Hydrogen
scaling up

A sustainable pathway for the global energy transition

This study is the first comprehensive, ambitious Hydrogen roadmap

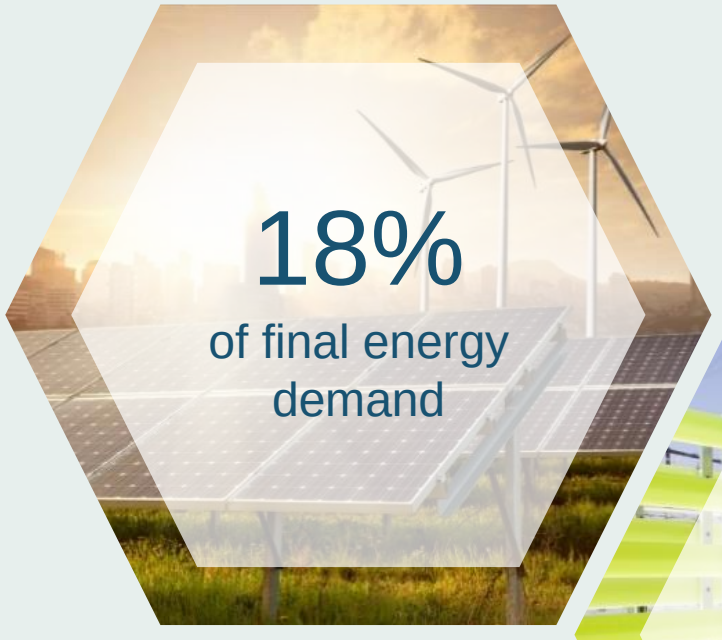
Objectives of the study

- First **comprehensive quantified vision** and **roadmap** for deployment
- Not a forecast, but an **ambitious yet realistic** scenario
- Answers the question “How could hydrogen contribute to **achieving the two degree scenario**?”

SOURCE: Hydrogen Council

Hydrogen: a central pillar of the required energy transition

Estimated impact in 2050



18%

of final energy demand

6 Gt

annual CO_2 abatement

$2500 bn

annual sales (hydrogen and equipment[1])

