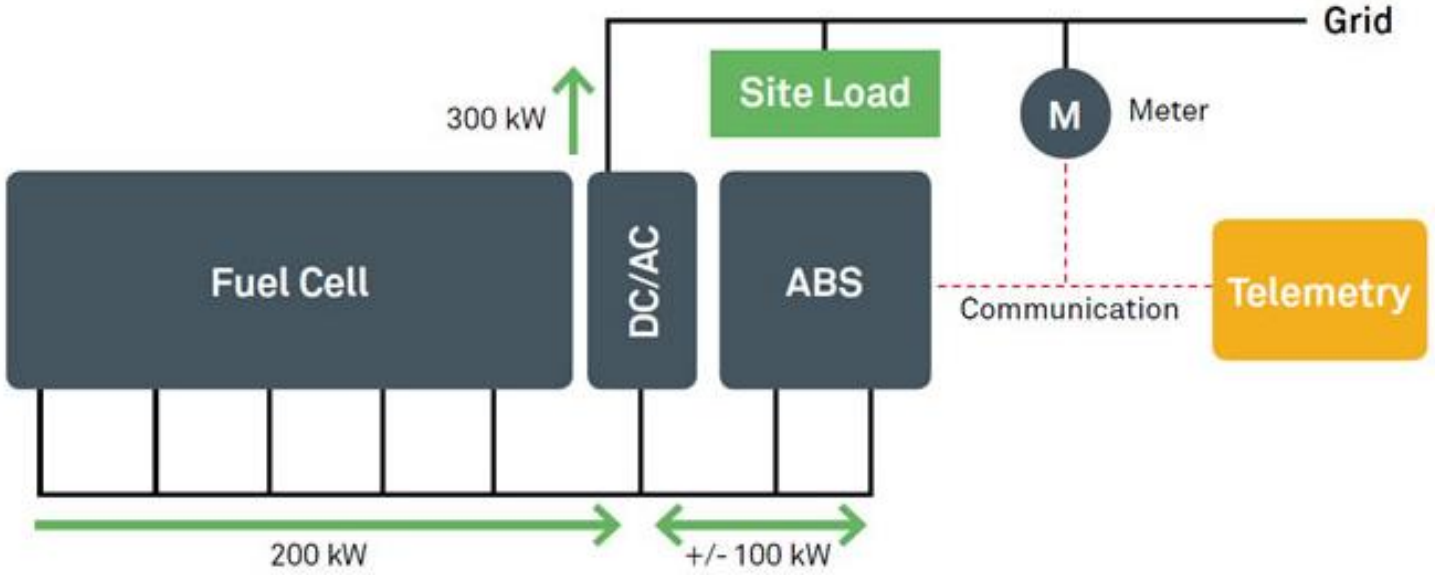
5 Energy-to-hydrogen

- Hydrogen production
- "Hydrogen-to-X"
- Energy storage
- Hydrogen injection into the gas grid
- Electricity grid services

Source: Fuel Cells and Hydrogen for Green Energy in European Cities and Regions- A Study for the Fuel Cells and Hydrogen Joint Undertaking

