Hydrogen Council

How hydrogen empowers the energy transition

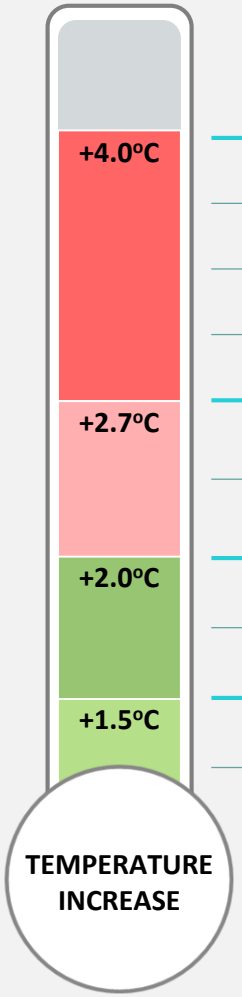
Air Liquide · ALSTOM · AngloAmerican · BMW GROUP · DAIMLER · ENGIE

HONDA · HYUNDAI · Kawasaki · THE LINDE GROUP · TOTAL · TOYOTA

Supported by Hydrogen Europe & FCHEA.

To limit climate change to well below 2°C by 2100 the energy sector needs to be decarbonized – Current efforts are not enough

Temperature increase by 2100 due to global energy related GHG emissions, in Gt CO2e/year[1]



Current policies lead to 44 Gt CO_2 e/year[2]

INDCs[3] / New policies decrease emissions to 37 Gt CO_2 e/year[2]

Emission reductions limit emissions to 19 Gt CO_2 e/year[2]

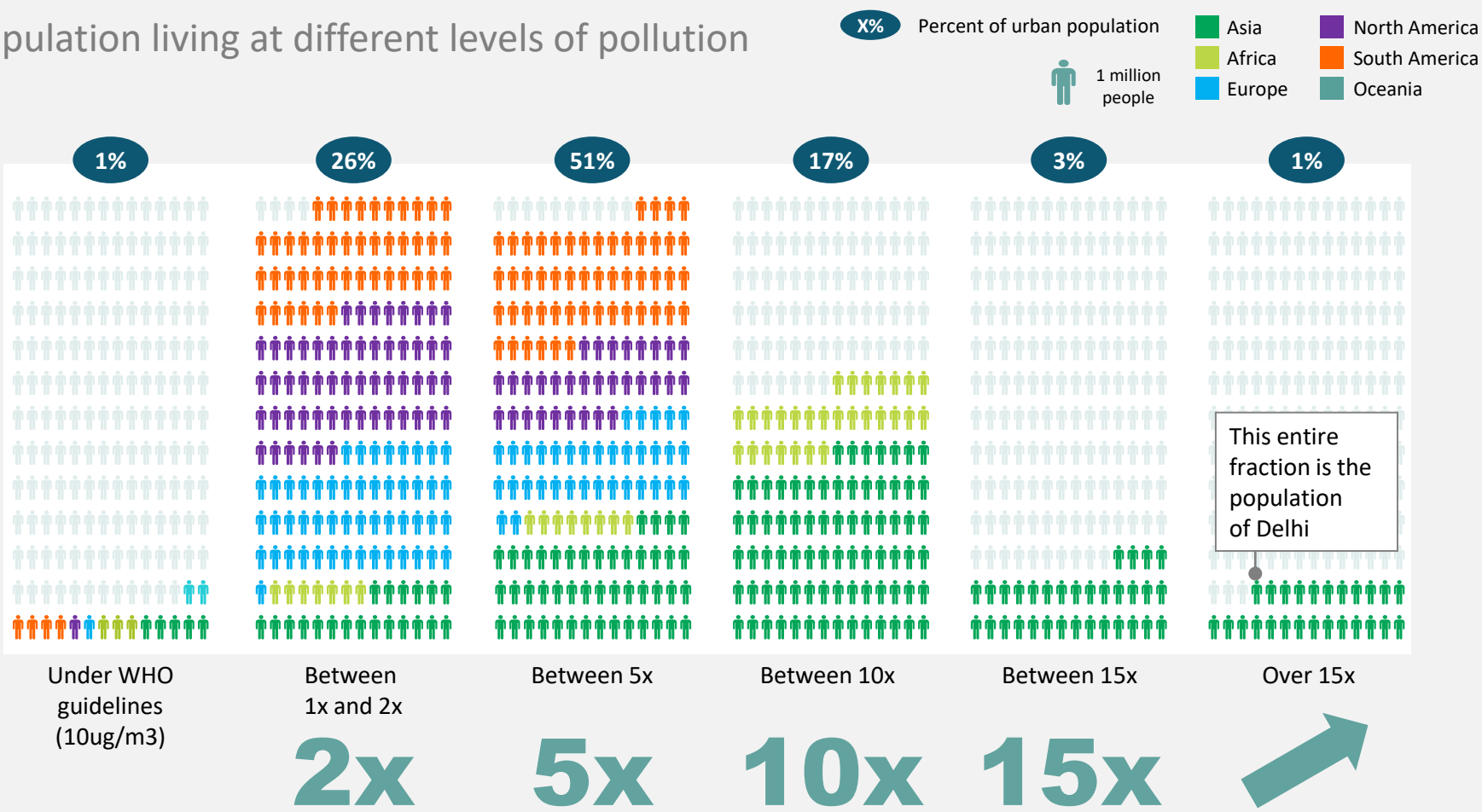
Significant emission reductions yield zero CO_2 emissions[2]

1 The GHG emissions in 2013 were 34 Gt CO_2 e/year
2 The GHG emissions forecasted for 2040 within the specified scenario
3 Intended Nationally Determined Contributions. The climate actions communicated in these INDCs help estimate whether the world achieves the long-term goals of the Paris Agreement

Source: IEA (2014), CO_2 Emissions from Fuel Combustion; IEA (2015) World Energy Outlook; IEA (2015) World Energy Outlook Special Report on Energy and Climate Change, IEA ETP 2016, ECCE 2016

Simultaneously, local air quality of cities to be improved urgently

Population living at different levels of pollution



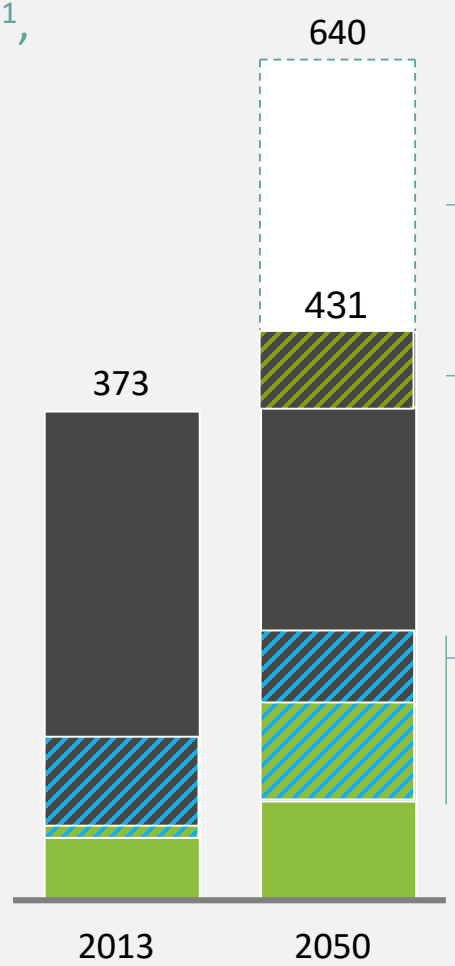
More than 99% of global population living areas where air pollution **is above current WHO guideline**

Source: World Bank, 2014, WHO 2014

NOTE: Africa is underrepresented since only 8 African cities reported emissions in 2014 (population of 42M)

Four major levers are needed to enable the energy transition

Final energy consumption[1], 2013 and 2050, in EJ



Energy demand w/o efficiency improvements[2]

Carbon capture and storage (CCS) or utilization (CCU)[3]

Fossil fuels

Power sector – Fossil fuels[4]

Power sector – Renewables

Biomass and waste

1. **Increasing energy efficiency** limits the rise of energy consumption
2. **CCS/U** decarbonizes the use of fossil fuels
3. **Switch to zero emission energy carriers,** e.g., electricity or hydrogen
4. **Renewables** replace fossil fuels

1 Final energy consumption within the 2°C scenario of the IEA
2 Increase of energy demand is determined via the relative increase of CO2 emissions w/o energy efficiencies
3 The fossil fuels amount processed using CCS/U was determined to be 25% of the total amount of fossil fuels by relating the CO2 emission reduction compared for the 2DS and 6DS scenario
4 The fossil fuel power sector also includes nuclear energy

Source: IEA ETP 2016

Hydrogen helps to overcome many of the challenges of the energy transition

SOURCES OF ENERGY | **BACKBONE OF ENERGY SYSTEM** | **END USES**

Increasing renewables share leading to **imbalances of power supply & demand**

Infrastructure needs to go through a major transformation

Global buffering capacity based on mostly fossil sources

Some energy uses are **hard to electrify** via the grid or with batteries:

- Transport
- Industry
- Residential heating

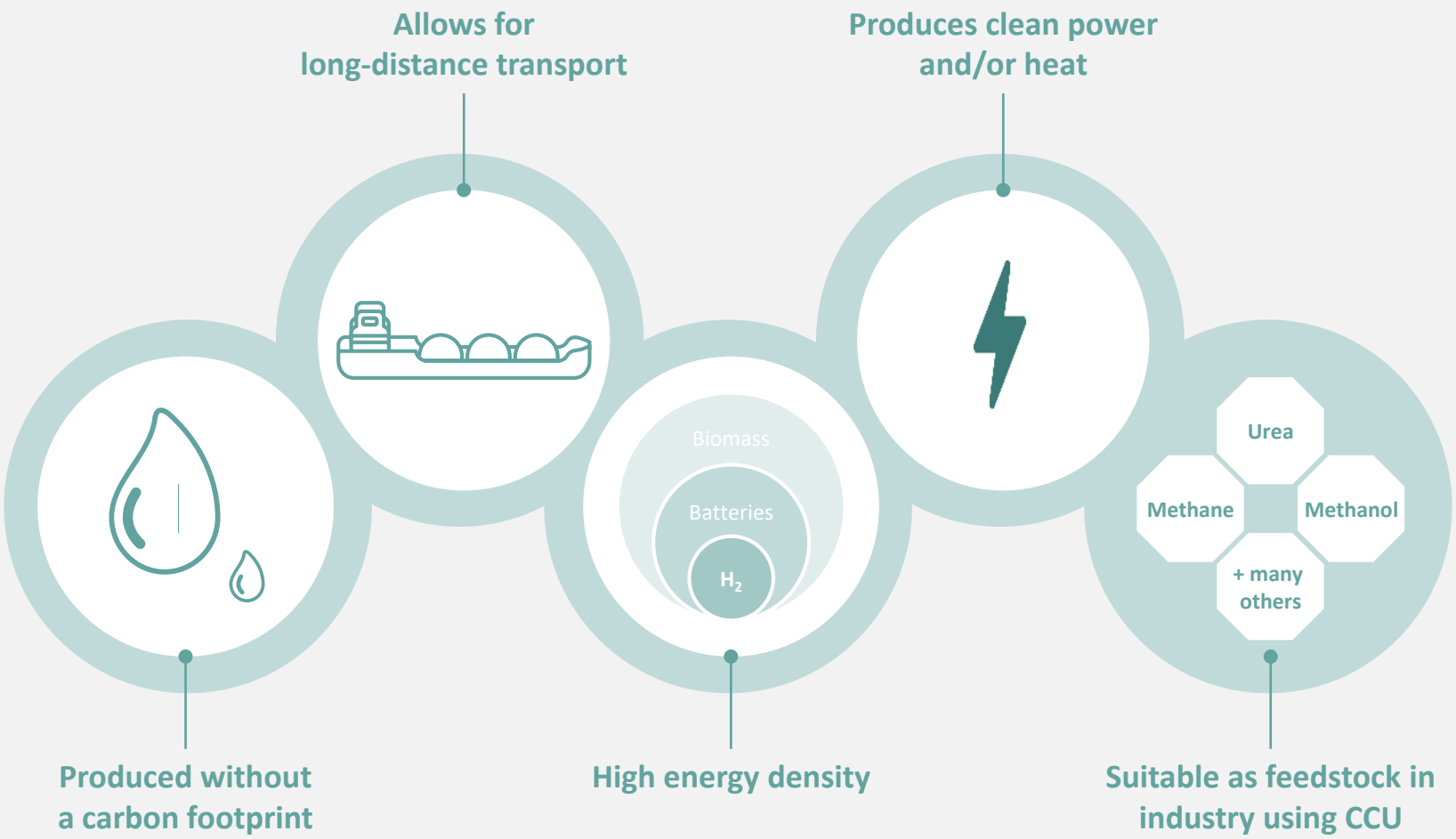
Carbon needs to be reused to decarbonize feedstock

Energy vectors

- Electricity
- Hydrogen
- Today
- Future

Source: Hydrogen Council

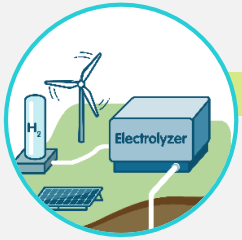
Hydrogen is a versatile, zero-emission energy carrier with many benefits to the energy transition



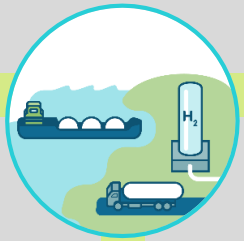
Source: Hydrogen Council

Hence, hydrogen has seven roles in the energy transition

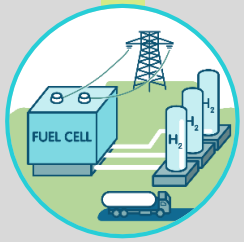
SOURCES OF ENERGY | **BACKBONE OF ENERGY SYSTEM** | **END USES**



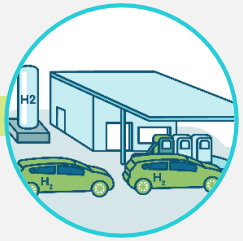
1. Enable **large-scale, efficient renewable energy** integration



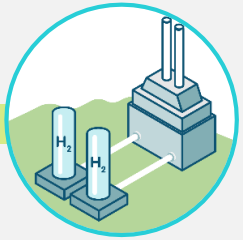
2. **Distribute** energy across sectors and regions



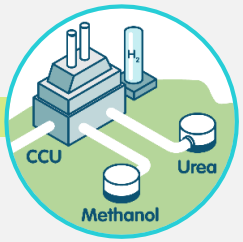
3. Act as a **buffer** to increase system resilience



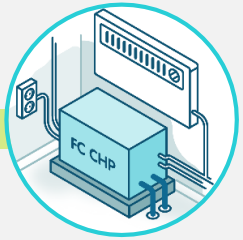
4. Decarbonize **transport**



5. Decarbonize **industry energy** use



6. Serve as **feedstock** using captured carbon



7. Help decarbonize **building heating**

Energy vectors
Hydrogen

Source: Hydrogen Council

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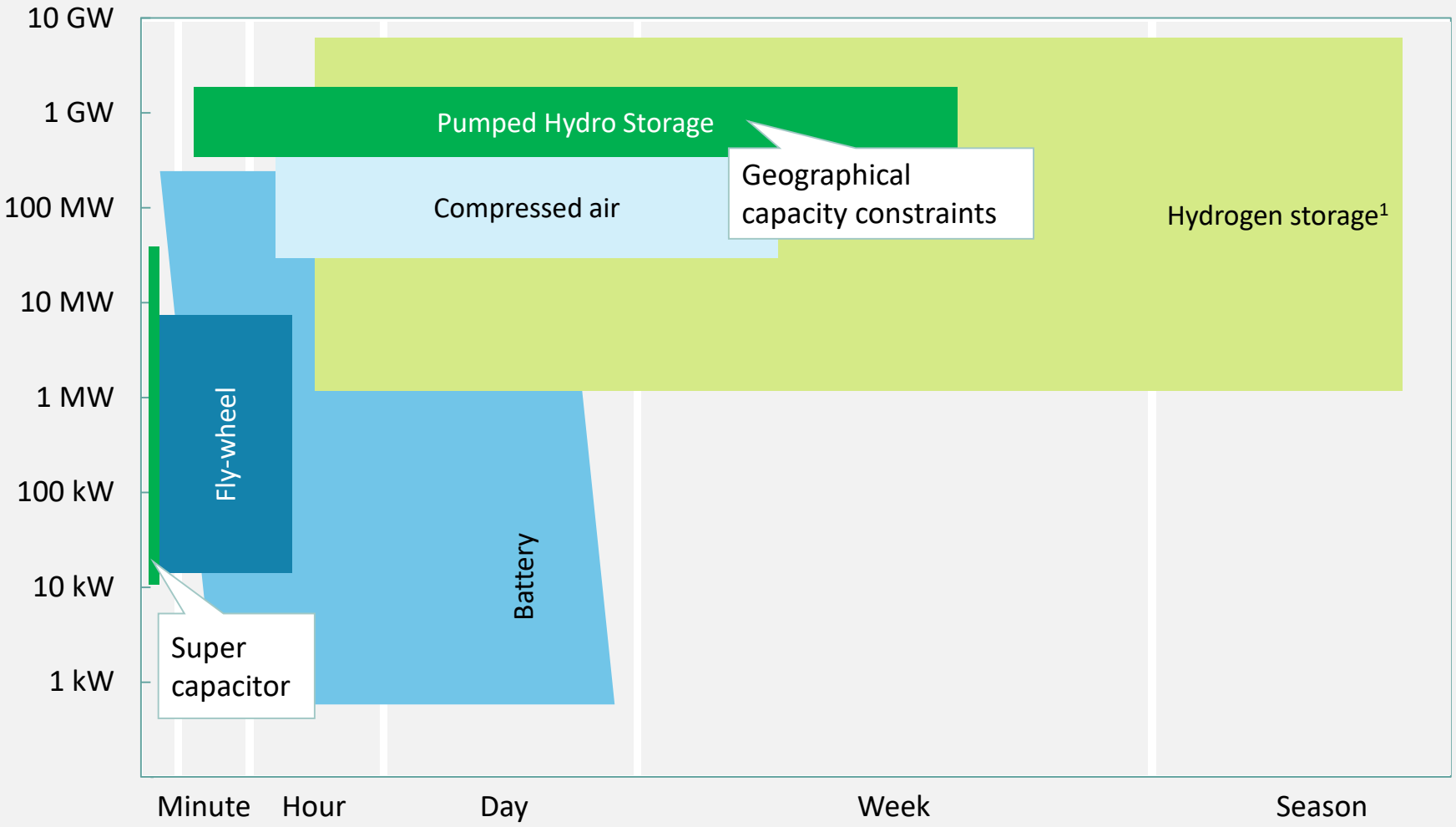
1. Hydrogen for long-term carbon-free energy storage