30

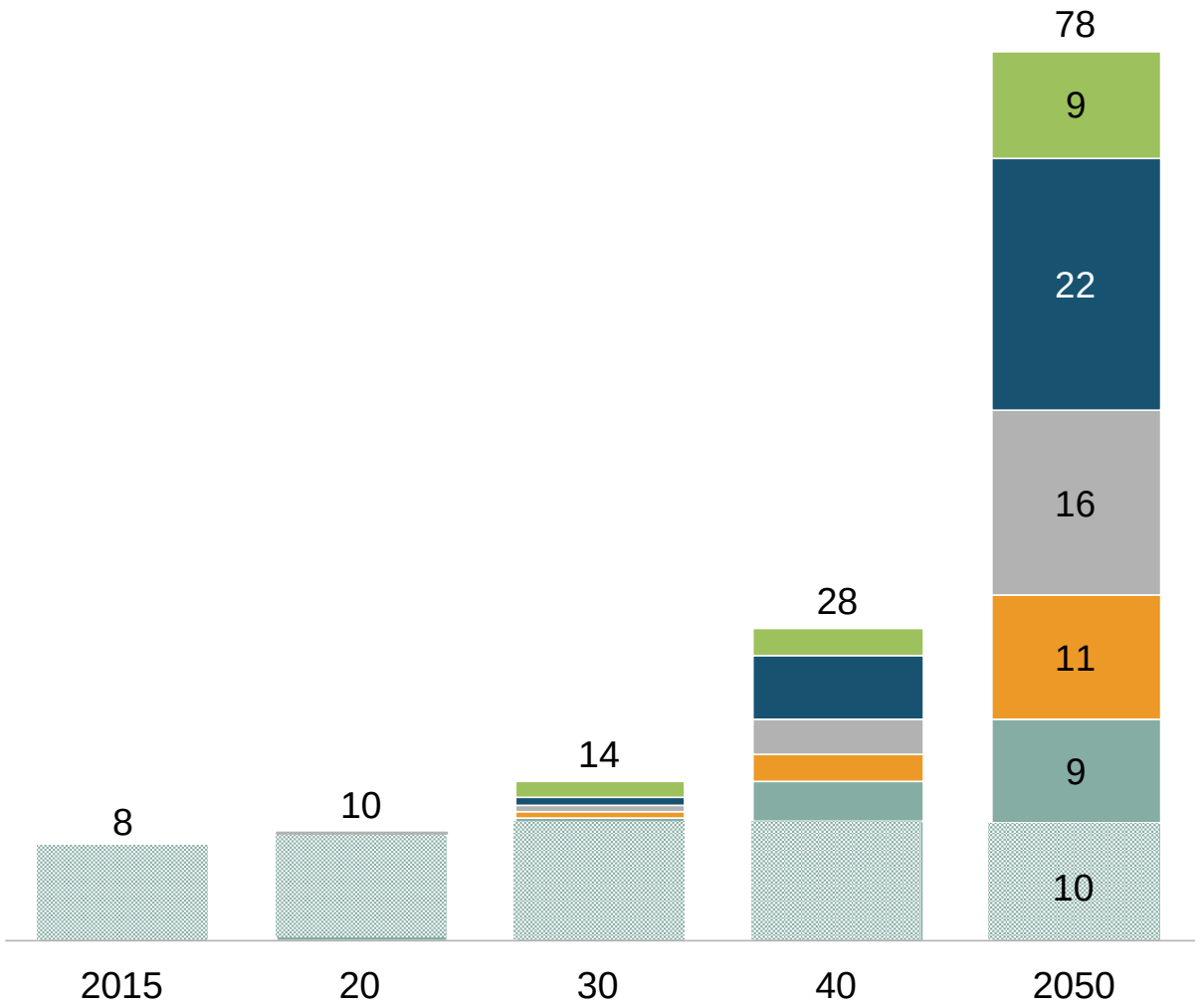
million jobs created

1 Value add of fuel cells

SOURCE: Hydrogen Council, IEA ETP Hydrogen and Fuel Cells CBS, National Energy Outlook 2016

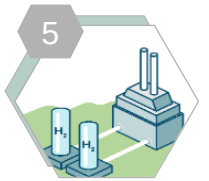
In a 2-degree-world, hydrogen could contribute ~18% of demand

Potential global energy demand supplied with hydrogen, Exajoule (EJ)