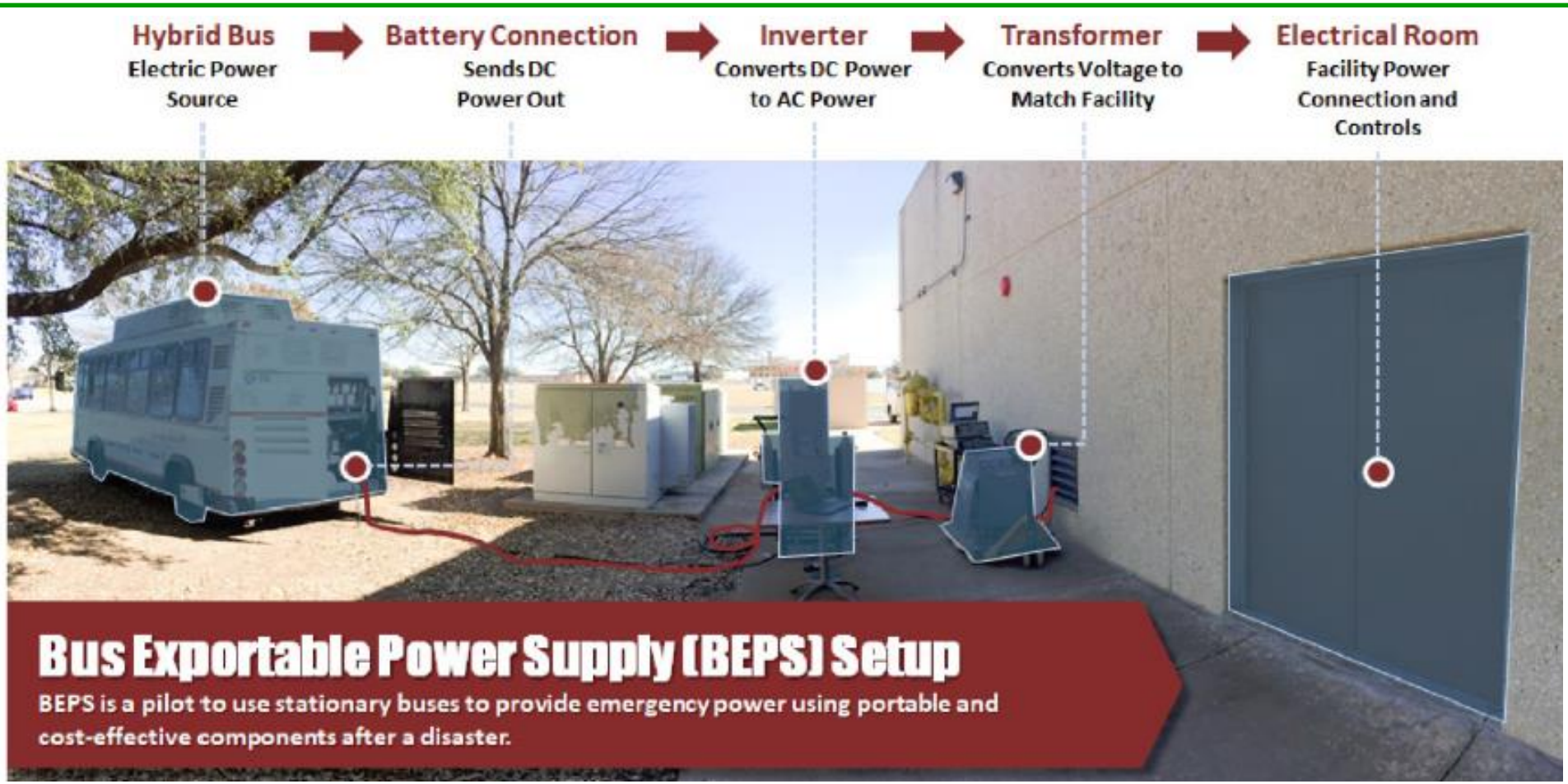
Integrated Energy- Fuel cell + Storage





Source: https://www.bloomenergy.com/datasheets/integrated-energy-storage

Bus Exportable Power Supply (BEPS)



Bus Exportable Power Supply (BEPS) System Use Strategy: Investigating the Use of Transit Buses as Emergency Generators , NOVEMBER 2019.
Federal Transit Administration, FTA Report No. 0146

Focus areas of Fuel Cell Technology

Technologies

Polymer Electrolyte Fuel Cells

To reduce the cost and improve the performance of PEFCs, DMFCs and corresponding fuel cell systems.

Solid Oxide Fuel Cells

To assist, through international co-operation, the development of SOFC technologies.

Electrolysis

To share information and learning on electrolyser technologies and their applications.

Applications

Fuel Cells for Stationary Applications

To understand better how stationary fuel cell systems may be deployed in energy systems.

Fuel Cells for Transportation

To understand better how fuel cells may be deployed in transportation applications.

Fuel Cells for Portable Applications

To assist, through international co-operation, the development and commercialisation of portable fuel cells.