Technology overview of carbon-free energy storage technologies

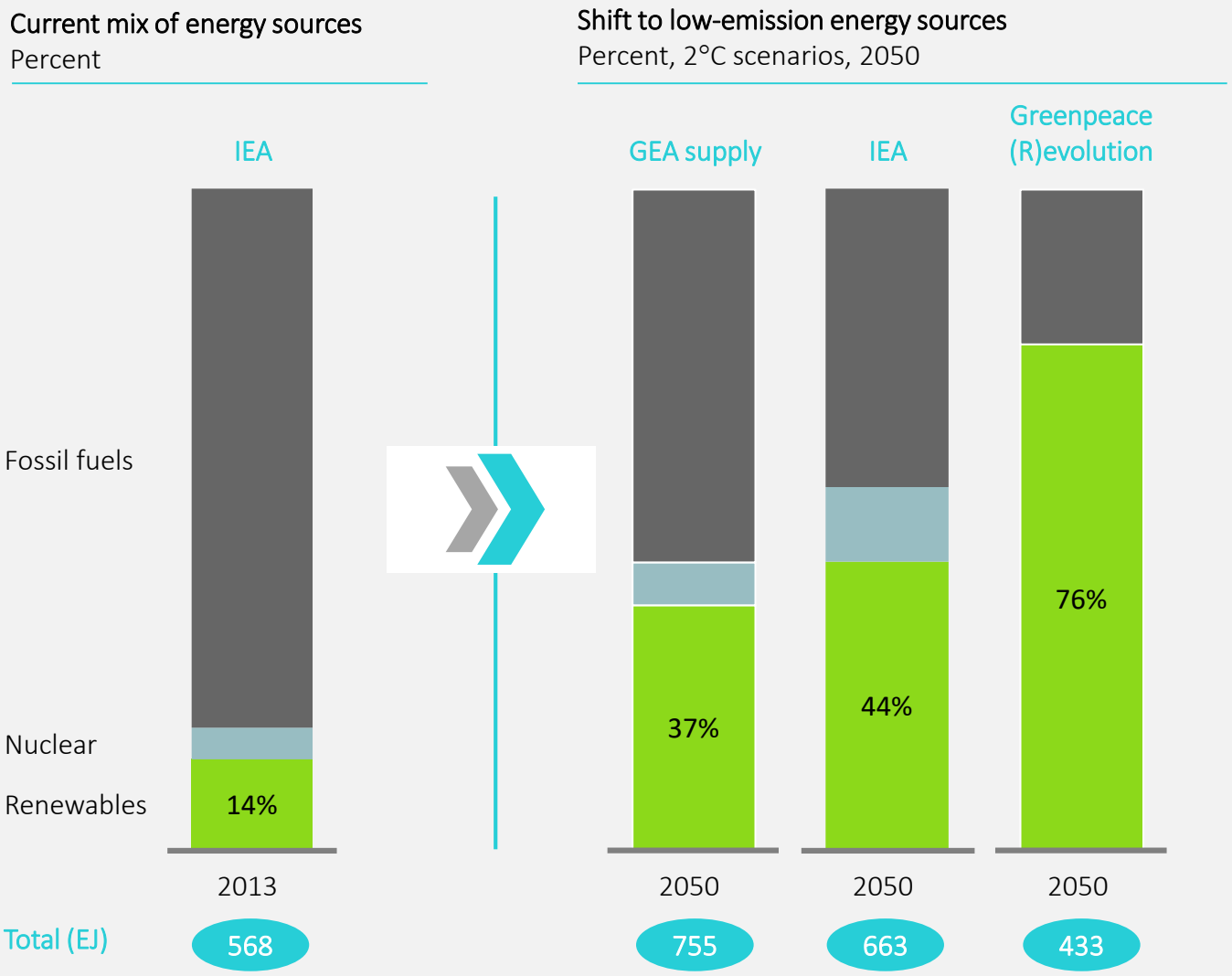


1 IEA data updated due to recent developments in building numerous 1MW hydrogen storage tanks

Source: IEA Energy Technology Roadmap Hydrogen and Fuel Cells, JRC Scientific and Policy Report 2013

BACKUP

Major shift towards renewable sources of energy …



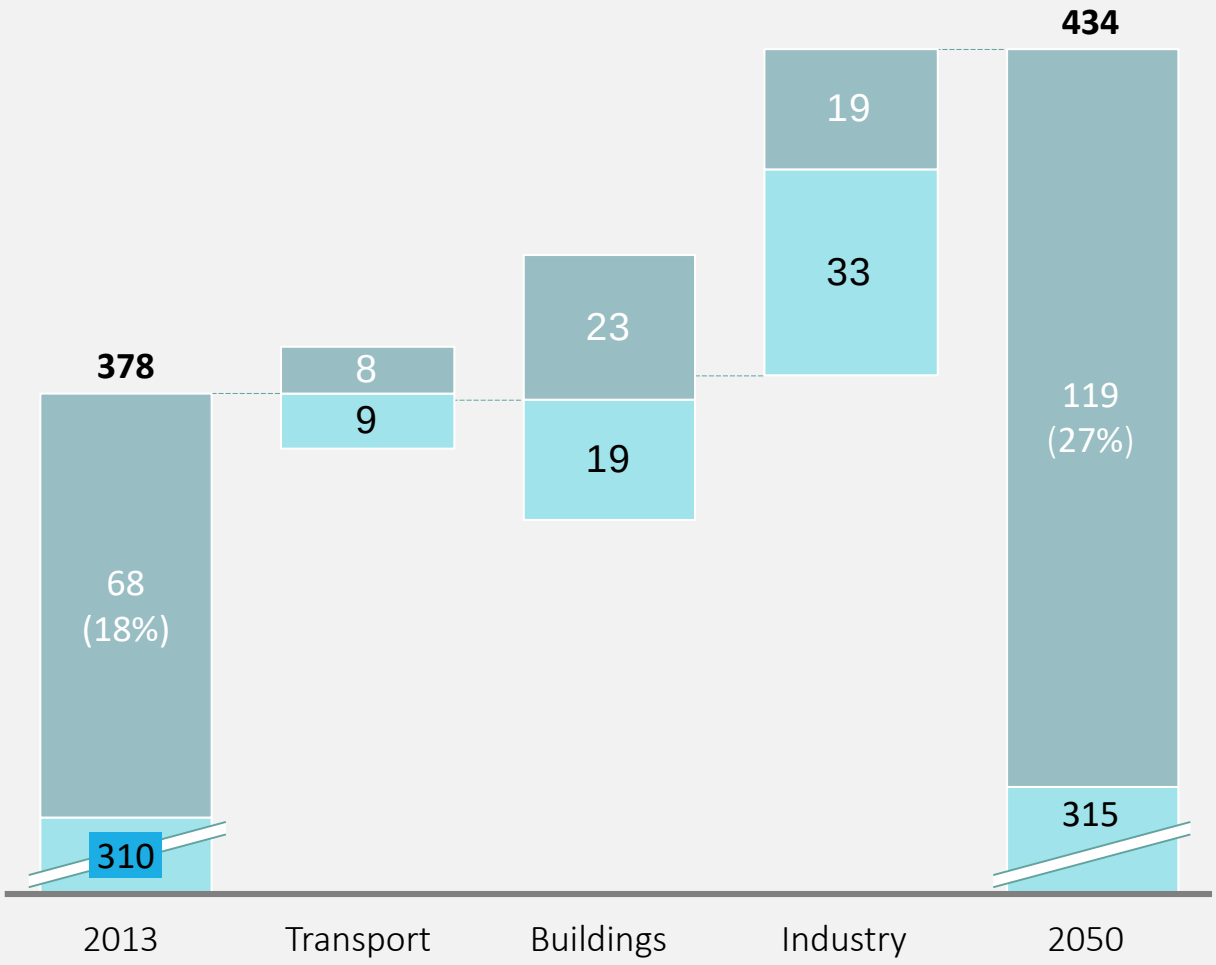
1 Based on the absolute growth of the total source energy via renewables in all three scenario's

