Green Hydrogen

In the framework of the postgraduate course “Renewable Energy”

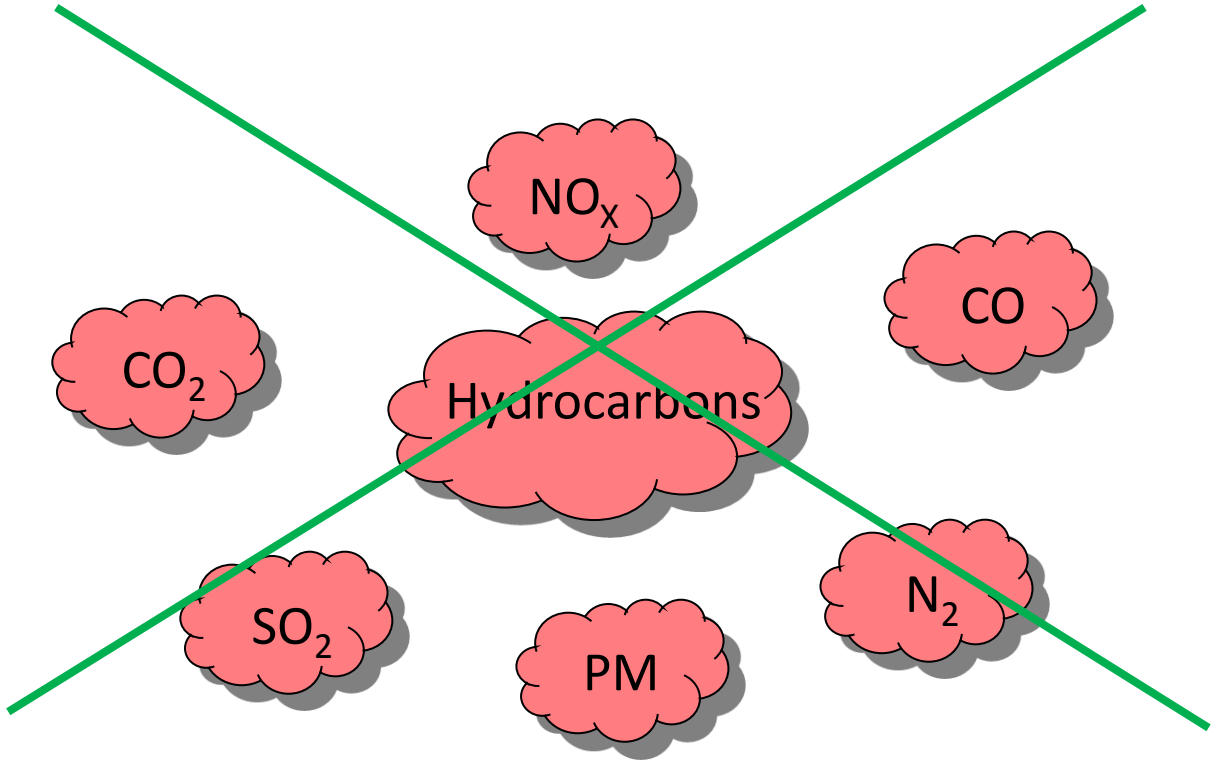
Prof. Dr. Mohamed Samer
Bioresource Engineering
Department of Agricultural Engineering
Faculty of Agriculture, Cairo University
E-Mails: msamer@agr.cu.edu.eg; samer@cu.edu.eg
Website: http://scholar.cu.edu.eg/samer/biocv

Introduction

Environmental Impact

The combustion of hydrogen with oxygen produces water as its only product:

$$2H_2 + O_2 \rightarrow 2H_2O$$



Green Hydrogen Systems (GHS)

Several countries have set for themselves the target of reducing CO_2 emissions

To achieve this goal with the greatest possible efficiency, more key technologies are needed in addition to the expansion of renewable energy generation and the electricity infrastructure

The conversion of electricity generated by renewable energies into hydrogen (H_2)—power-to-gas—is such a key to a successful energy transition

Source: GET H_2 initiative

The key concept:

1. Electricity from renewable energies (wind and sun) is converted into H_2
2. H_2 is transported via a separate infrastructure, for whose development the existing gas infrastructure is used
3. In the industry, transport and heating sectors, green H_2 is used as a CO_2-free raw material, fuel and energy source
4. In industry, it replaces, among other things, fossil generated H_2
5. Green H_2 is used as the basis for the production of e-fuels, especially for aircraft and rail vehicles
6. H_2 not directly used is efficiently stored in existing underground salt caverns
7. H_2 can be used for re-electrification, e.g. via a gas turbine

Source: GET H_2 initiative

Hydrogen Fuel:

1. Hydrogen fuel is a zero-emission fuel burned with oxygen.
2. It can be used in fuel cells or internal combustion engines.
3. H_2 is usually considered an energy carrier as it must be produced from a primary energy source such as solar energy, biomass, electricity, or hydrocarbons (e.g. natural gas or coal).
4. Recently, the majority of H_2 (~95%) is produced from fossil fuels by steam reforming or partial oxidation of methane and coal gasification with only a small quantity by alternative routes such as biomass gasification or electrolysis of water or solar thermochemistry, a solar fuel with no carbon emissions.

Ogden (1999)

Disadvantages:

1. Hydrogen fuel is hazardous because of the low ignition energy and high combustion energy of hydrogen, and because it tends to leak easily from tanks.

2. Explosions at hydrogen filling stations have been reported.

3. Hydrogen fuelling stations generally receive deliveries of hydrogen by truck from hydrogen suppliers. An interruption at a hydrogen supply facility can shut down multiple hydrogen fuelling stations.

Dobson (2019)

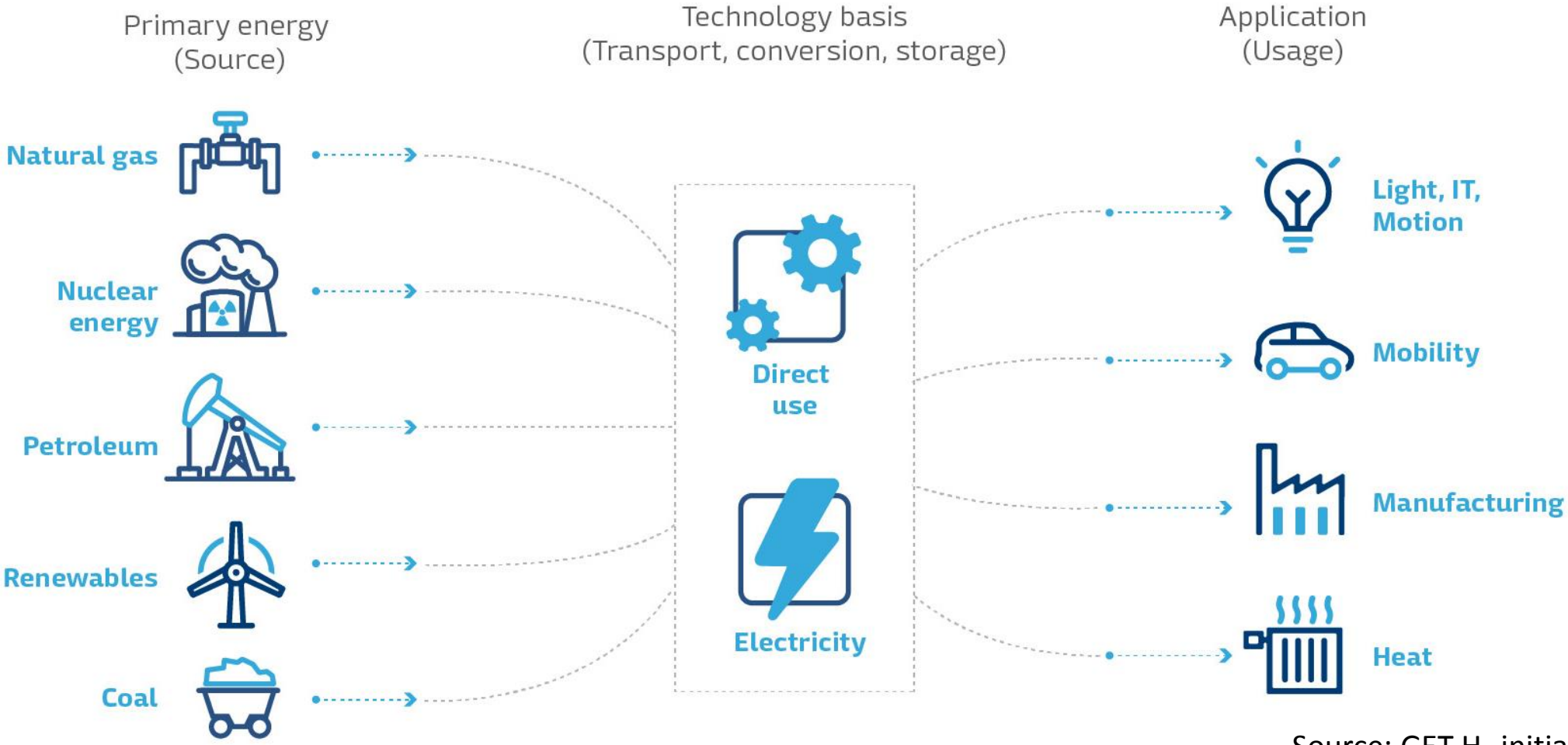
Internal combustion engine conversions to hydrogen:

1. Combustion engines in commercial vehicles have been converted to run on a hydrogen-diesel mix, where up to 70% of emissions have been reduced during normal driving conditions.
2. Minor modifications are needed to the engines, as well as the addition of hydrogen tanks at a compression of 350 bars.
3. Trials are now underway to test the efficiency of the 100% conversion of a Volvo FH16 heavy-duty truck to use only hydrogen. The range is expected to be 300 km/ 17 kg; which means an efficiency better than a standard diesel engine (where the embodied energy of 1 gallon of gasoline is equal to 1 kilogram of hydrogen).