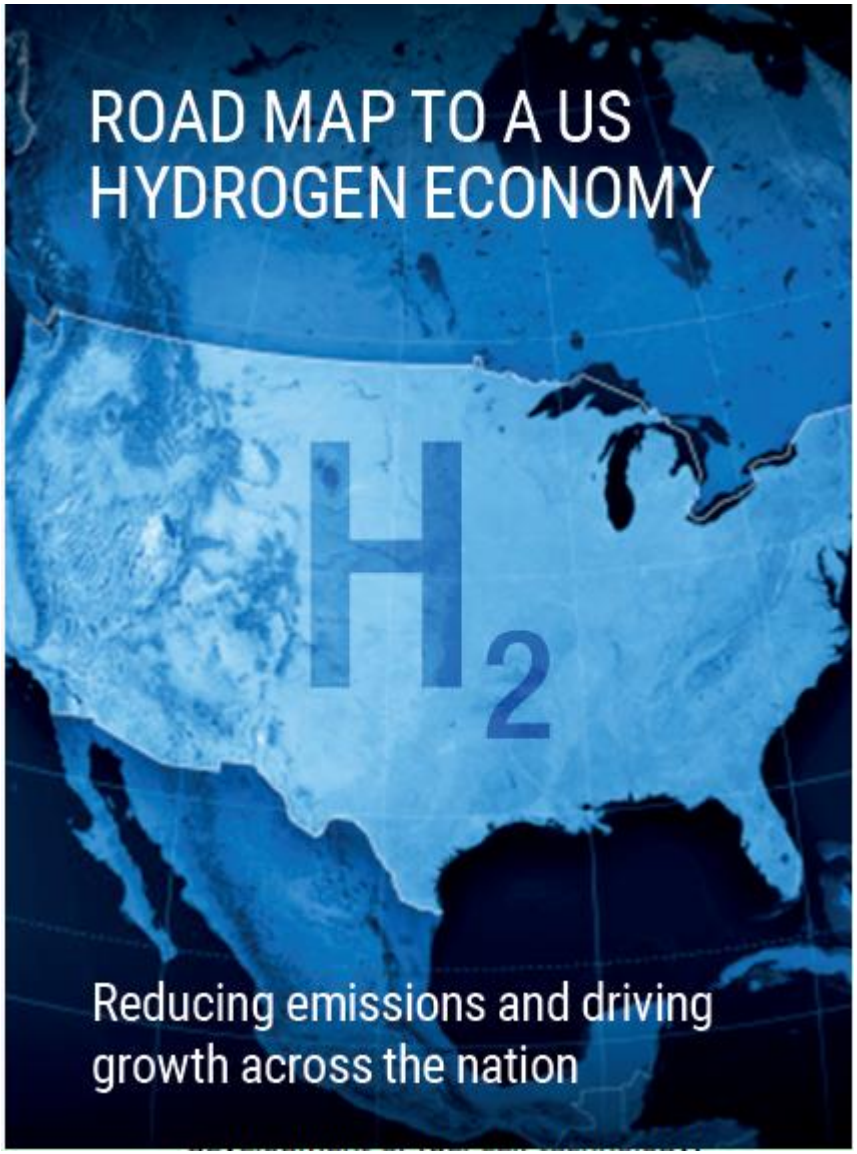
Systems Analysis

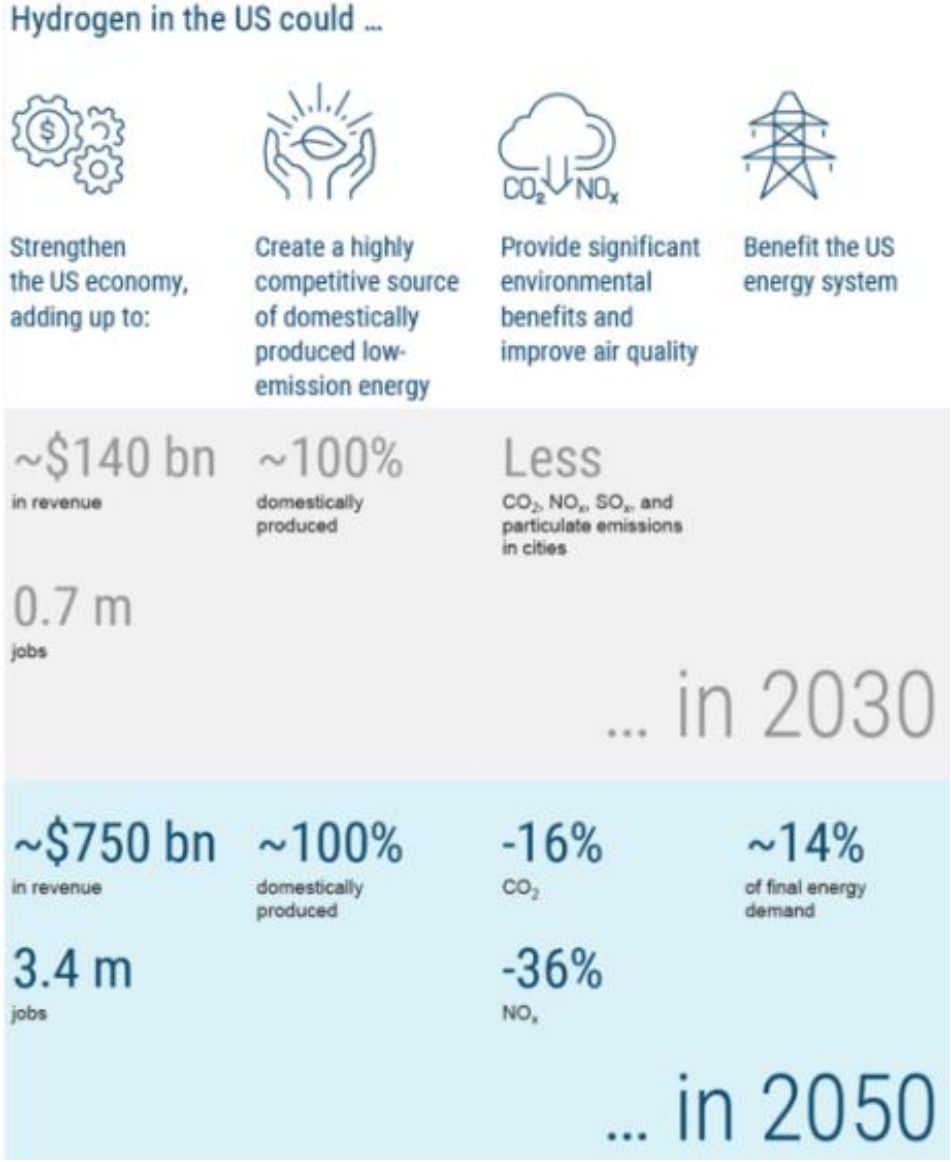
To assist the development of fuel cells through analysis work to enable a better interpretation of the current status, and the future potential, of the technology. This work will provide a competent and factual information base for technical and economic studies.

Modelling of Fuel Cell Systems

To further develop the open source modelling approaches and knowledge base to facilitate the development of fuel cell technology.