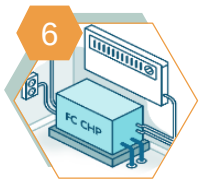


Power generation, buffering

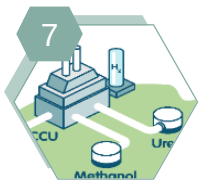
Transportation



Industrial energy



Building heat and power



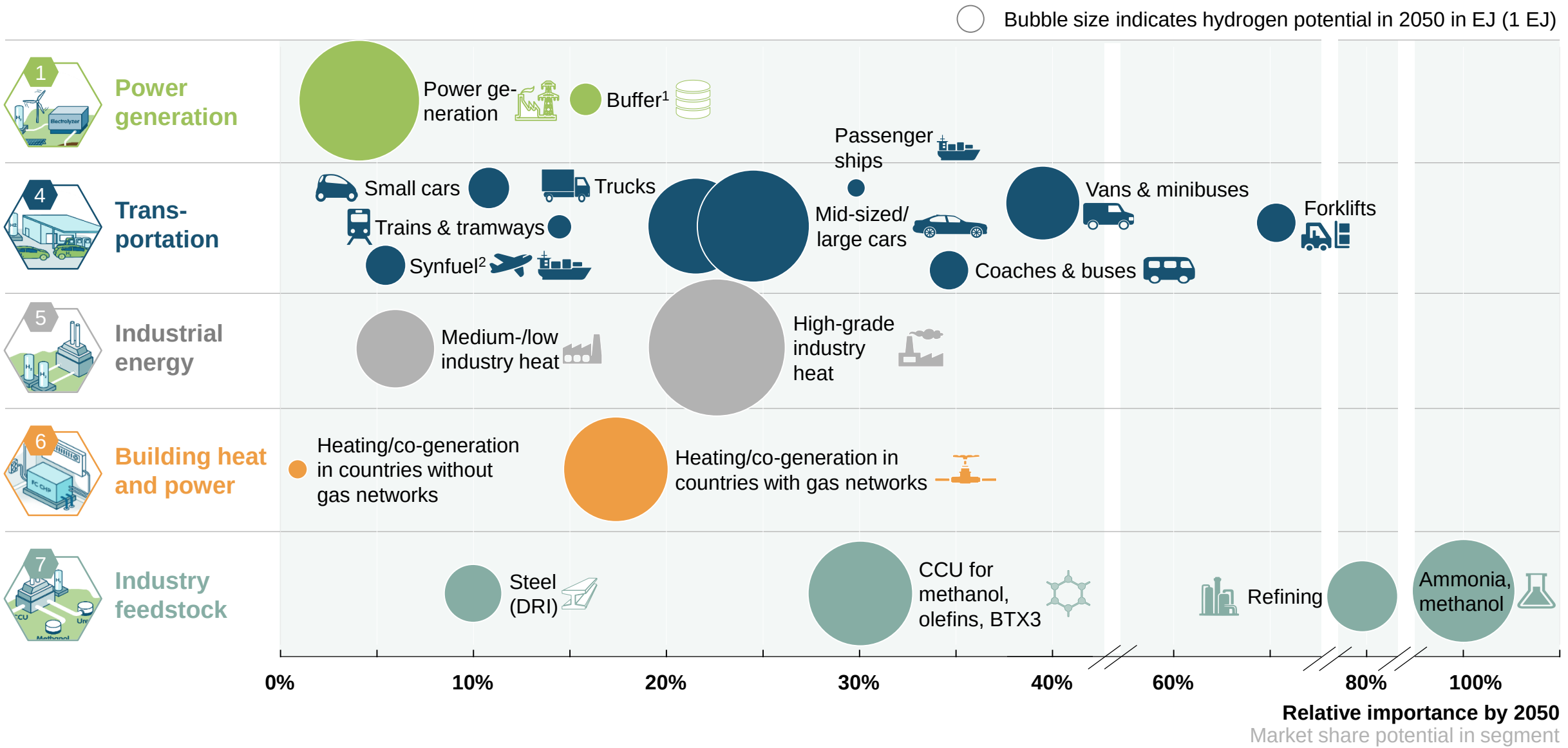
New feedstock (CCU, DRI)