SOURCE: IEA (2016), Energy Technology Perspectives; GEA (2012), MESSAGE Scenario database (Version 2.0.2); Greenpeace (2015), Energy Revolution

BACKUP

… to meet the increasing energy demand, esp. the increasing demand for electricity

Total Energy demand[1]
EJ, 2°C scenarios



Total energy consumption in 2050 expected to be

+15%

higher than consumption today, however electricity consumption to be expected to grow by

+75%

mainly driven by increasing **electrification** in the building sector and industry

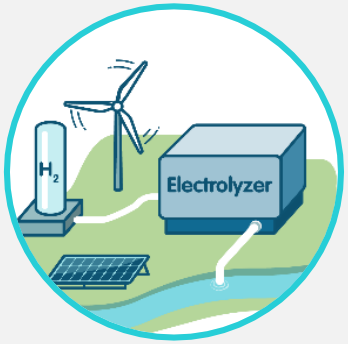
1 The sum of the total energy demand is determined assuming only end-usage within transport, buildings and industry, and thereby, neglecting the presence of other end-uses. This explains the difference in total energy demand between this split and the fuel-based split

SOURCE: IEA (2016), Energy Technology Perspectives

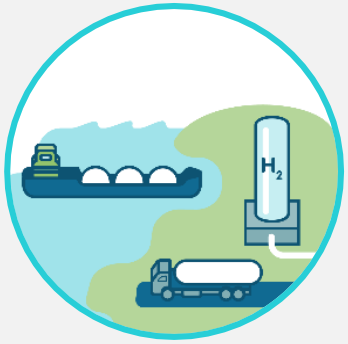
2 & 3. Hydrogen is a carbon neutral energy carrier which is easily stored and distributed

Energy vectors
Hydrogen

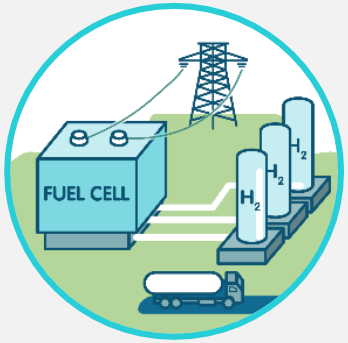
A Hydrogen production is **carbon neutral and provides seasonal storage**



B High energy density supports **efficient energy distribution** across sectors and regions



C Hydrogen storage acts as an **energy buffer** to increase system resilience



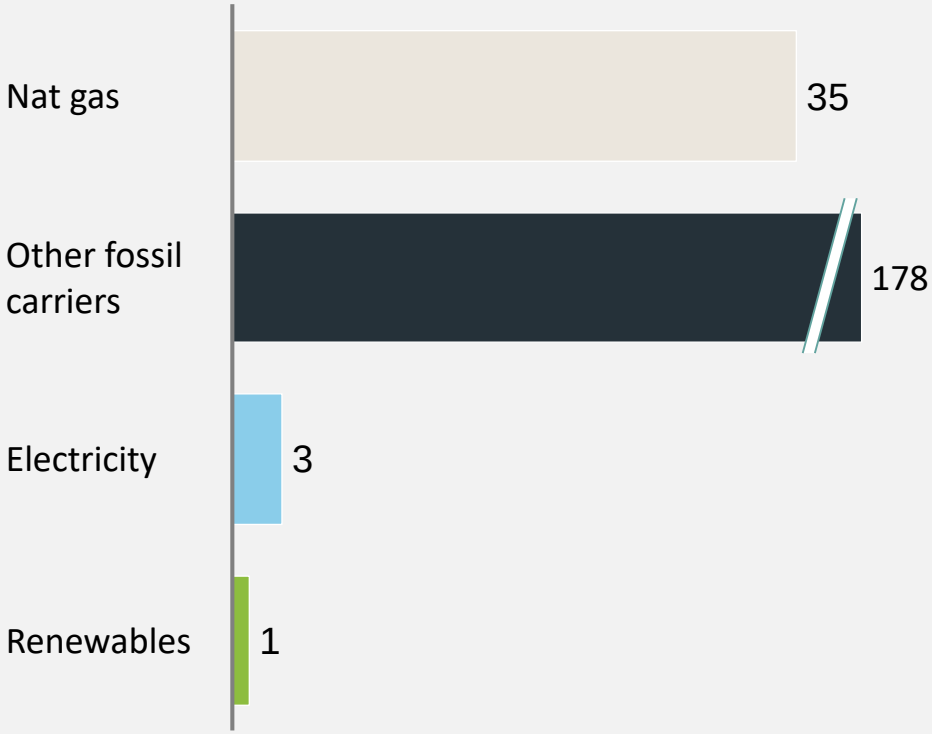
D Hydrogen to be used as a **versatile energy carrier in various end uses**

Source: Hydrogen Council

The energy transfer between countries (~220 EJ), accounting for local mismatches of demand and supply, almost exclusively relies on fossil vectors

Energy transfer between countries

EJ



Western and Central European[1] nat. gas grid:

- ~145,000 km main pipelines
- ~24,000 GWh/d cross-border capacity

By ship (capacity per year)

- ~100 mn cbm LNG or LPG
- ~200 mn dwt coal
- ~500 mn dwt oil

40% of world's fleet tonnage

but also by train & trucks

Hydrogen can provide a cost effective, clean alternative infrastructure to help ensure security of energy supply and continued trading

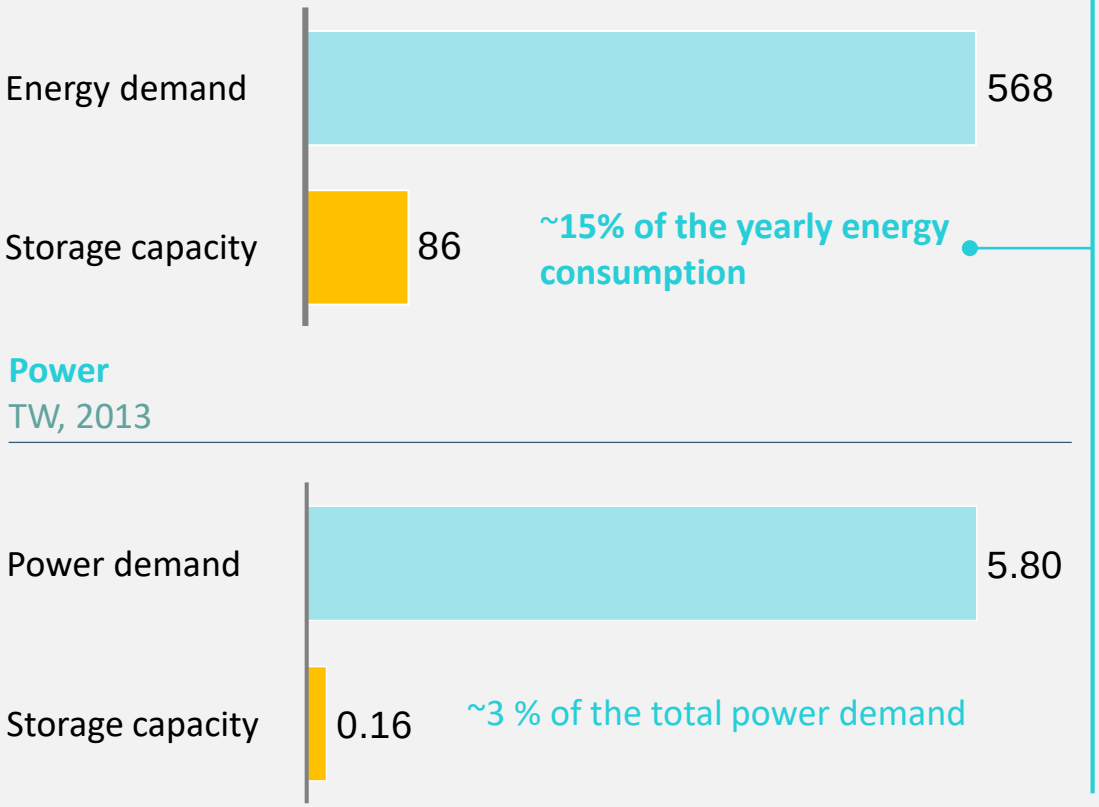
1 EGIG/ENTSOG

SOURCE: McKinsey, expert interviews, cedigaz; IGU wrld LNG report, DoE Global energy storage database, CIA