(Dalagan, 2018; Martensson, 2018)

Energy system today

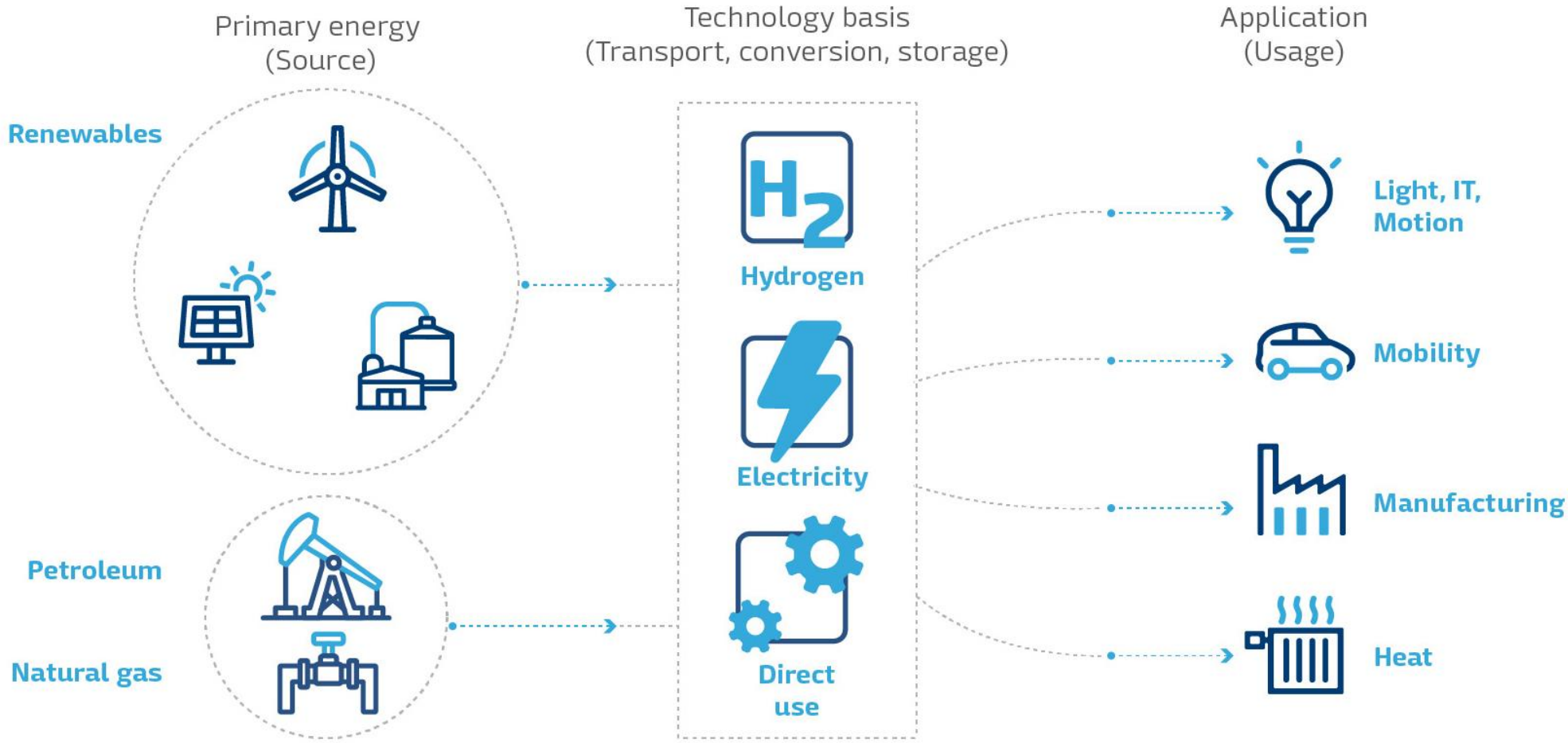
Despite the expansion of renewable energies, the **energy system** in **Germany** continues to feed itself largely from non-renewable sources.



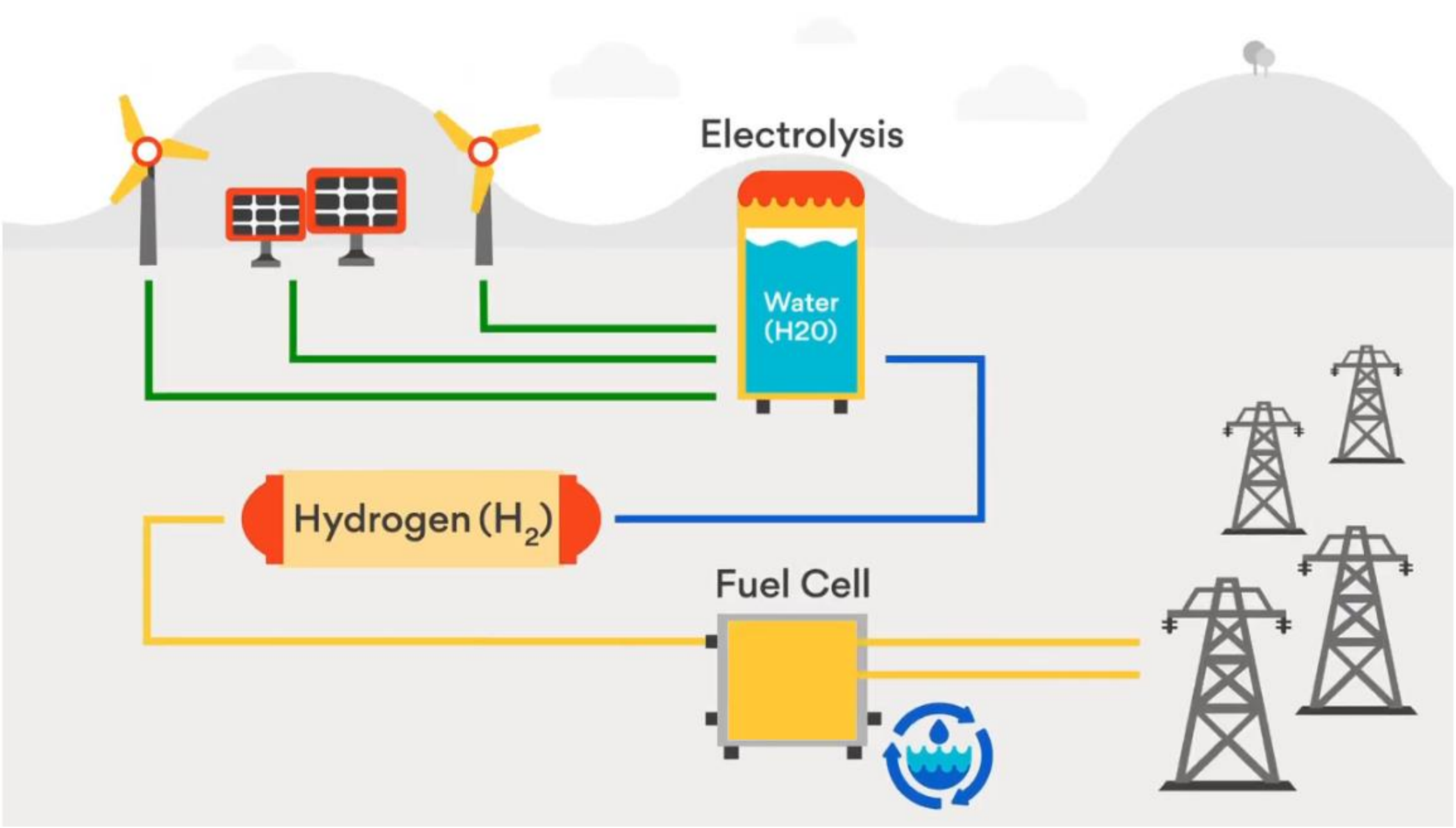
Source: GET H_2 initiative

Energy system tomorrow

Our vision is to establish **hydrogen** as the **second central technology basis**. Most of the energy is generated from renewable sources.