Existing feedstock uses

18%
of final energy demand

SOURCE: Hydrogen Council

Hydrogen has significant potential across all applications



1 Percent of total annual growth in hydrogen and variable renewable power demand

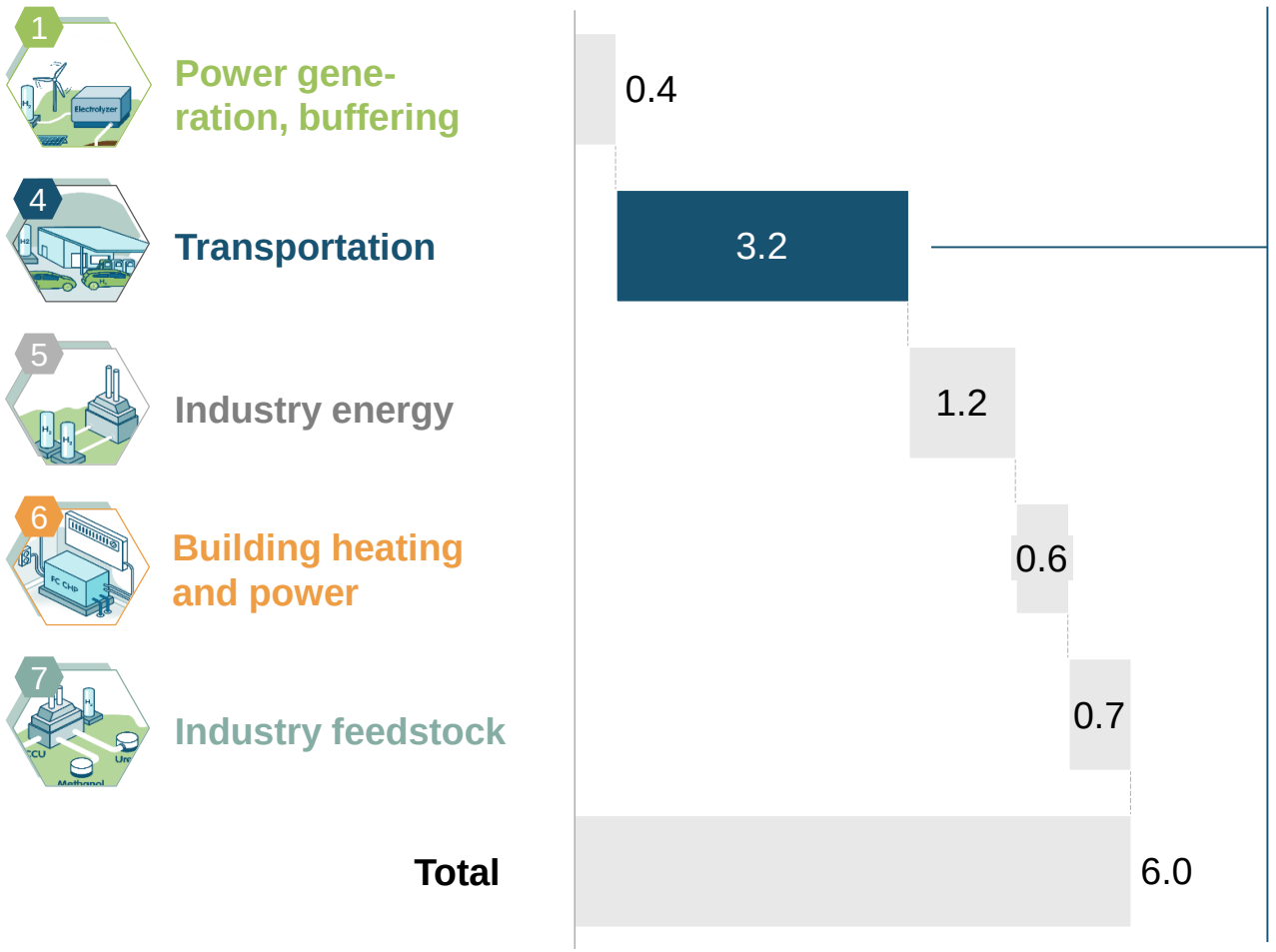
2 For aviation and freight ships

3 Percent of total methanol, olefin, BTX production using olefins and captured carbon

SOURCE: Hydrogen Council

Half of the total CO2 abatement potential will come from transport

CO2 avoidance potential 2050, Gigatons



Hydrogen has the potential to achieve

~40%

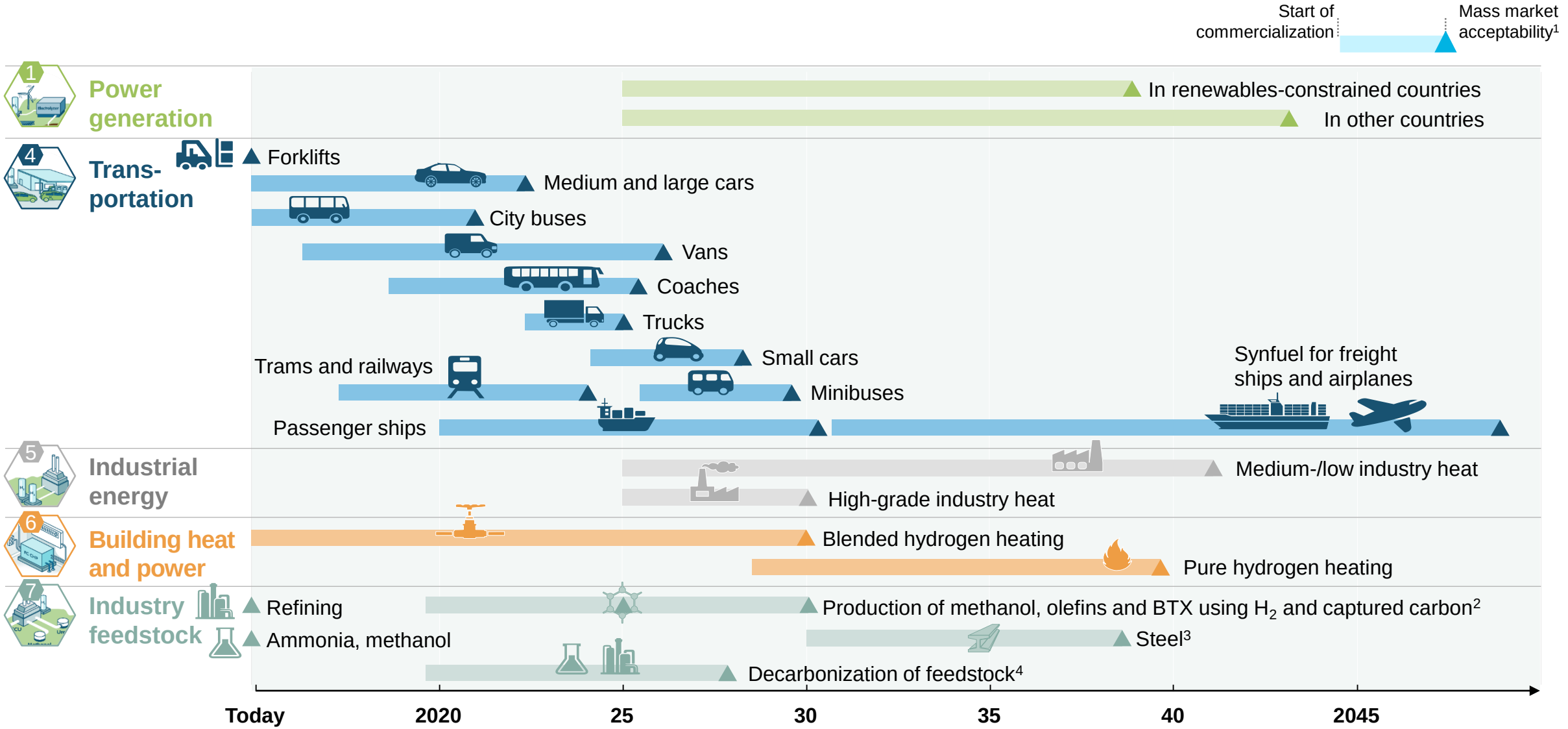
of the required abatement[2] in transport by 2050

1 Aviation, shipping, rail, material handling

2 Difference between IEA Reference Technology and 2 degree scenario

SOURCE: IEA, Hydrogen Council

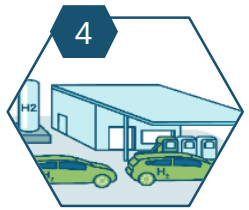
The technologies exist and are ready to be deployed



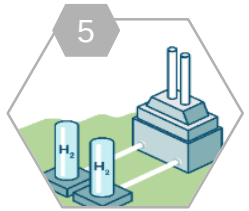