BACKUP

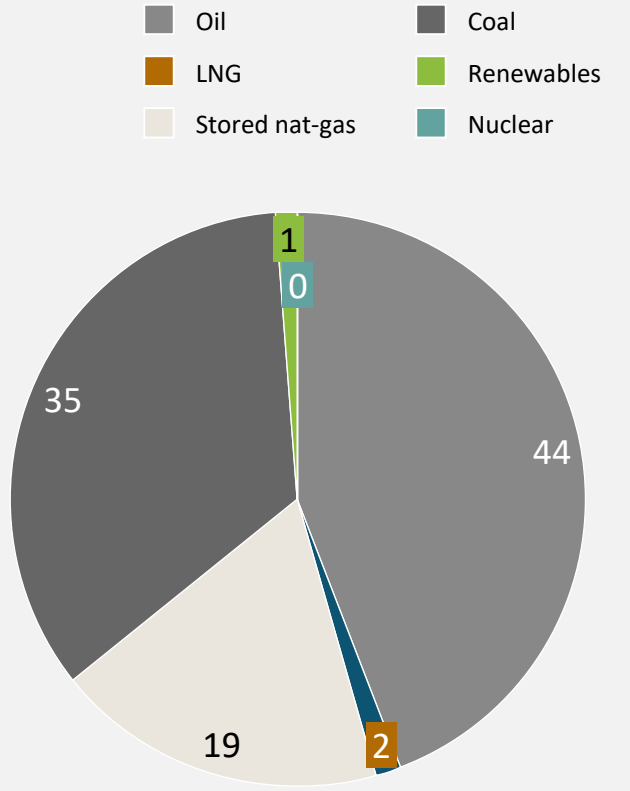
Currently there is around 86 EJ of fossil storage capacity but only around 160 GW power storage capacity

Energy
EJ, 2014



Power
TW, 2013

Energy storage split
%



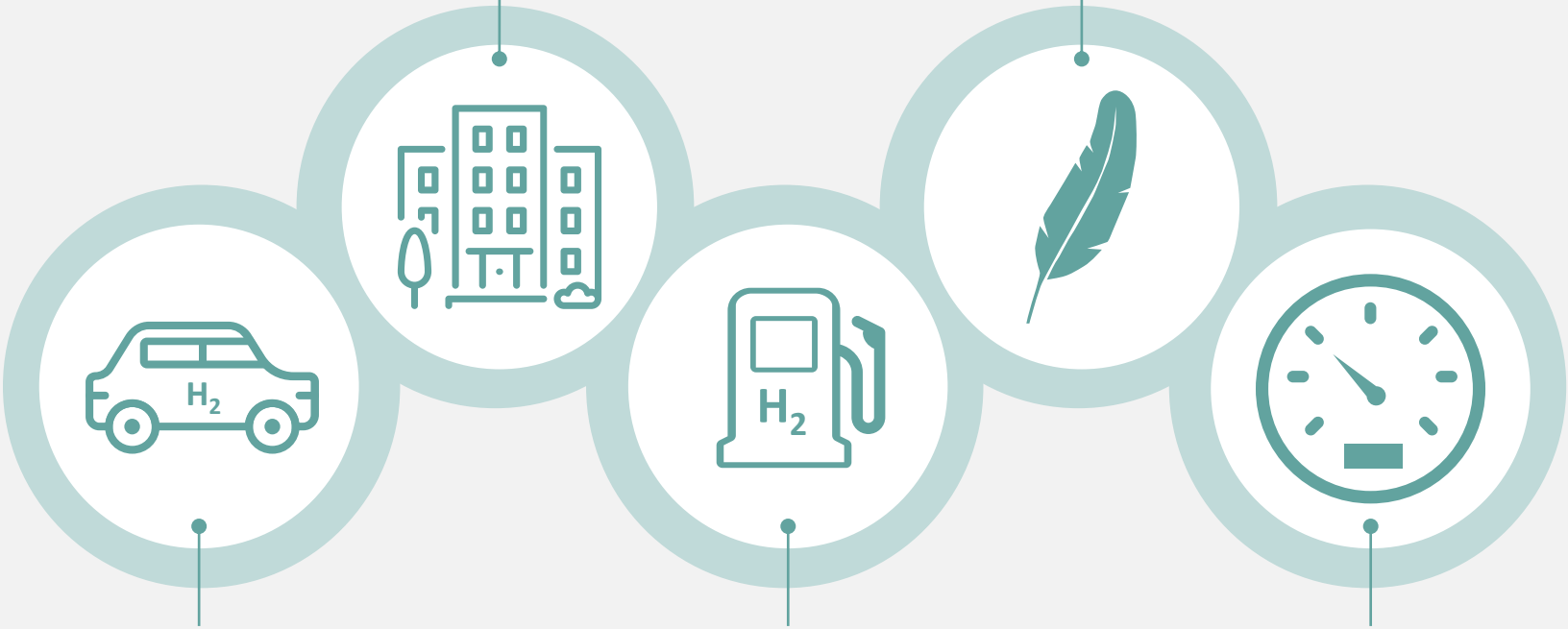
As electrification increases, the need for alternative global buffering capacity arises. Hydrogen can be used as alternative storage and buffering provider.

SOURCE: McKinsey, expert interviews, Cedigaz; IGU wrld LNG report, DoE Global energy storage database, CIA

4. The benefits of Fuel Cell Electric Vehicles (FCEVs)

Can build on existing infrastructure
- Help preserve local jobs
- Reuse of existing assets
- Distribution infrastructure

Fast refuelling
- 3-5 minutes
- High customer convenience

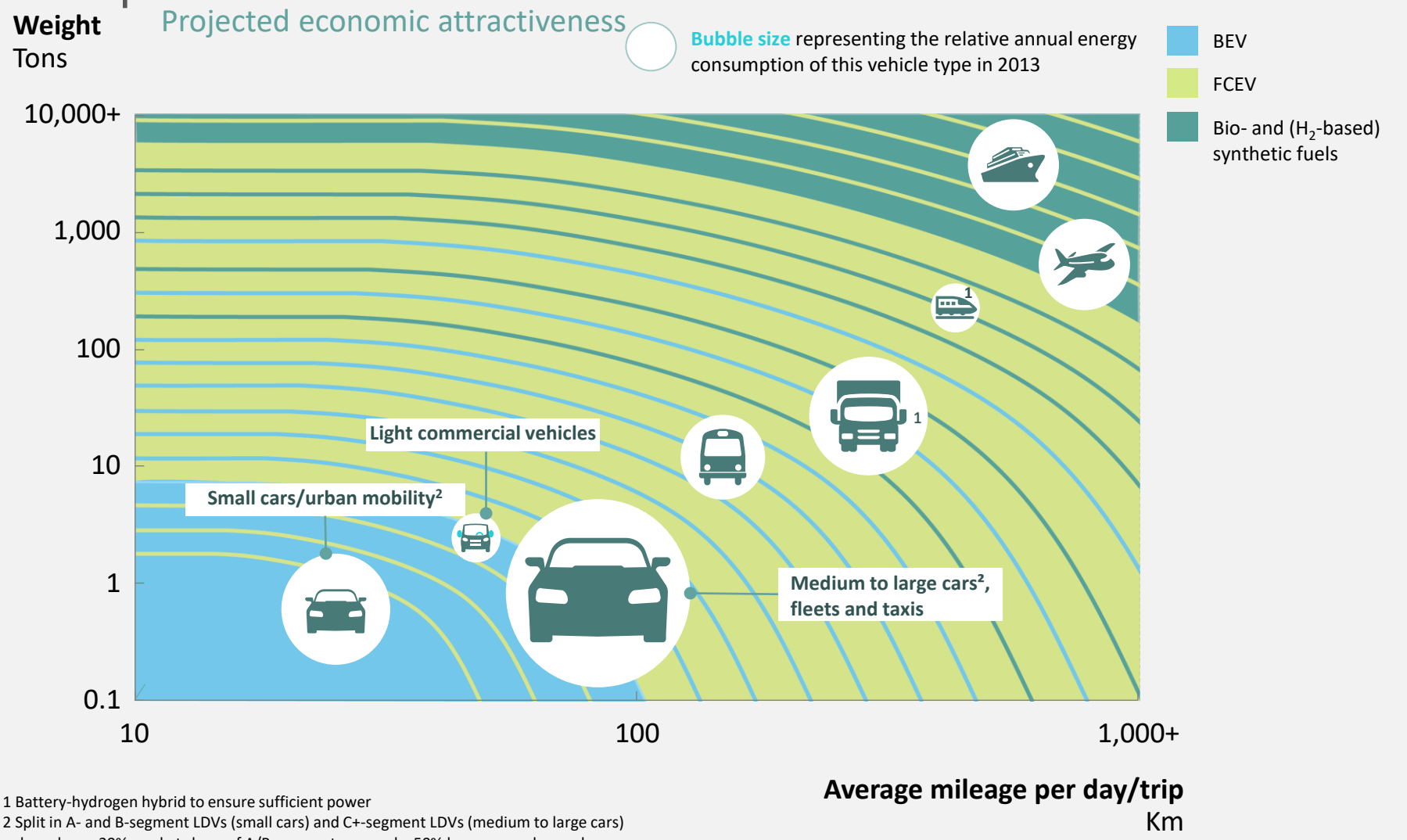


Zero local emissions
- No pollutants
- No CO_2
- Improved air quality

High energy density
- Less storage weight enhances payload
- Suitable for heavy duty and heavy usage applications