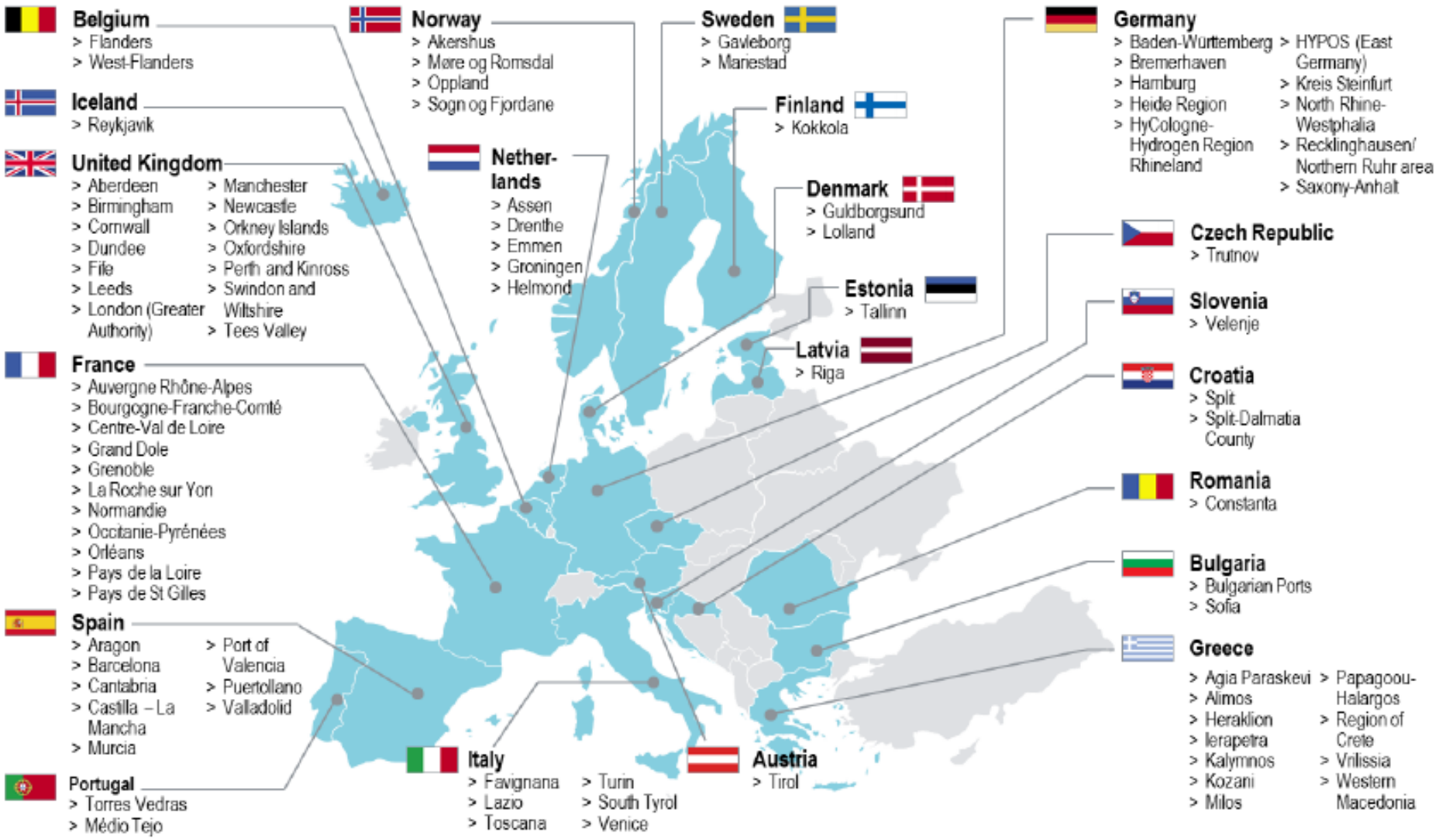
Road Map to a US- Hydrogen Economy





Source: http://www.fchea.org/us-hydrogen-study

FCH JU- European Venture- 89 Regions



Source: Fuel Cells and Hydrogen for Green Energy in European Cities and Regions- A Study for the Fuel Cells and Hydrogen Joint Undertaking-https://www.fch.europa.eu/

Road Map for Europe- Hydrogen

BESIDES CO_2 ABATEMENT, DEPLOYMENT OF THE HYDROGEN ROADMAP ALSO CUTS LOCAL EMISSIONS, CREATES NEW MARKETS AND SECURES SUSTAINABLE EMPLOYMENT IN EUROPE