1 Mass market acceptability defined as sales >1% within segment in priority markets
2 Market share refers to the amount of production that uses hydrogen and captured carbon to replace feedstock
3 DRI with green H_2, iron reduction in blast furnaces and other low-carbon steel making processes using H2
4 Market share refers to the amount of feedstock that is produced from low-carbon sources

SOURCE: Hydrogen Council

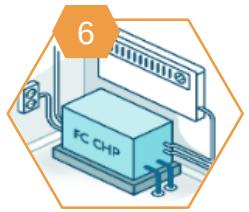
Important milestones already for 2030 to reach the 2050 vision

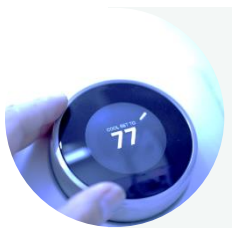


- **1 in 12 passenger cars sold** in early-adoption markets (Germany, California, Japan and South Korea) FCEVs

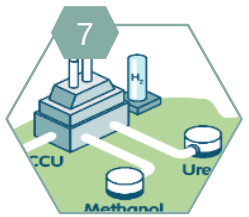


- **3.5 Mt** hydrogen used for **high-grade heat** in first large-scale projects





- **50 million households** connected to a network safely blending hydrogen and natural gas



- **20 Mt CO_2** converted to chemicals and intermediates such as **methanol** using hydrogen