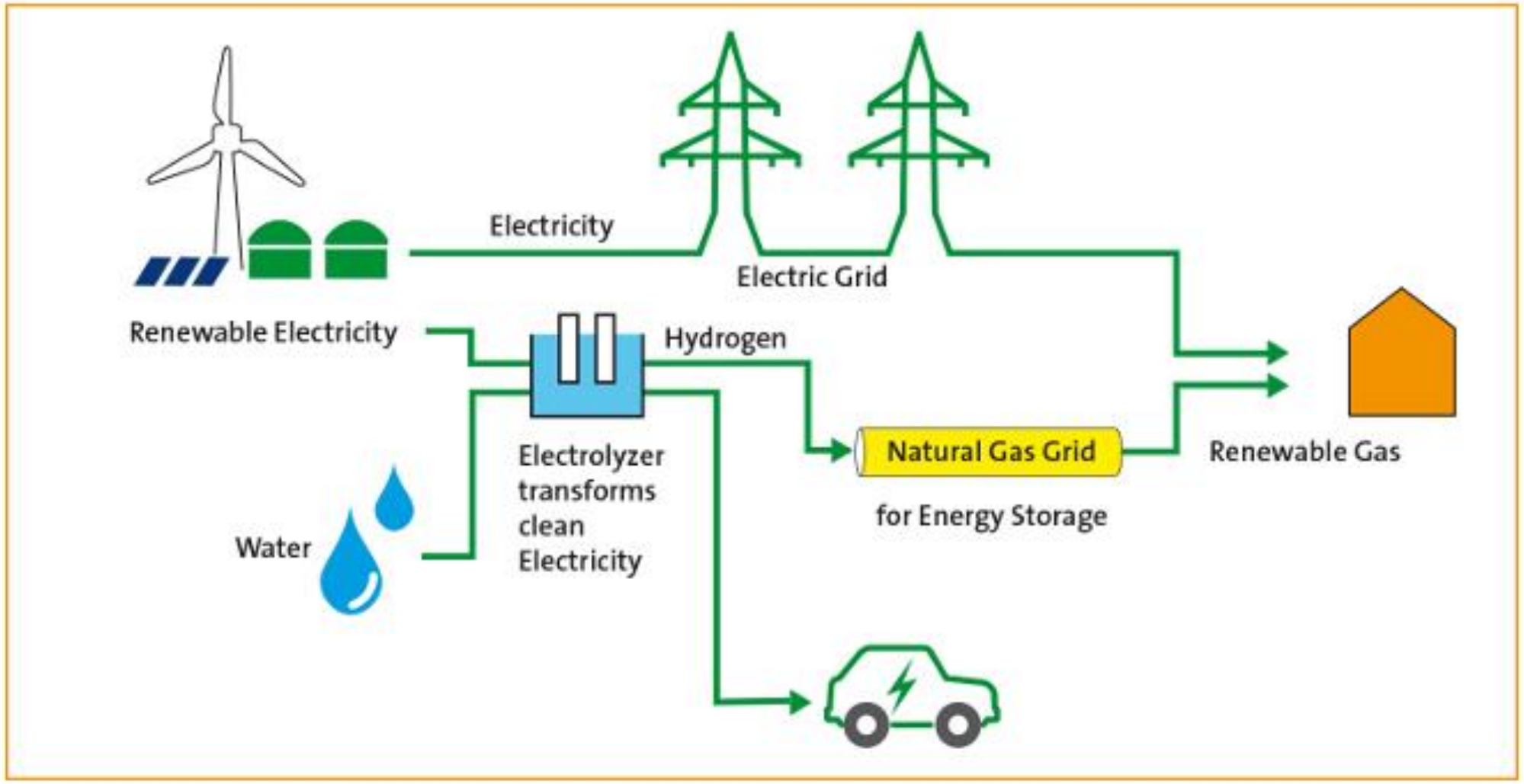


Source: GET H_2 initiative

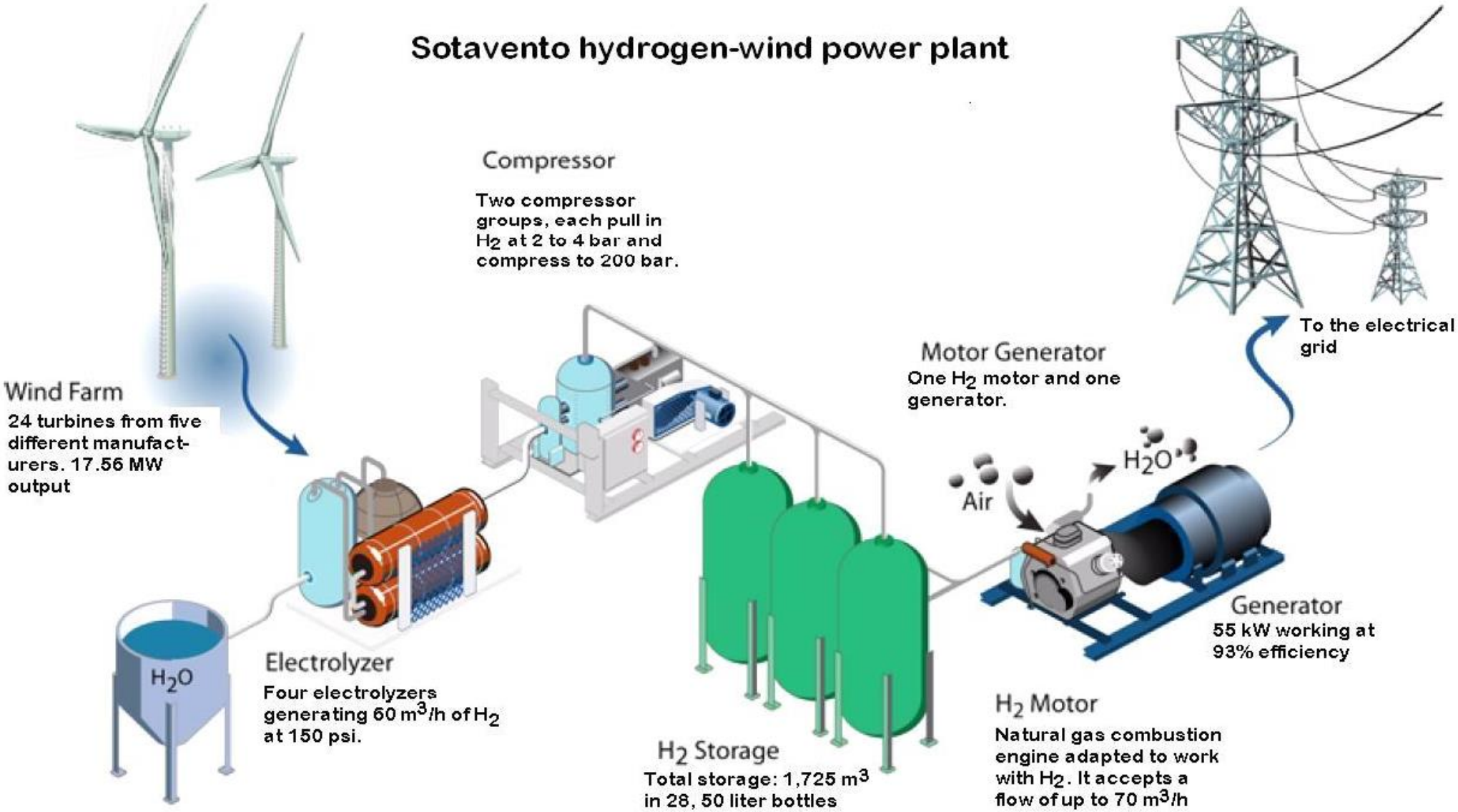


Key Concept

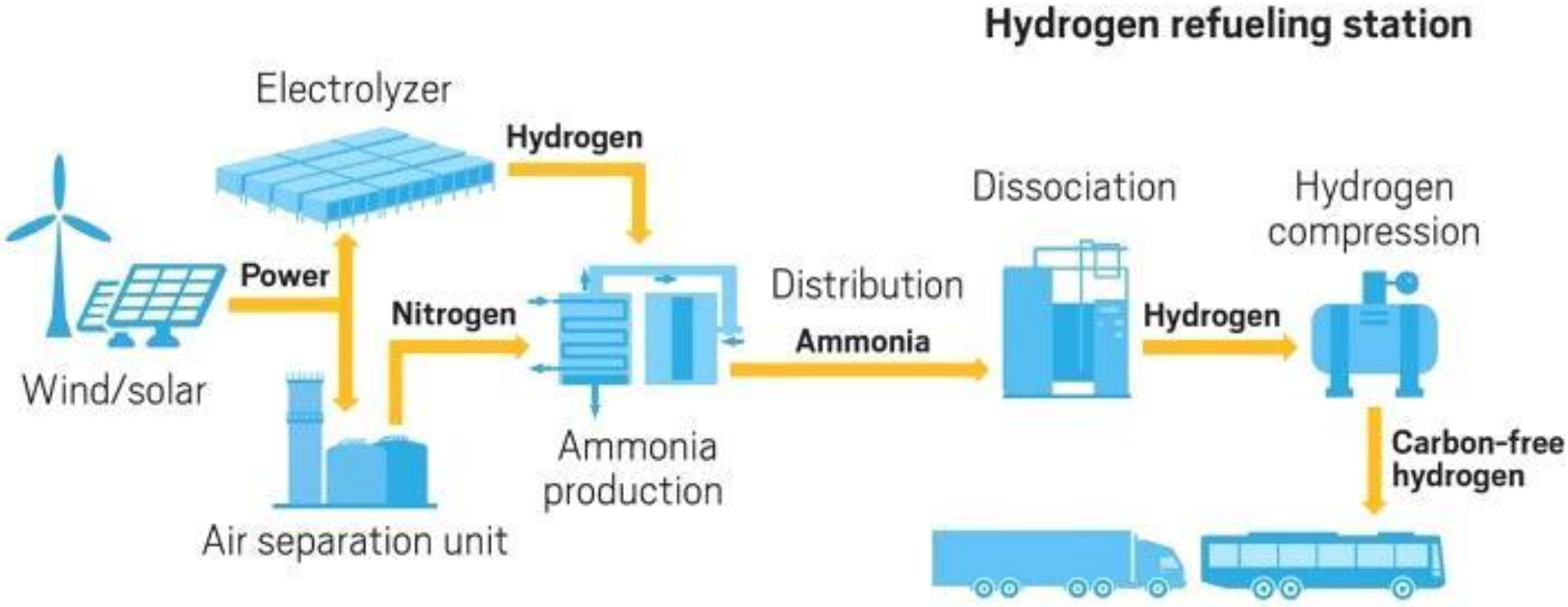
Source: Origin Energy Limited


Electricity
Electric Grid
Renewable Electricity
Hydrogen
Natural Gas Grid
Renewable Gas
for Energy Storage
Water
Electrolyzer
transforms
clean
Electricity

Key Concept

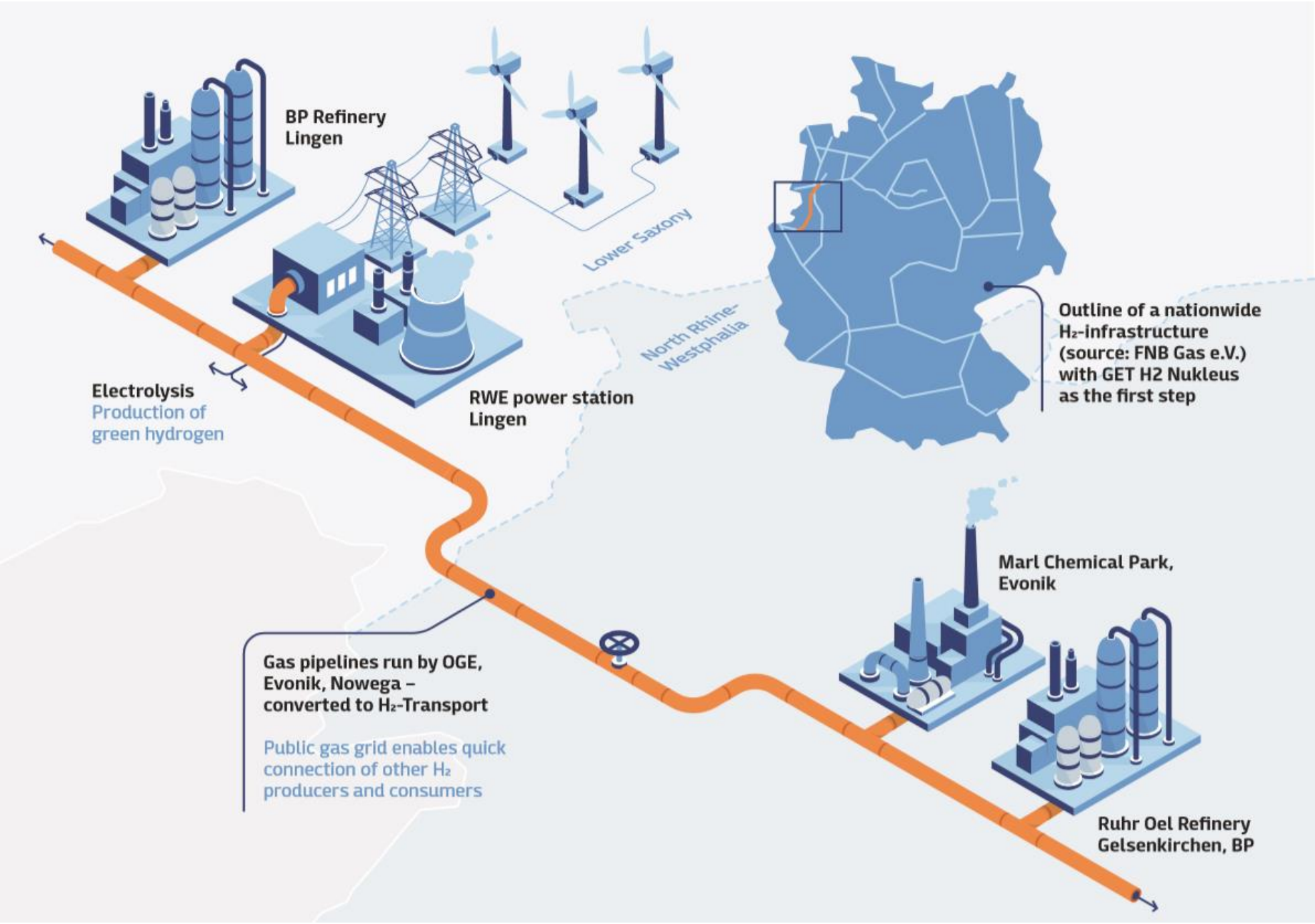

Sotavento hydrogen-wind power plant
Wind Farm
24 turbines from five different manufact-urers. 17.56 MW output
Compressor
Two compressor groups, each pull in H_2 at 2 to 4 bar and compress to 200 bar.
Motor Generator
One H_2 motor and one generator.
To the electrical grid
H_2O
Electrolyzer
Four electrolyzers generating 60 m^3/h of H_2 at 150 psi.
H_2 Storage
Total storage: 1,725 m^3 in 28, 50 liter bottles
Air
H_2O
H_2 Motor
Natural gas combustion engine adapted to work with H_2. It accepts a flow of up to 70 m^3/h
Generator
55 kW working at 93% efficiency