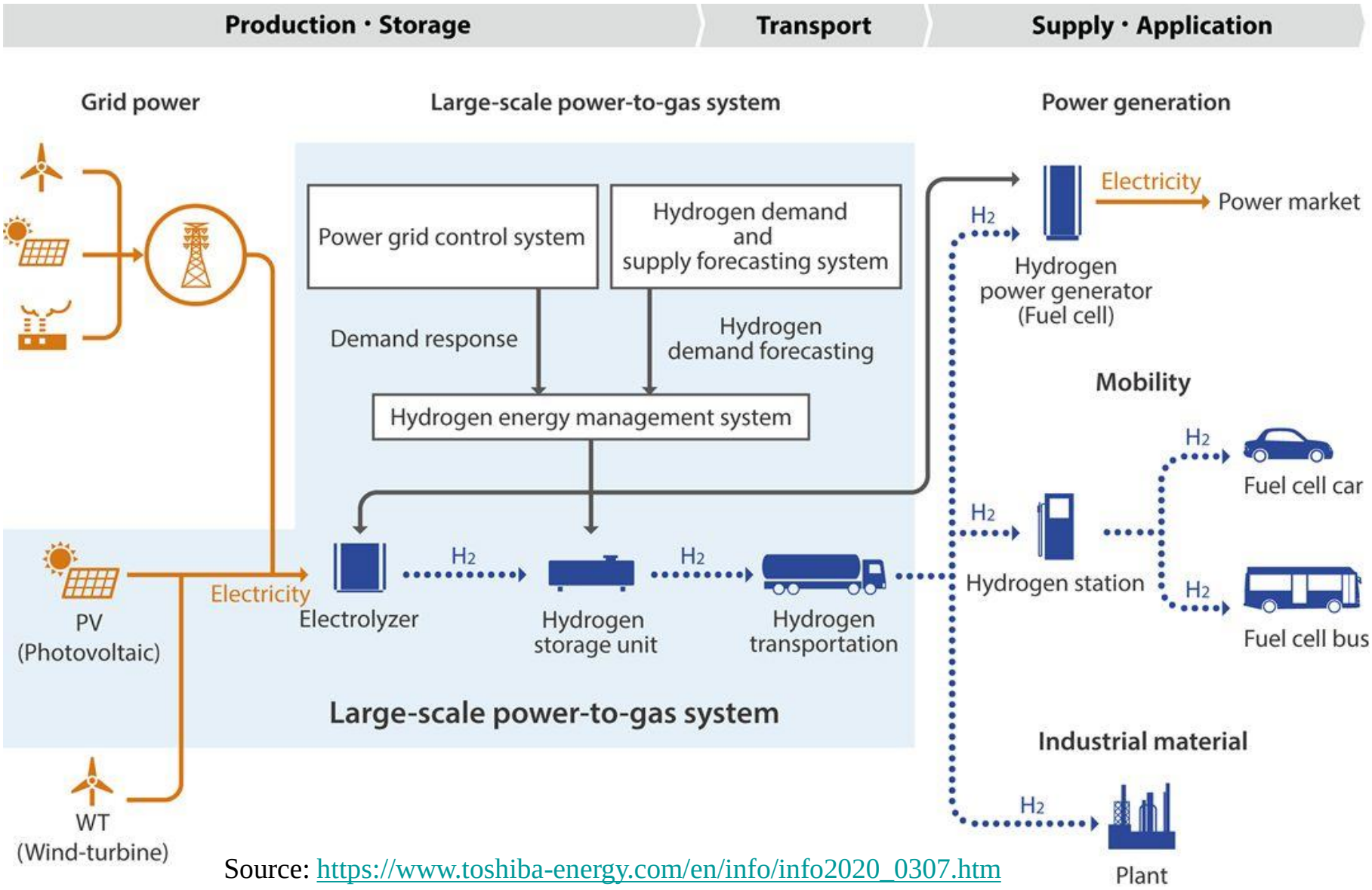
2050 hydrogen vision

~24%	~560 Mt	~EUR 820bn	~15%	~5.4m
of final energy demand[1]	annual CO_2 abatement[2]	annual revenue (hydrogen and equipment)	reduction of local emissions (NO_x) relative to road transport	jobs (hydrogen, equipment, supplier industries)[3]

Fukushima Hydrogen Energy Research Field (FH2R)

Source: https://www.toshiba-energy.com/en/info/info2020_0307.htm

Fukushima Hydrogen Energy Research Field (FH2R)



Source: https://www.toshiba-energy.com/en/info/info2020_0307.htm

World's largest fuel cell power plant-South Korea

The world's largest fuel cell plant. 58.8 MW molten carbonate fuel cell park in Whasung City, Gyeonggi Province, South Korea (courtesy of FuelCell Energy Solutions)

Global Fuel cell Market

The global **Fuel Cell market** size is valued at 5.057 Billion USD in 2020 and is expected to reach 40.030 Billion USD by the end of 2026, growing at a CAGR of 34.0% during 2021-2026.

The industry's leading producers are:
Bloom Energy, Panasonic, and Toshiba ESS,
which together account for 50.10% of revenues.

- Ballard Power System
- Ceramic Fuel Cells Limited
- Fuel Cell Energy
- Hydrogenics Corporation
- AFC Energy PLC
- Ceres Power Holdings PLC
- Doosan Corporation
- Plug Power
- POSCO ENERGY
- Horizon Fuel Cell Technologies
- Quantum Fuel Systems Technologies
- GM
- Honda
- Others.