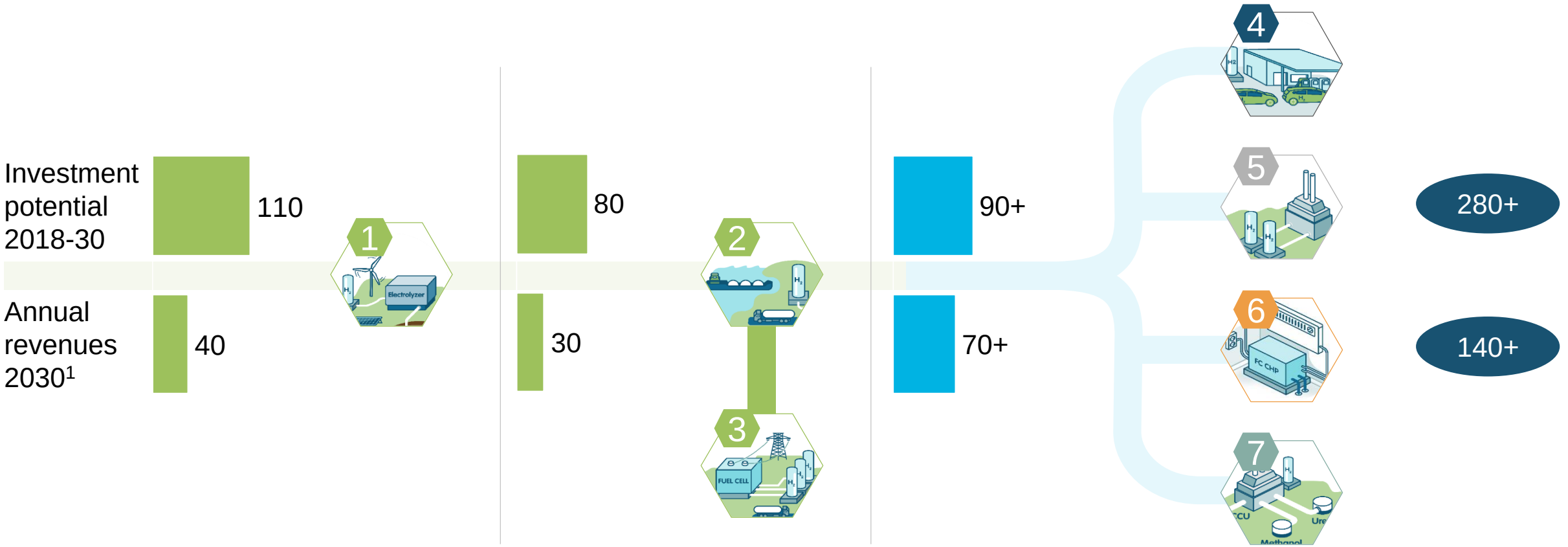
SOURCE: Hydrogen Council

Investments of $280bn until 2030 build $140bn+ annual market

$ billion[1]

Enable the renewable energy system → Decarbonize end uses — Total

Hydrogen production → Storage, transport, and distribution → End-uses in transportation, industry energy, buildings and feedstock



1 Excluding existing feedstock uses, Considering only hydrogen value-added

SOURCE: Hydrogen Council

Hydrogen Council members have started investing and deploying

Enable the renewable energy system ⟶ Decarbonize end uses

Hydrogen Council Steering members

Air Liquide creative oxygen
THE LINDE GROUP
Kawasaki
Audi
BMW GROUP
PLASTIC OMNIUM
Shell
TOTAL
Statoil
HONDA
HYUNDAI
DAIMLER
TOYOTA
Iwatani
ENGIE
ALSTOM
AngloAmerican