Key Concept



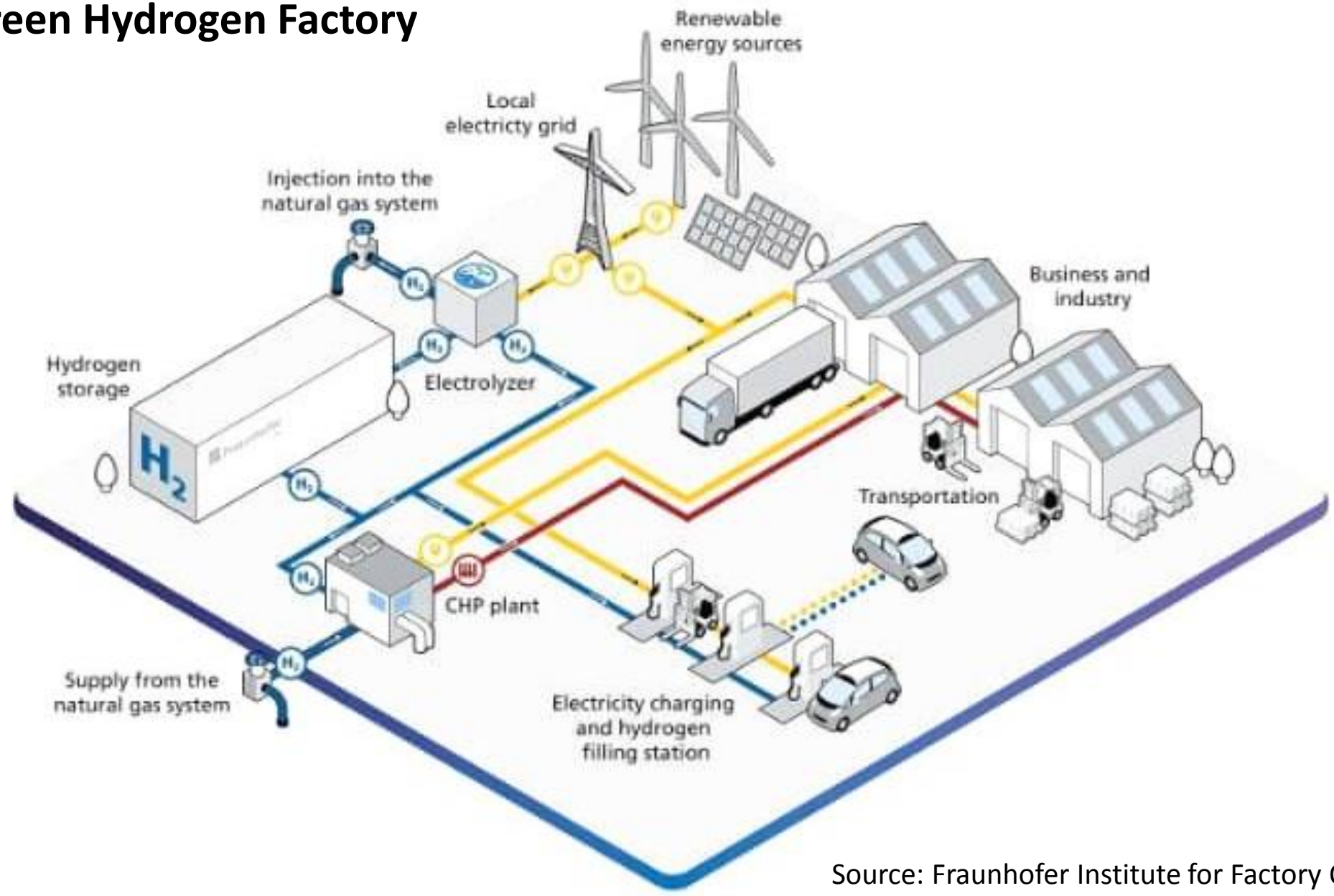
Key Concept

Source: American Chemical Society

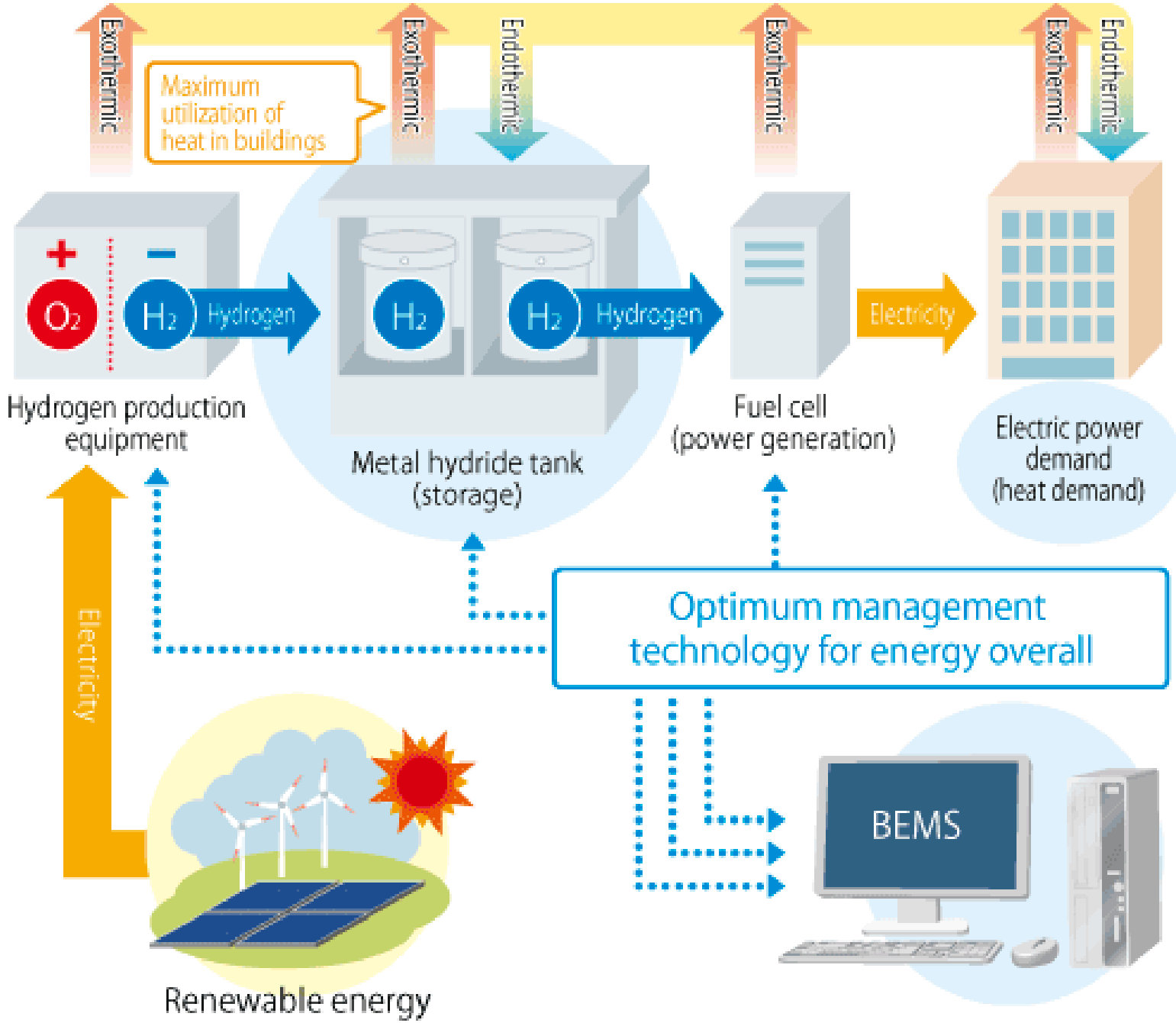


Source: GET H_2 initiative

Green Hydrogen Factory

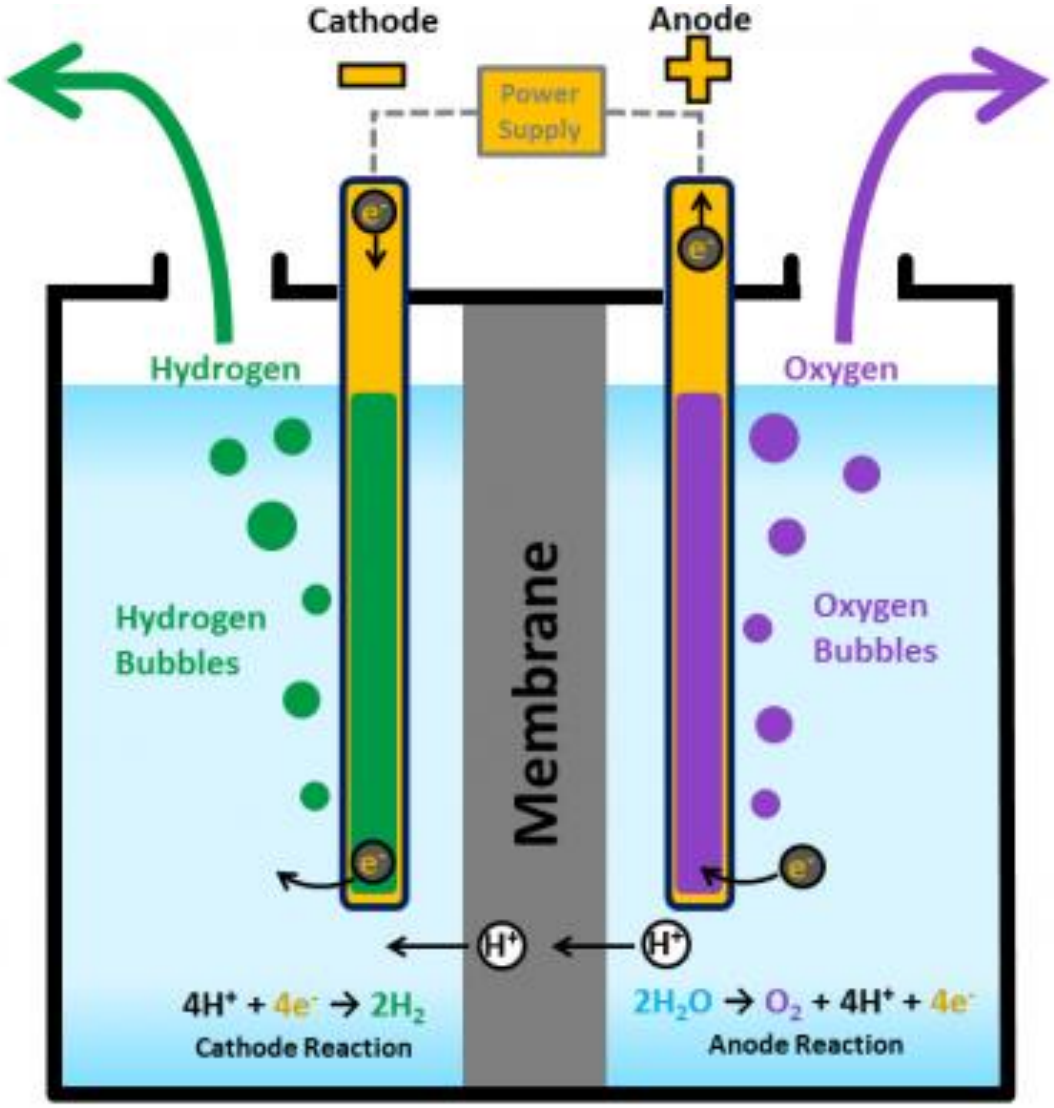


Source: Fraunhofer Institute for Factory Operation and Automation IFF



Source: National Institute of Advanced Industrial Science and Technology (AIST)