Long driving range
- High customer convenience

4. FCEVs will play an essential role in decarbonizing transport

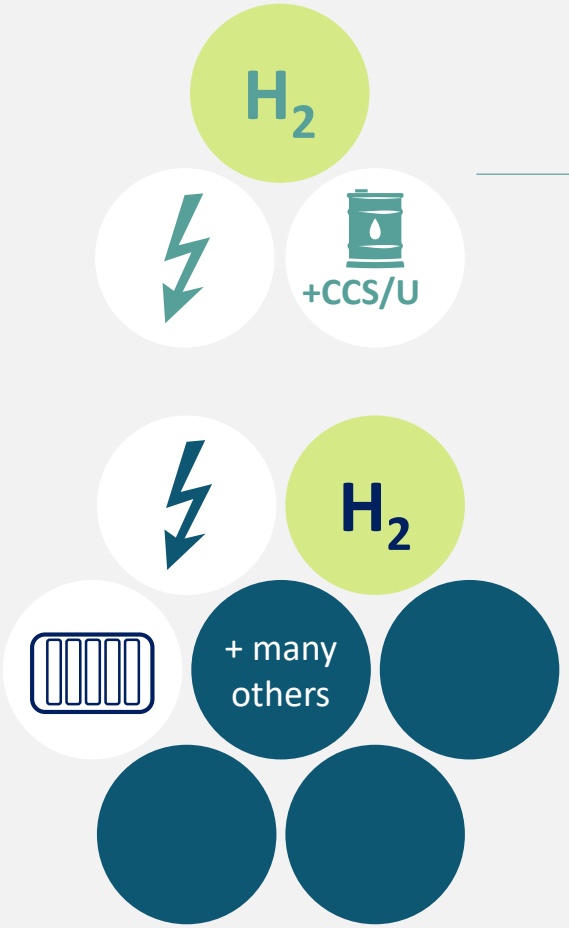


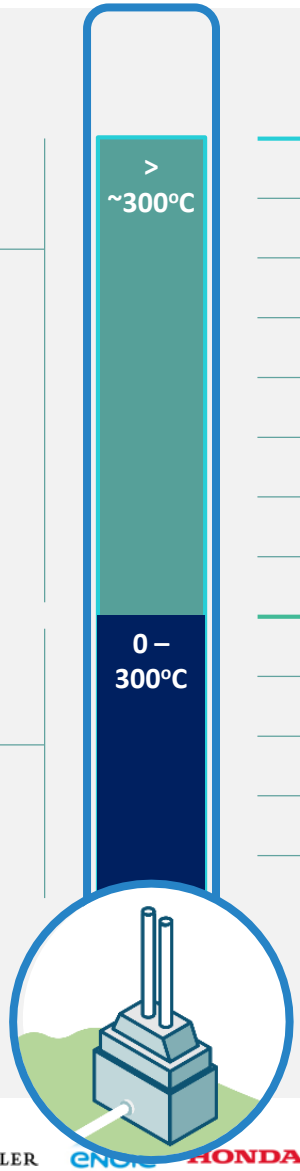
1 Battery-hydrogen hybrid to ensure sufficient power
2 Split in A- and B-segment LDVs (small cars) and C+-segment LDVs (medium to large cars) based on a 30% market share of A/B-segment cars and a 50% less energy demand

Source: Toyota, Hyundai, Daimler

5. Using hydrogen in fuel cells and burners can enable decarbonization in low- and high-grade heating in industrial processes

Carbon neutral heating processes





HIGH-GRADE HEAT

- Expected to consume 30 EJ in 2050
- Hydrogen burners can complement electric heating

LOW-GRADE HEAT

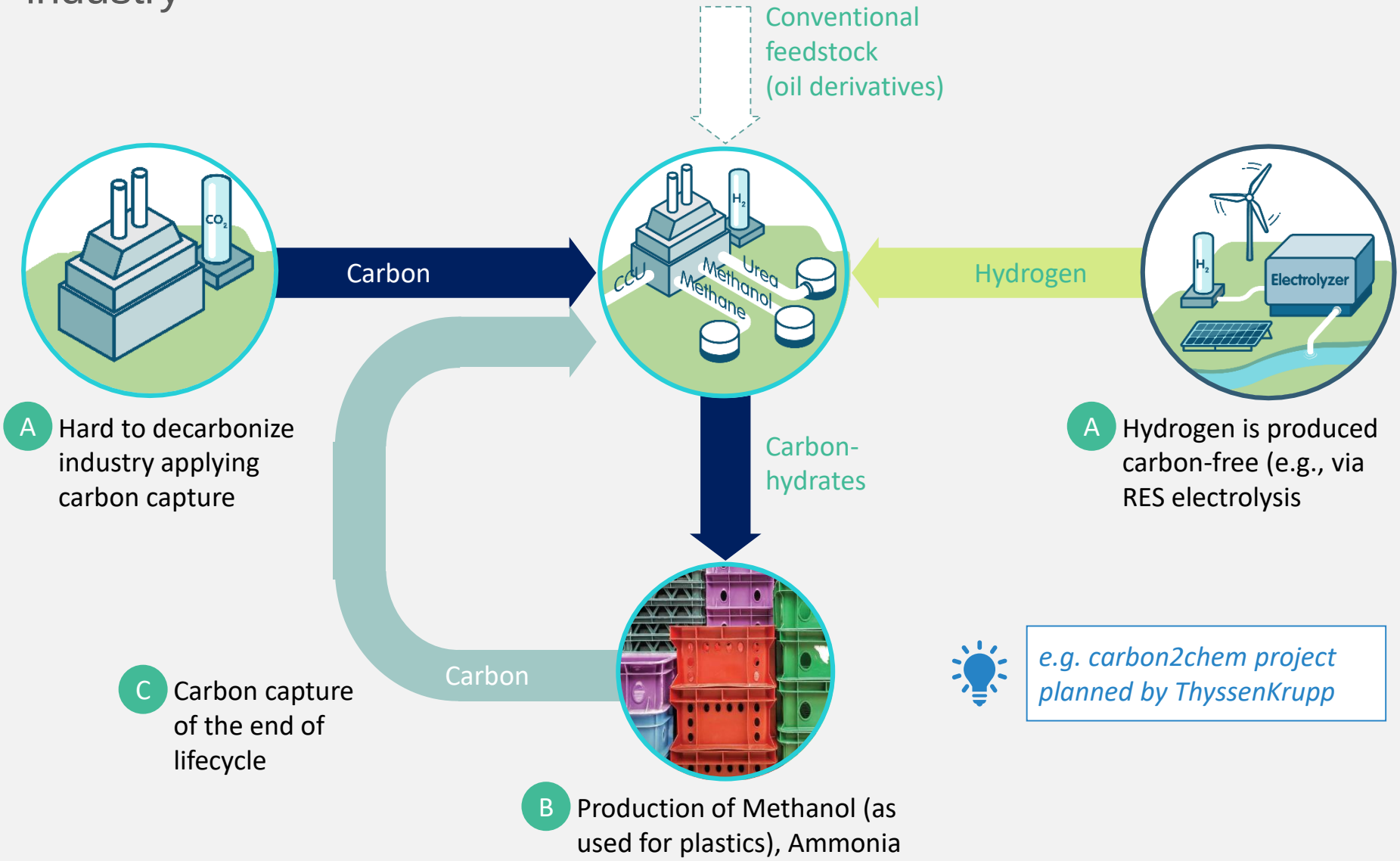
- Expected to consume 124 EJ in 2050
- Hydrogen is especially advantageous when available as by-product

by-product → H_2

1 Expected energy usage of the specified heating process in 2050

Source: Hydrogen Council

6. Hydrogen complements chemical feedstock to decarbonize industry



Source: Hydrogen Council

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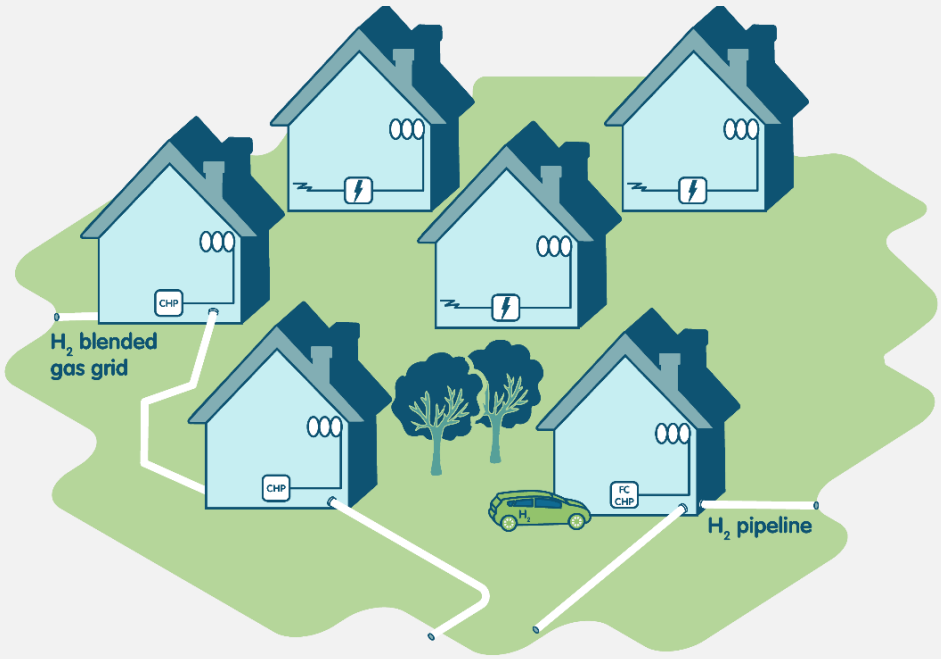
7. Building heating can use hydrogen as a fuel or leverage hydrogen technologies