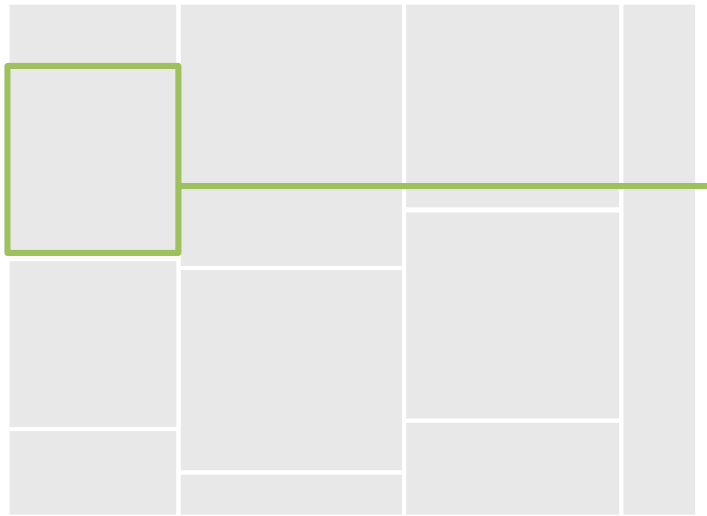
Supporting members

FIRSTELEMENT FUEL
MITSUI & CO.
faurecia inspiring mobility
TOYOTA TSUSHO
GORE Creative Technologies Worldwide
HABER INDUSTRIAL TECHNOLOGIES
PLUG POWER

First comprehensive quantified vision of the long-term potential of hydrogen and a roadmap for deployment

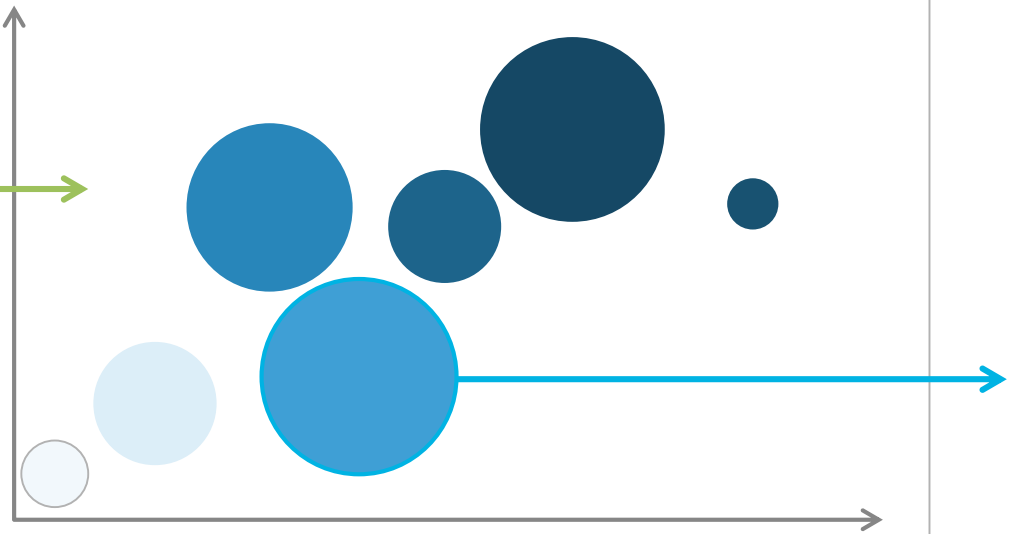
Energy system development

2050 energy system



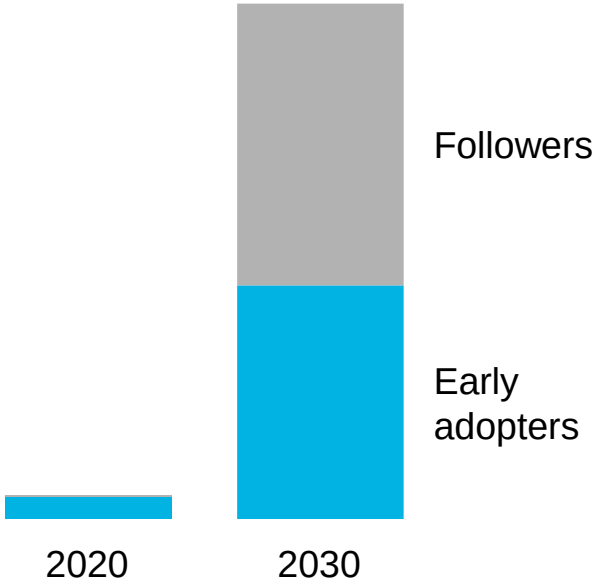
2050 hydrogen vision

Hydrogen adoption in industry segments



2030 hydrogen milestones

Ramp-up logic and investments



An **ambitious yet realistic scenario** of the role of hydrogen in a two degree scenario, based on the perspectives of the Hydrogen Council

SOURCE: Hydrogen Council

Global rollout after 2030 could amplify growth towards 2050

Example: FCEV Rollout – Million Vehicles