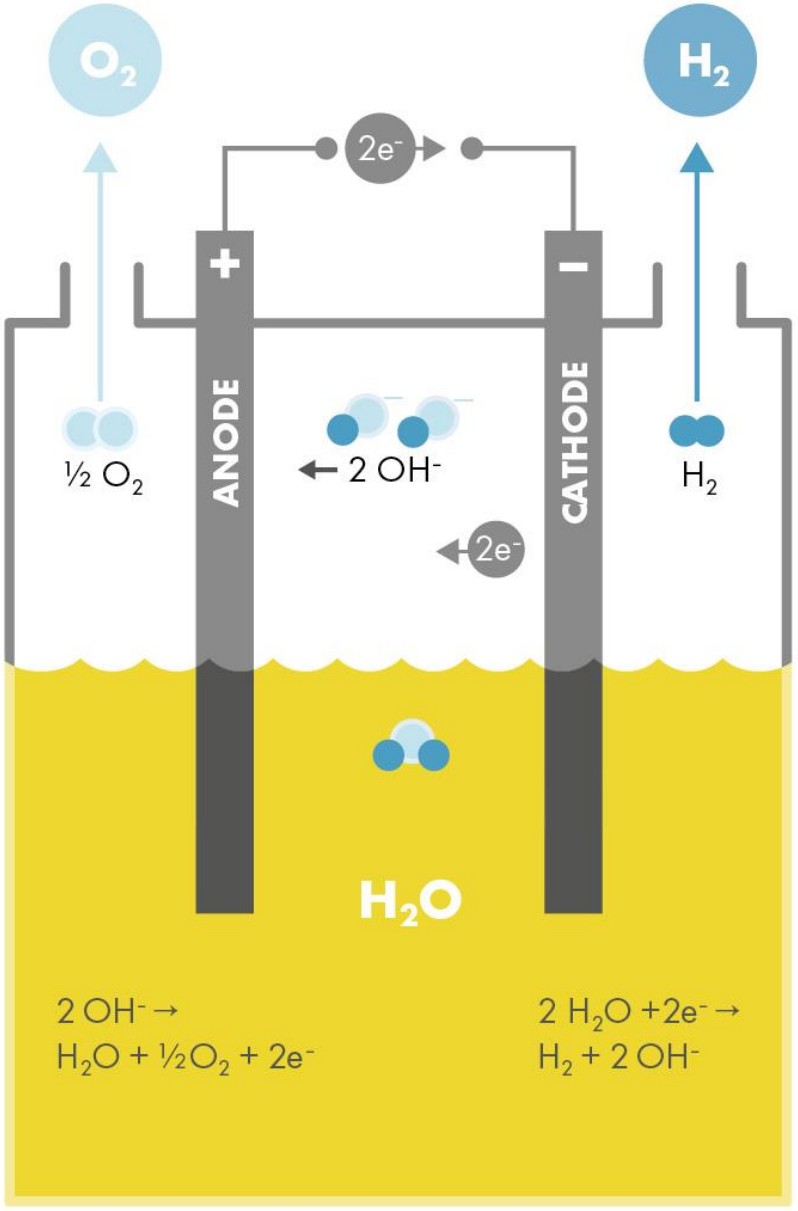
Electrolysis



Proton exchange membrane (PEM) electrolyzer

Source: U.S. Department of Energy

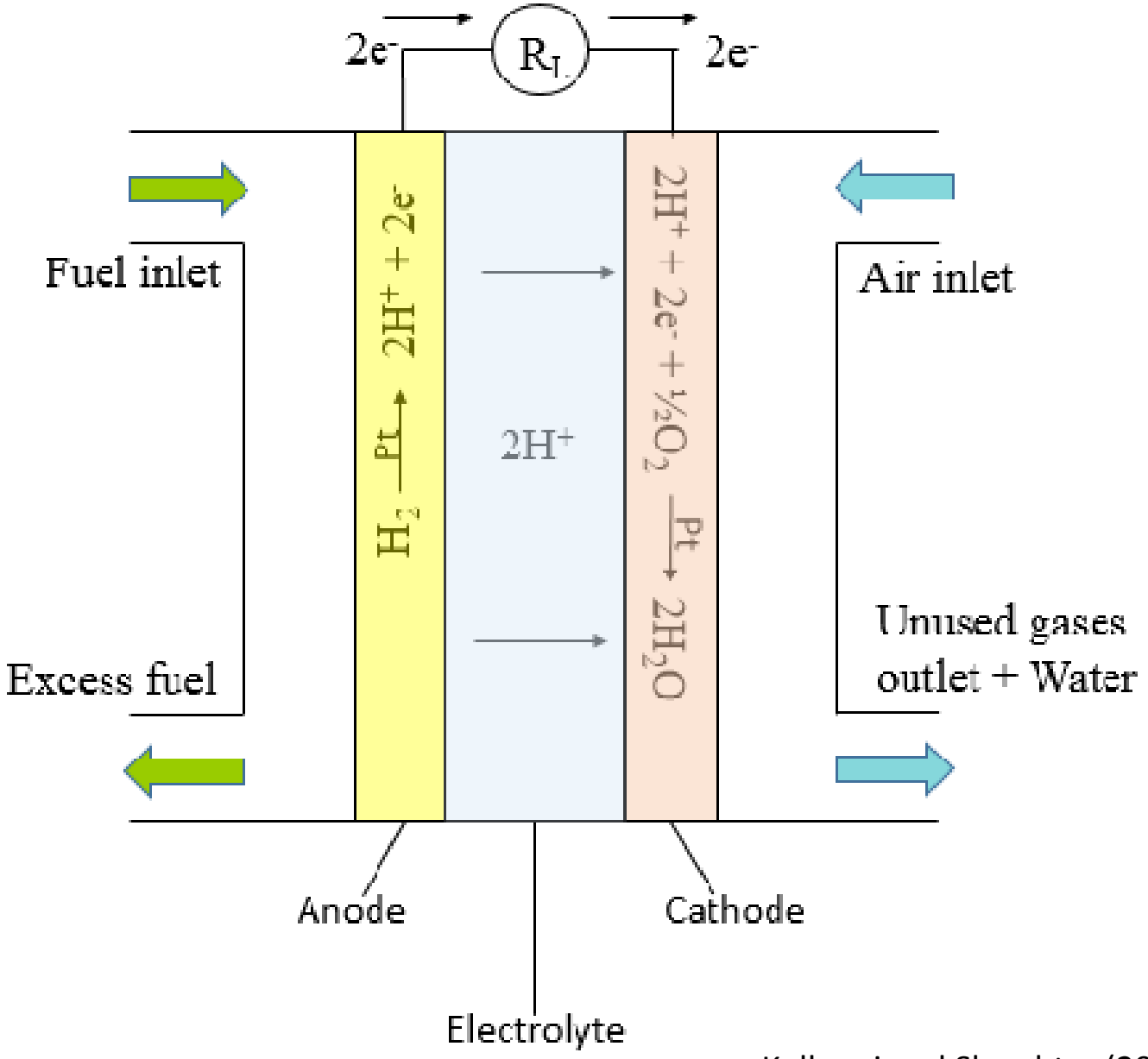
Electrolysis



Shell Hydrogen Study © Shell

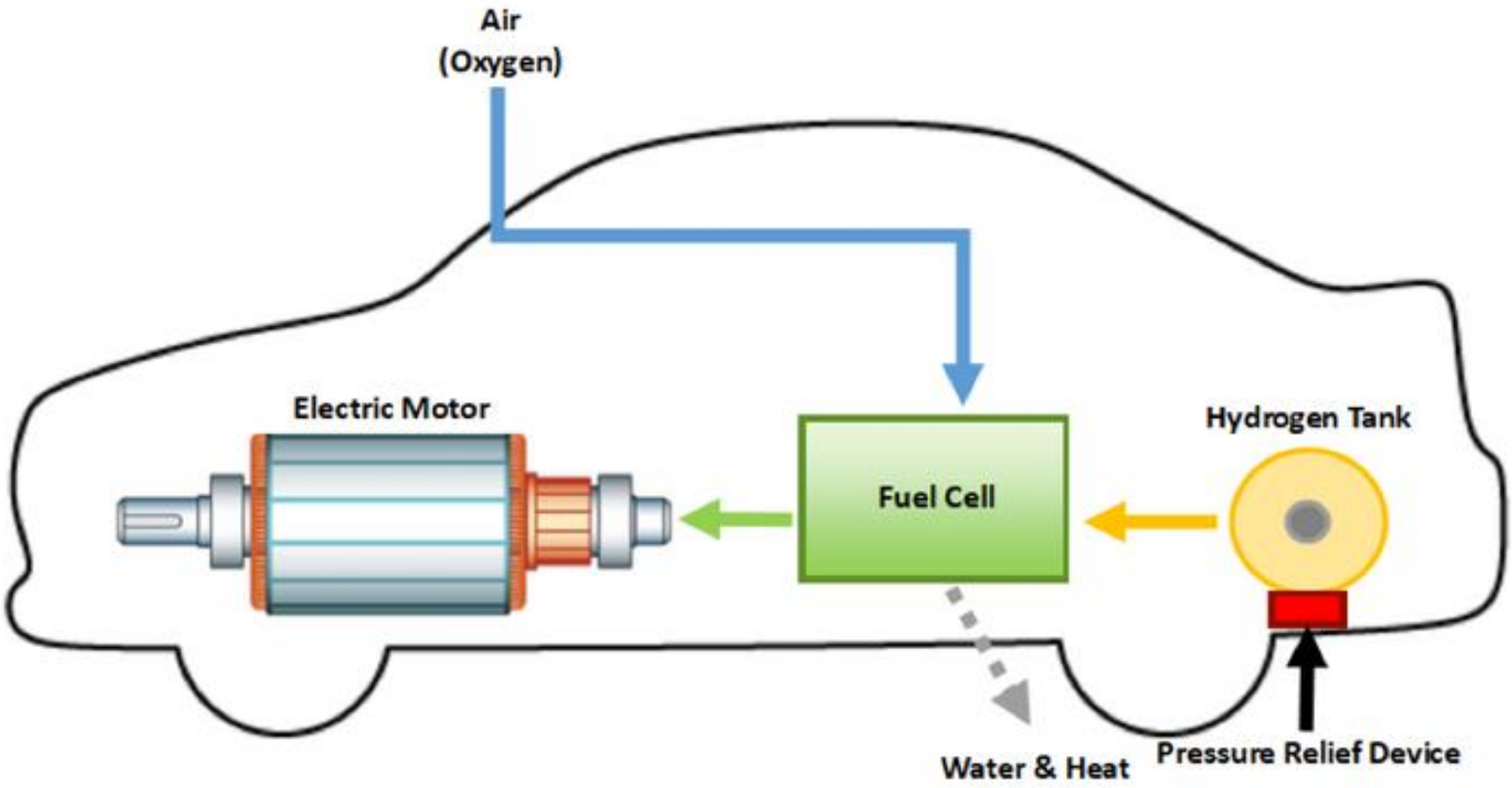
Using a fuel cell to power an electric motor is 2 to 3 times more efficient than using a combustion engine.