Already 190,000 buildings are heated with hydrogen-based fuel cell micro CHPs

- **Hydrogen is part of a portfolio of solutions for decarbonizing building heating** (choice depending on local conditions)
- Hydrogen through the gas grid[1] can fuel heating technology

Leeds planning to convert natural gas grid in hydrogen grid by 2026

Plan to ban oil and natural gas for heating purposes in Germany by 2030

- Hydrogen technologies can serve as energy converter

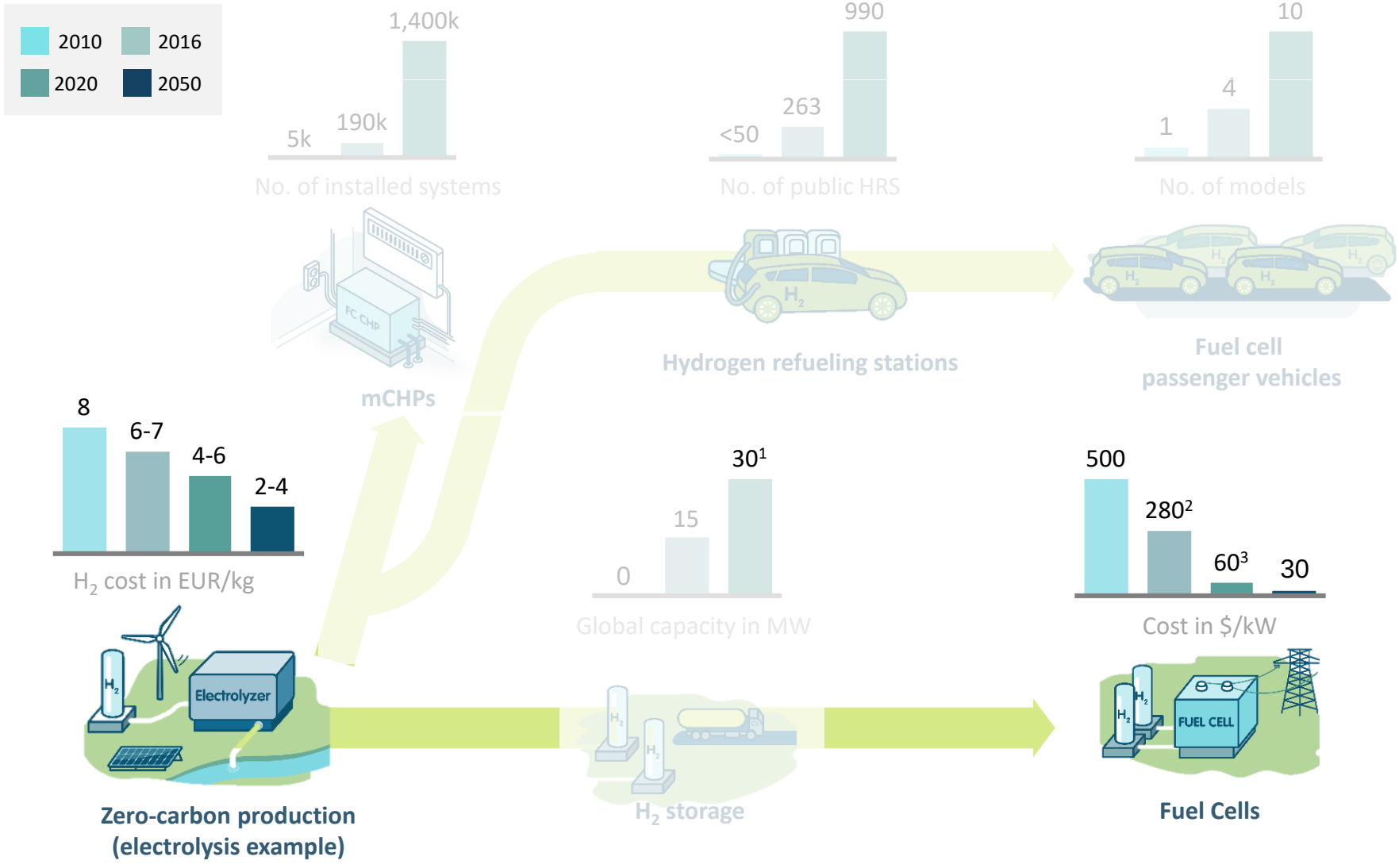
Japan is expanding to 5.3 million micro CHP-based households by 2030.

1 pure or blended to the gas grid

Source: Hydrogen Council

Hydrogen technology is ramping up, both in technology improvements …

Selected examples of the hydrogen sector

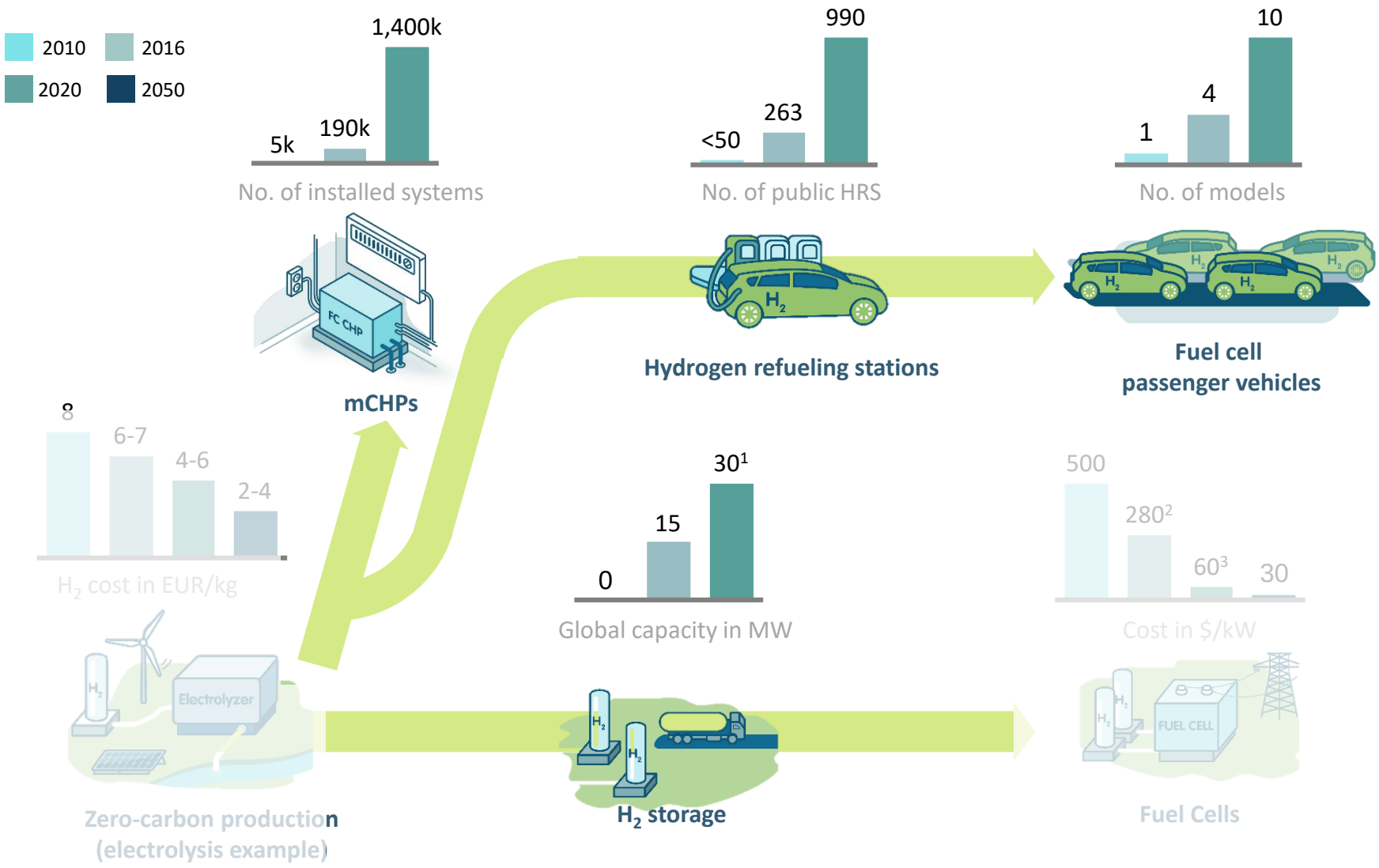


1 Extrapolating the growth to 20 MW in 2017/2018 from outstanding projects, 2 Assuming 20k units production per year, 3 Assuming 100k units production per year in 2025