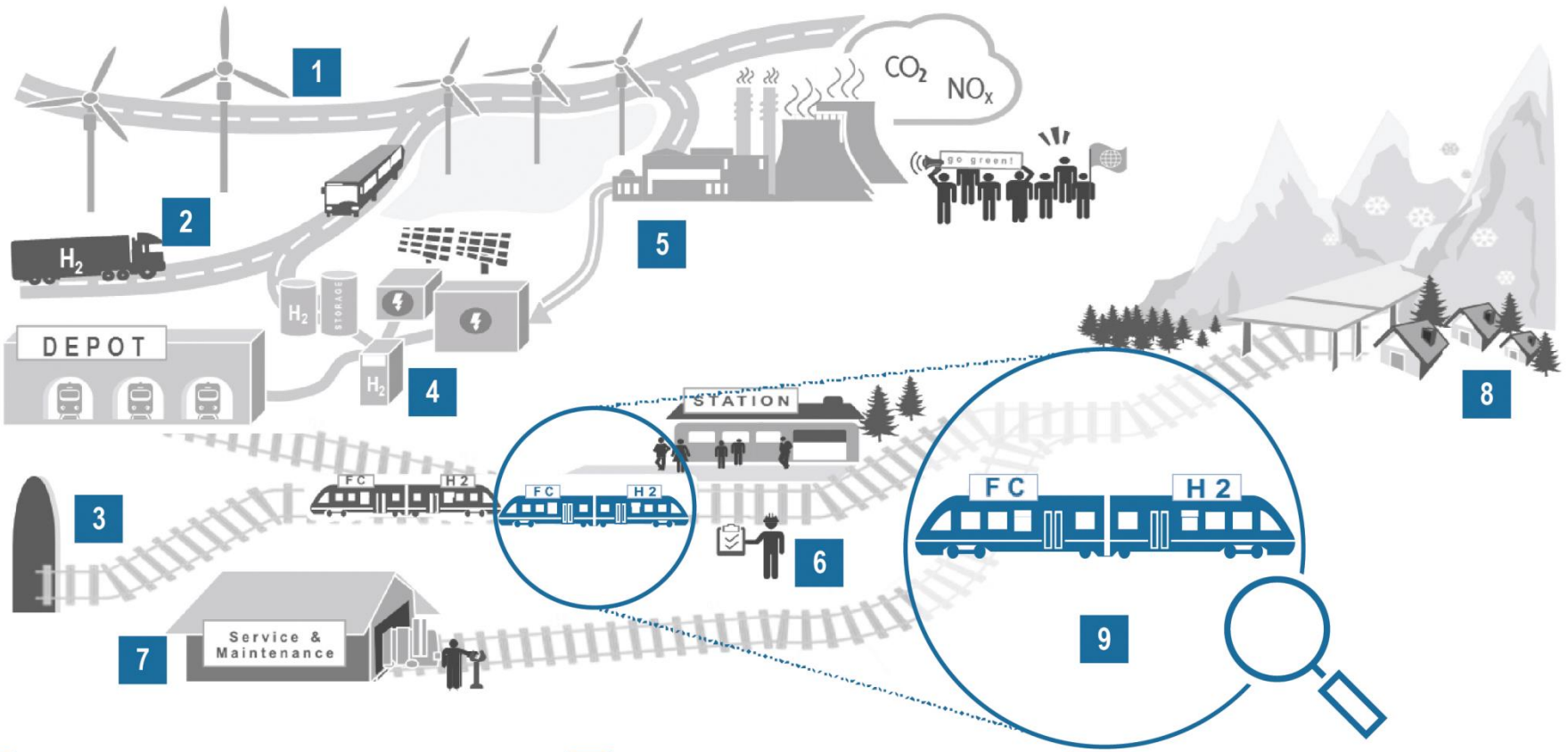
Hydrogen Powered Aviation

H_2 combustion could reduce climate Impact in flight by 50 to 75 %, and fuel-cell propulsion by 75 to 90 %.

An inspiring midterm target could be the introduction of a H2-powered short range aircraft before 2035. Aircraft development cycles occur about every 15-20 years until a new aircraft platform is introduced.

LH_2 price projected to drop by factor of 4 from today to roughly the same cost per unit energy as for kerosene by 2050.

Hydrogen Powered Locomotives



1 Renewable H_2 generation via electrolysis
2 Multimodal approach with buses/trucks/etc.
3 Interoperability with other infrastructure
4 H_2 refuelling station
5 Industrial H_2 supply
6 Regulations and permitting
7 Service and maintenance requirements
8 Safety/public acceptance of H_2 technology
9 Technical requirements

Fuel cell and Hydrogen-Supply chain