This means that much greater fuel economy is available using hydrogen in a fuel cell.



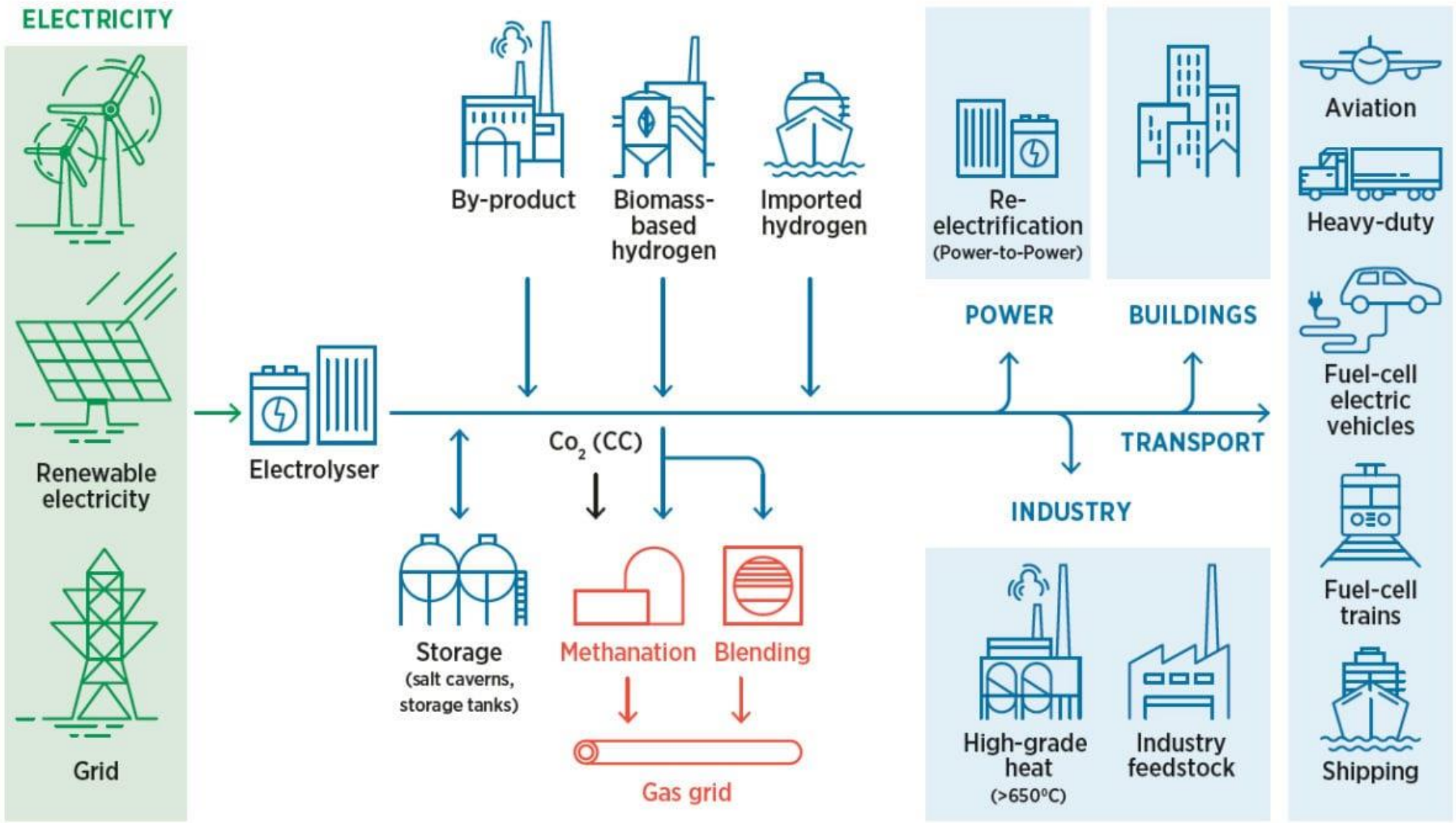
Hydrogen Fuel Cell

Kulkarni and Slaughter (2015)