Source: IEA, E4Tech, US DOE, Press research

… as well as in market deployment

Selected examples of the hydrogen sector



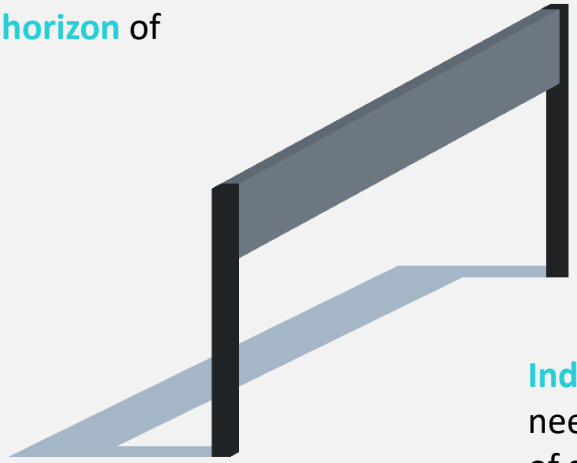
1 Extrapolating the growth to 20 MW in 2017/2018 from outstanding projects, 2 Assuming 20k units production per year, 3 Assuming 100k units production per year in 2025

Source: IEA, E4Tech, US DOE, Press research

However, barriers need to be removed to fully unlock the potential of hydrogen

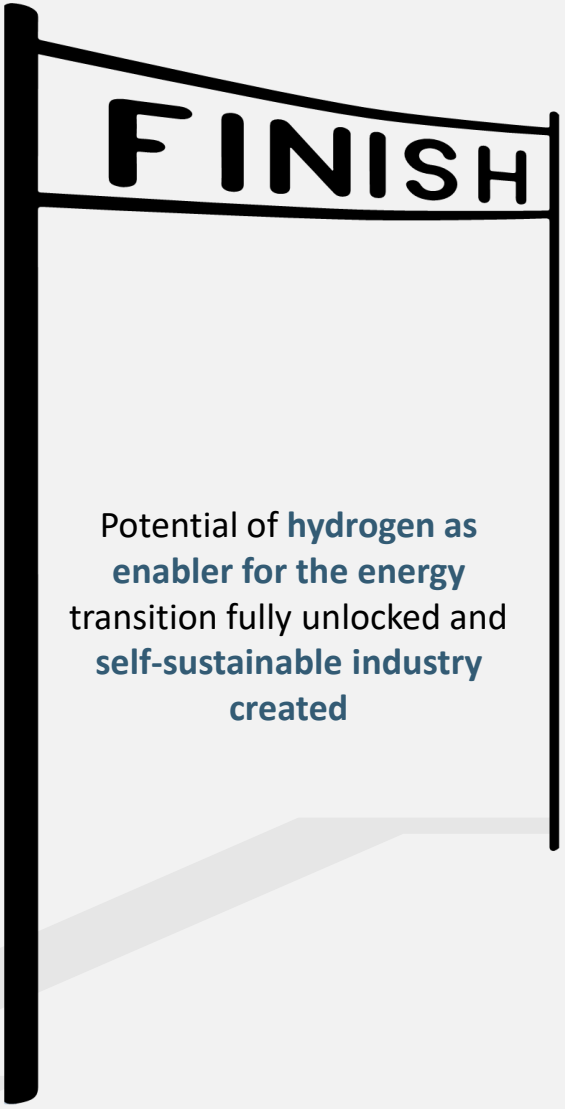
Mobility applications require a **coordinated effort across industries**

Many hydrogen **investments require a long horizon** of 10 to 20 years



Industry standards are needed to drive economies of scale

Competing technologies have benefitted from **clear regulatory guidelines** on financial stimuli



Potential of **hydrogen as enabler for the energy** transition fully unlocked and **self-sustainable industry created**

Source: Hydrogen Council

Hydrogen Council' launching on January, 17th in Davos

Public launch & Press conference

- 13 CEOs and Council members' Sherpas
- High-level guests
- Press interviews

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Media highlights : +350 articles published worldwide

- International visibility with press & social media
- Most mentioned languages : English, Korean, German, French and Japanese

Bloomberg Markets

Toyota, Shell Among Giants Betting $10.7 Billion on Hydrogen

THE BUSINESS TIMES

Toyota, Shell among auto and oil giants forming hydrogen council

REUTERS

AFP

BFM BUSINESS

LesEchos

LE QUOTIDIEN DE L'ÉCONOMIE

Les géants de l'hydrogène unissent leurs forces

Handelsblatt

朝日新聞 DIGITAL

トヨタなど13社、「Hydrogen Council（水素協議会）」を設立

HYDROGEN COUNCIL

Der Traum vom Wasserstoff

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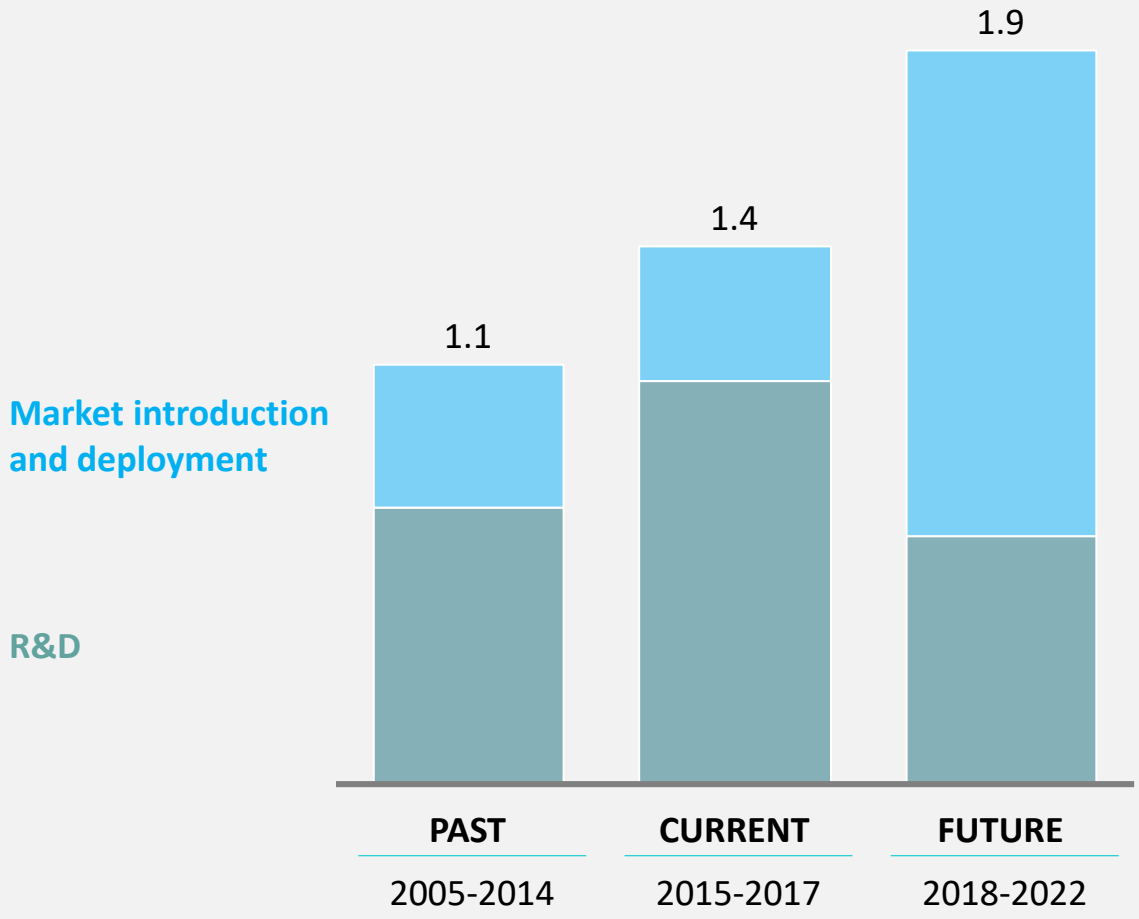
The members of the Hydrogen Council already plan to orient their increasing annual investments towards hydrogen on market development

Investments planned by Hydrogen Council members, in EUR billions per year



- Hydrogen Council members **plan to invest at least EUR 1.9 billion per year** in hydrogen technology for the coming 5 years
- Investments in market introduction and deployment are growing and are showing the **beginning of commercialization**

Source: Hydrogen Council

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A collaborative approach of policy makers and industry is needed today to enable the full potential of hydrogen in the energy transition

Provide long-term and stable policy frameworks to guide the energy transition in all sectors

Develop hydrogen-specific coordination and incentive policies to encourage early deployment of hydrogen solutions and sufficient private-sector investments.

Facilitate harmonization of industrial standards across regions and sectors to enable hydrogen technologies and take advantage of scale effects and decrease costs.

As a council, we invite you to discuss concrete next steps with us

Source: Hydrogen Council

Thank You


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Kawasaki
THE LINDE GROUP
TOTAL
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