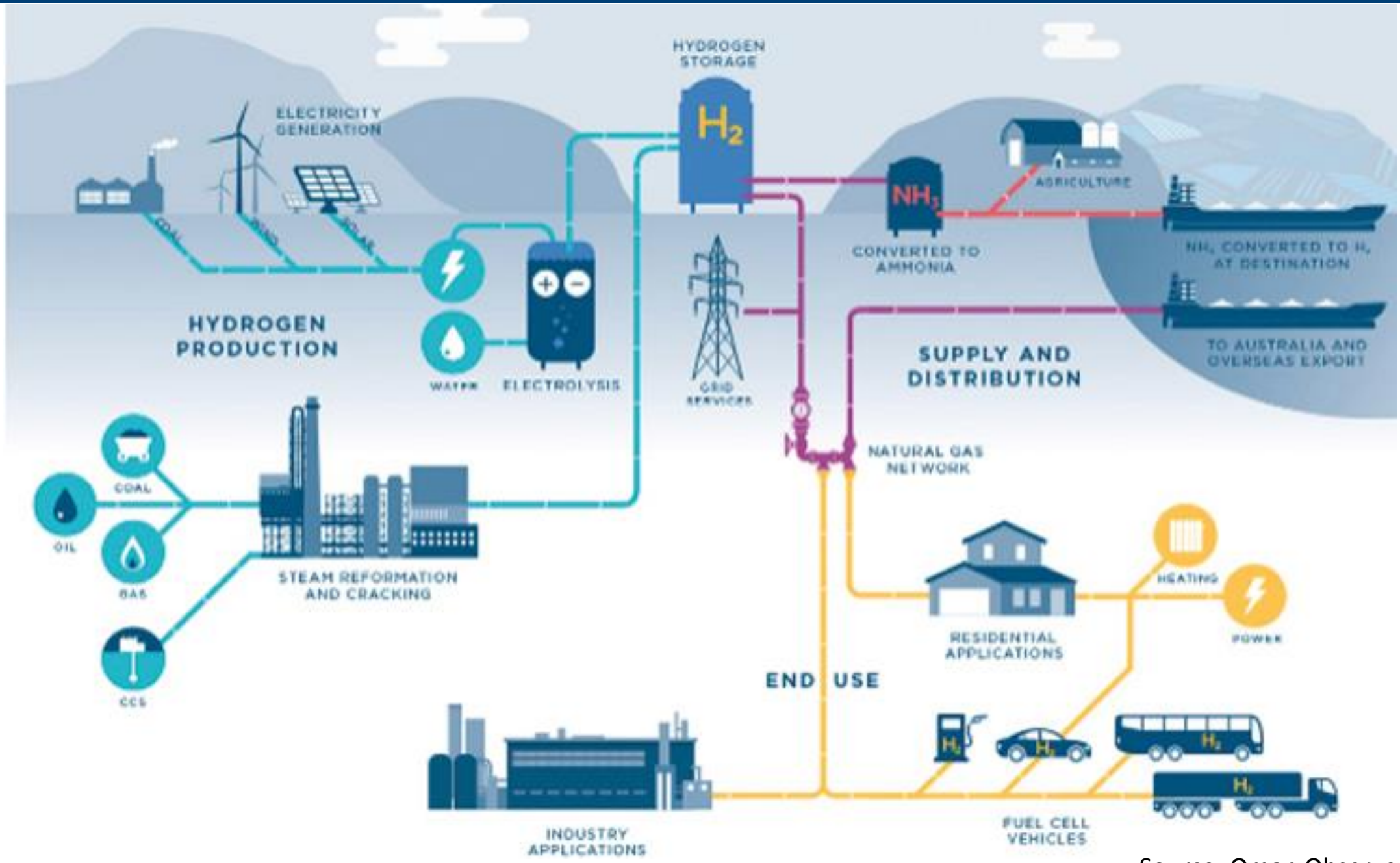


Hydrogen Fuel Cell Vehicles

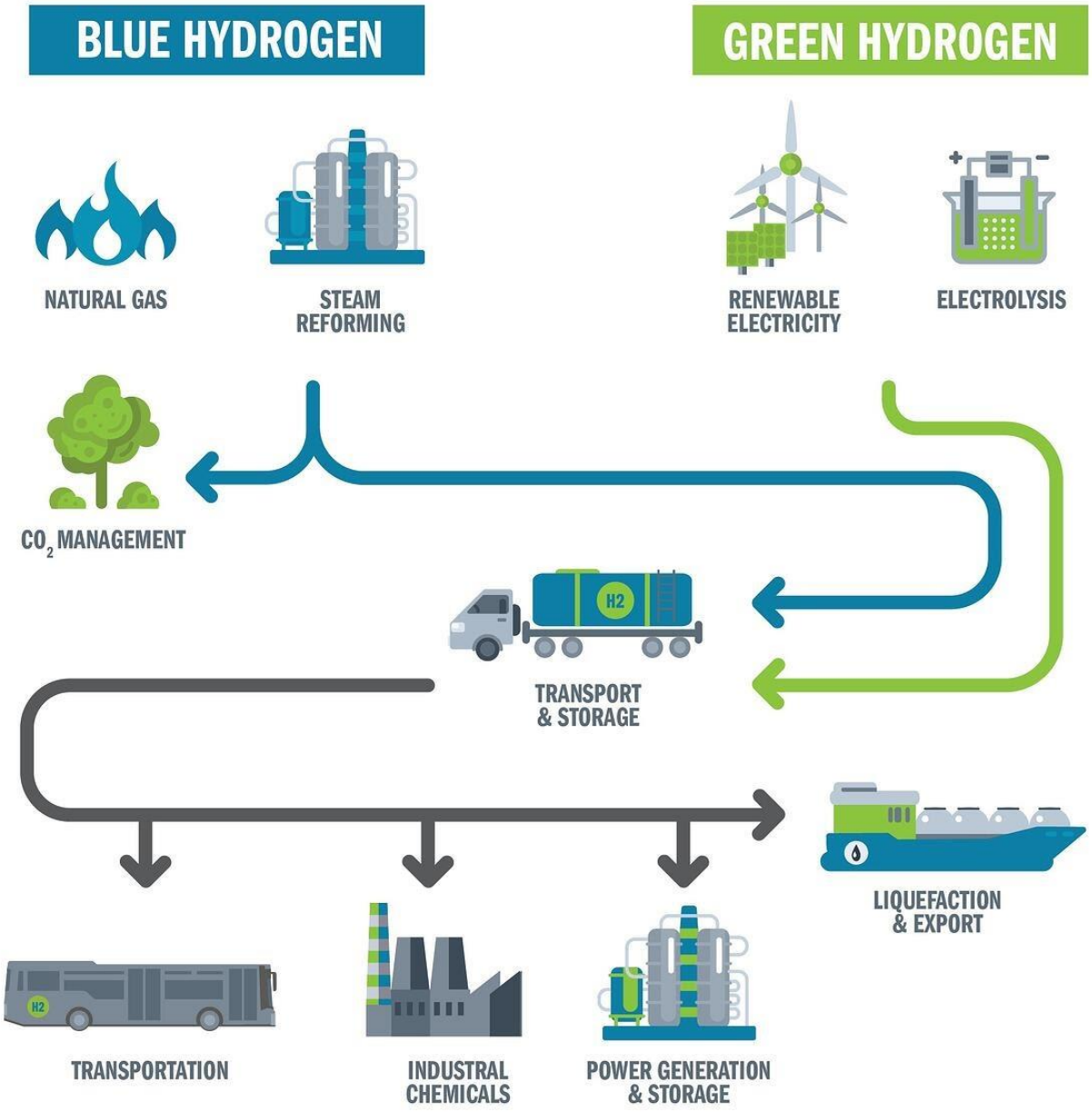
Source: Firehouse



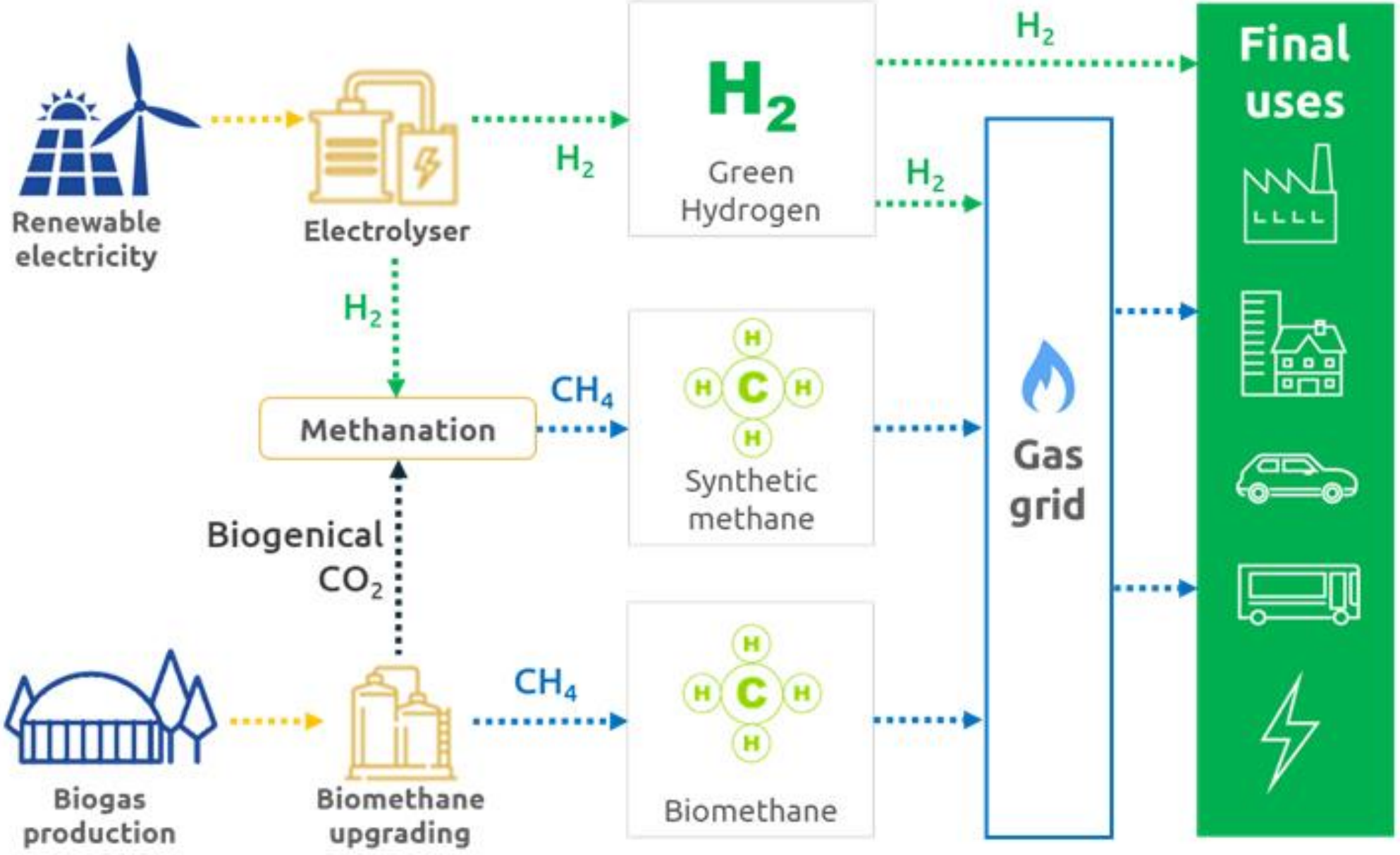
Source: *POWER*



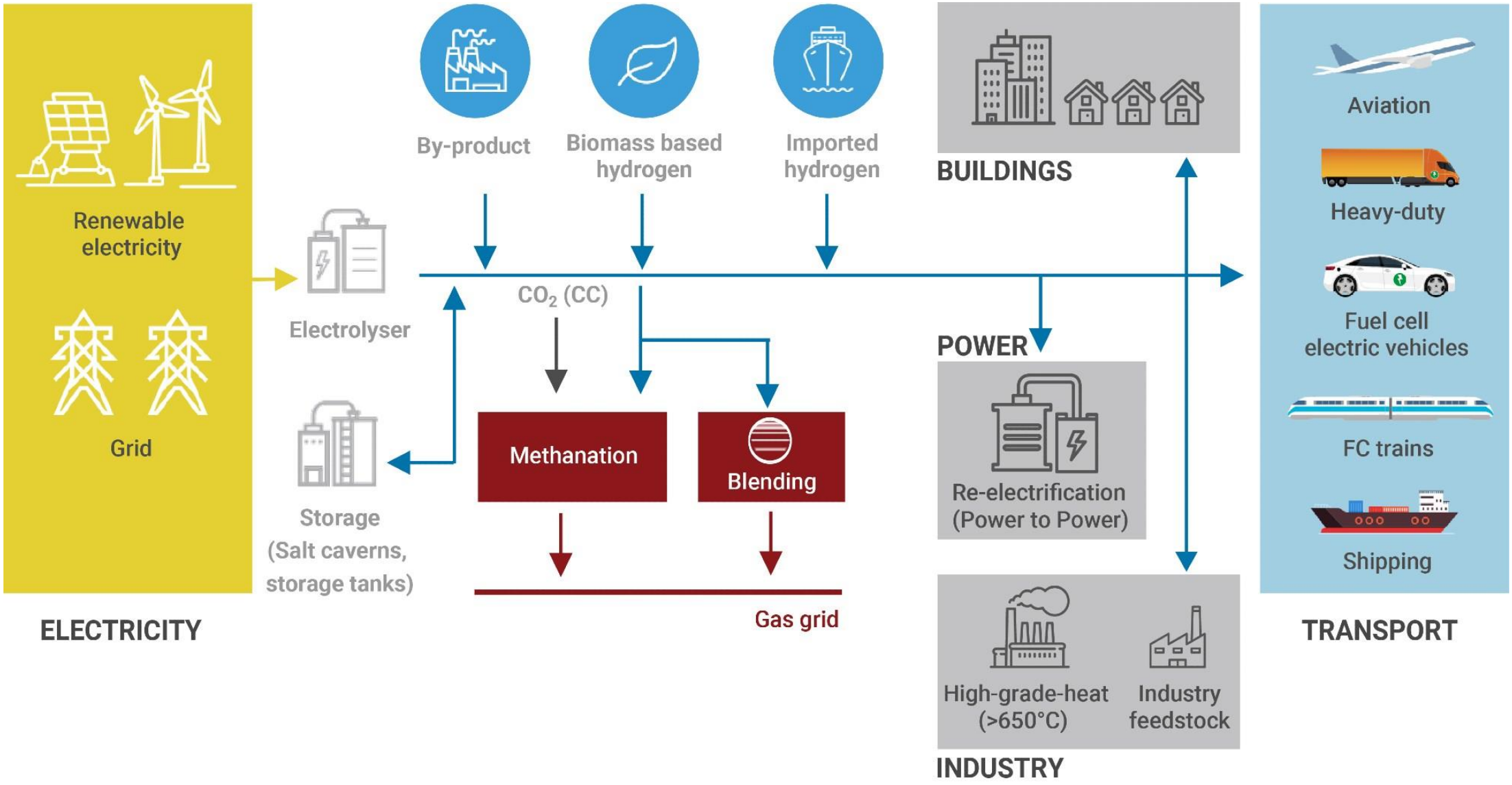
Source: Oman Observer



Source: Ballard Power Systems

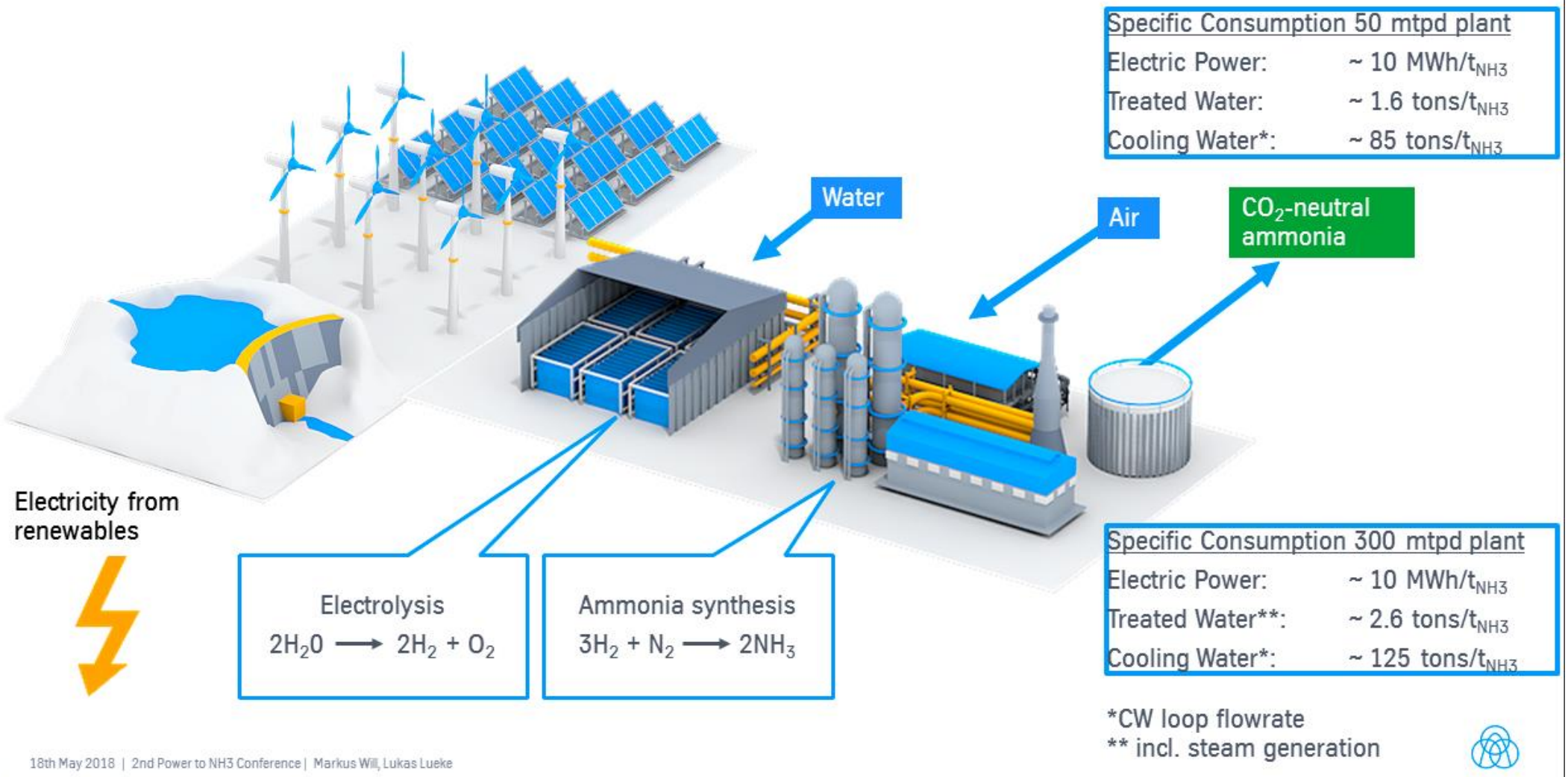


Source: Snam SPA



Source: International Renewable Energy Agency (IRENA)

Introducing renewable ammonia by thyssenkrupp



Green Hydrogen and Renewable Ammonia

Source: Ammonia Energy Association

Example of a Hydrogen Production Facility

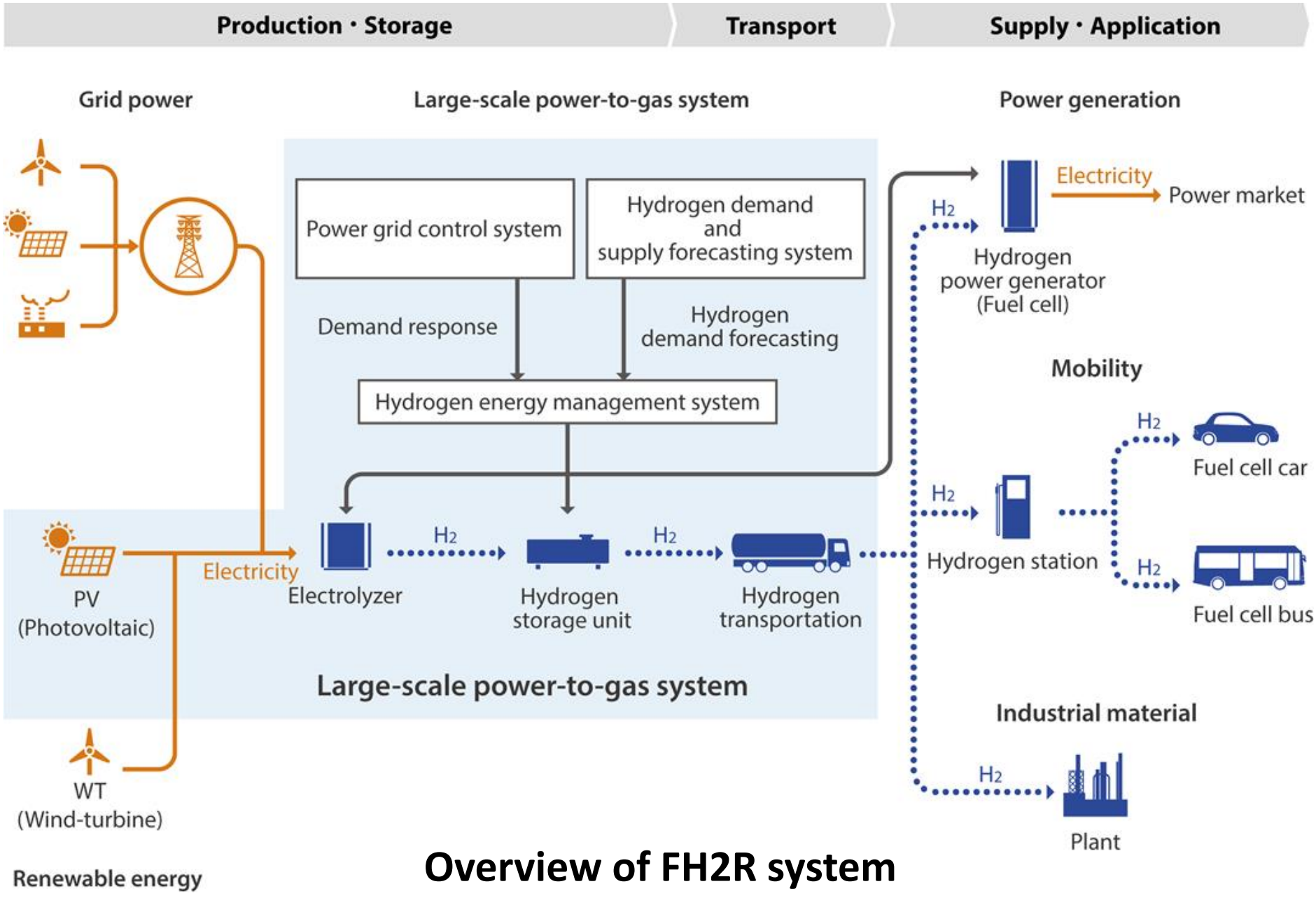
The world's largest facility for producing hydrogen fuel is claimed to be the Fukushima Hydrogen Energy Research Field (FH2R), a 10 MW-class hydrogen production unit, inaugurated on 7 March 2020, in Namie, Fukushima Prefecture, Japan.

The site occupies 180,000 m^2 of land, much of which is occupied by a solar array; but power from the grid is also used to conduct electrolysis of water to produce hydrogen fuel.

Source: Toshiba Energy Systems & Solutions Corporation

Fukushima Hydrogen Energy Research Field (FH2R)

Source: Toshiba Energy Systems & Solutions Corporation

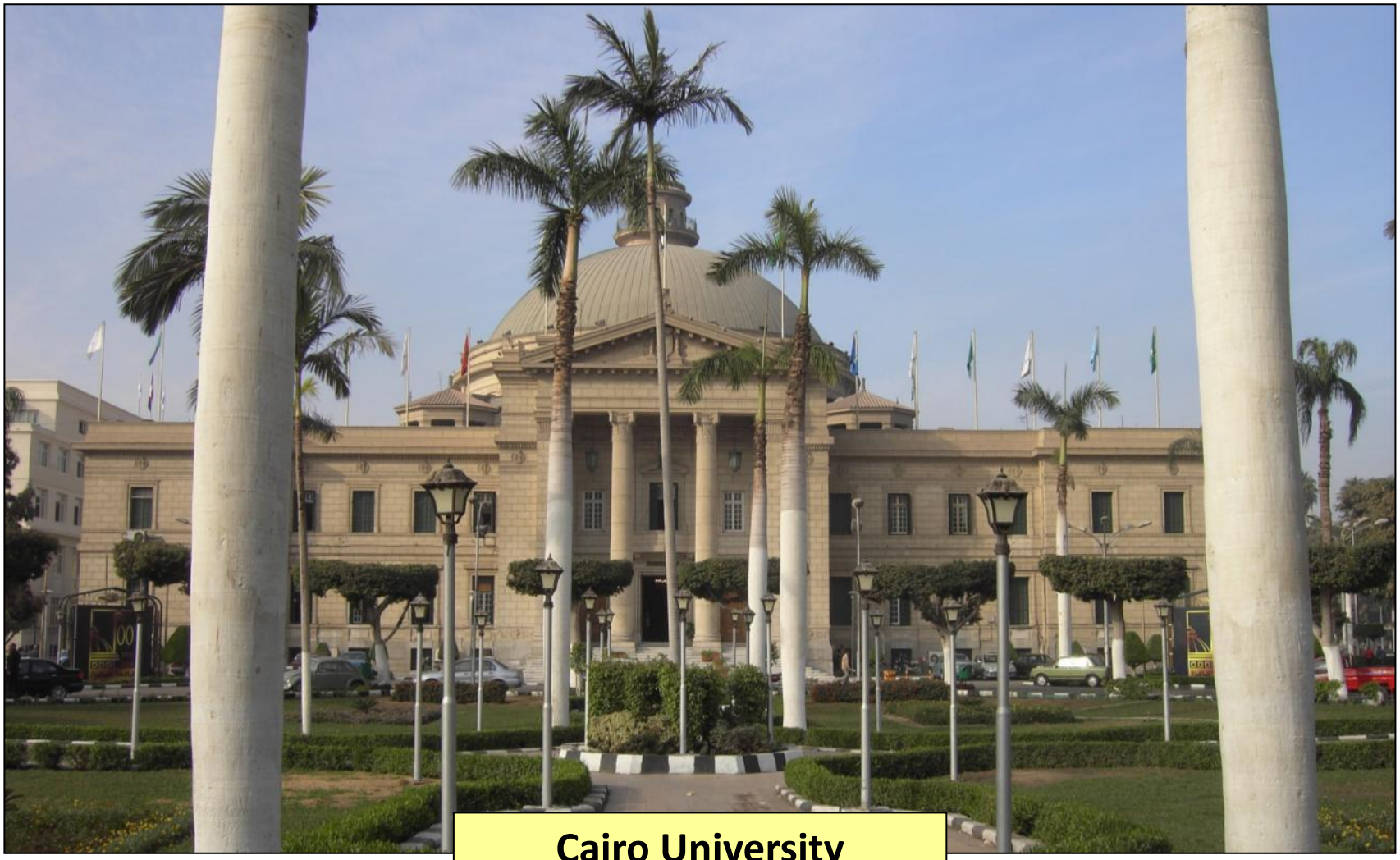


Overview of FH2R system

Source: Toshiba Energy Systems & Solutions Corporation

Videos

Thank You!



Cairo University