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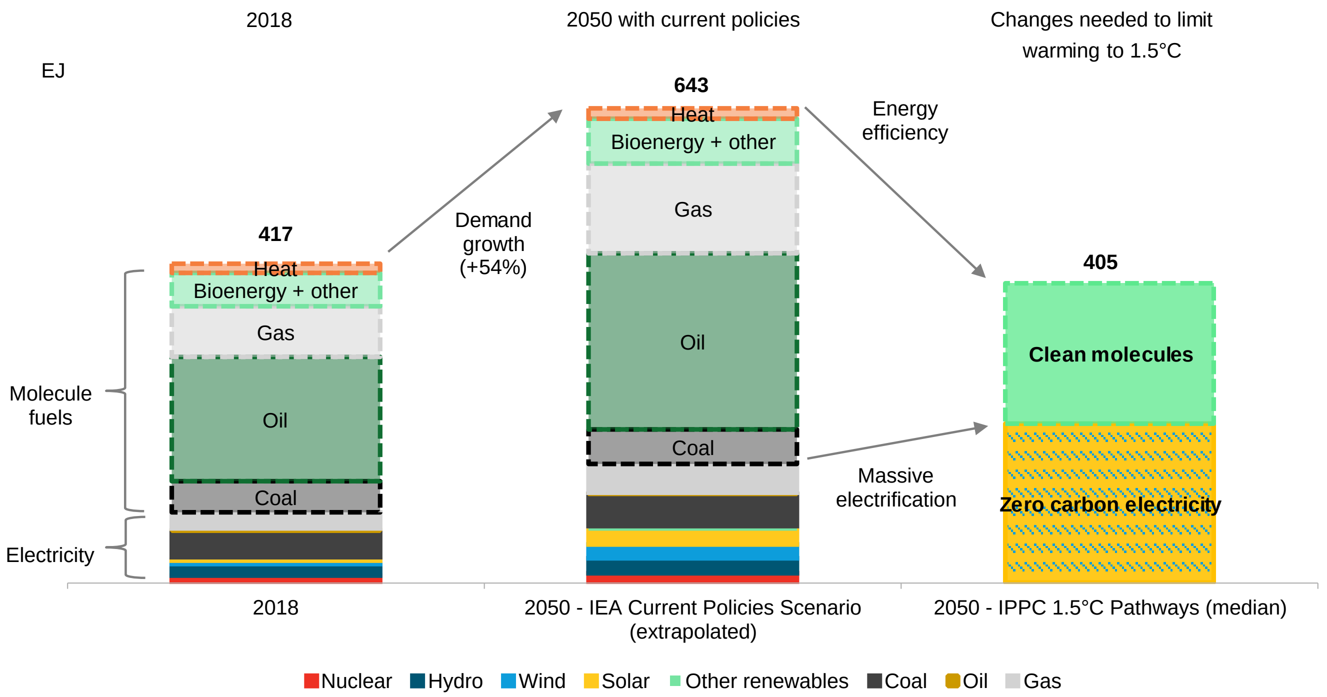
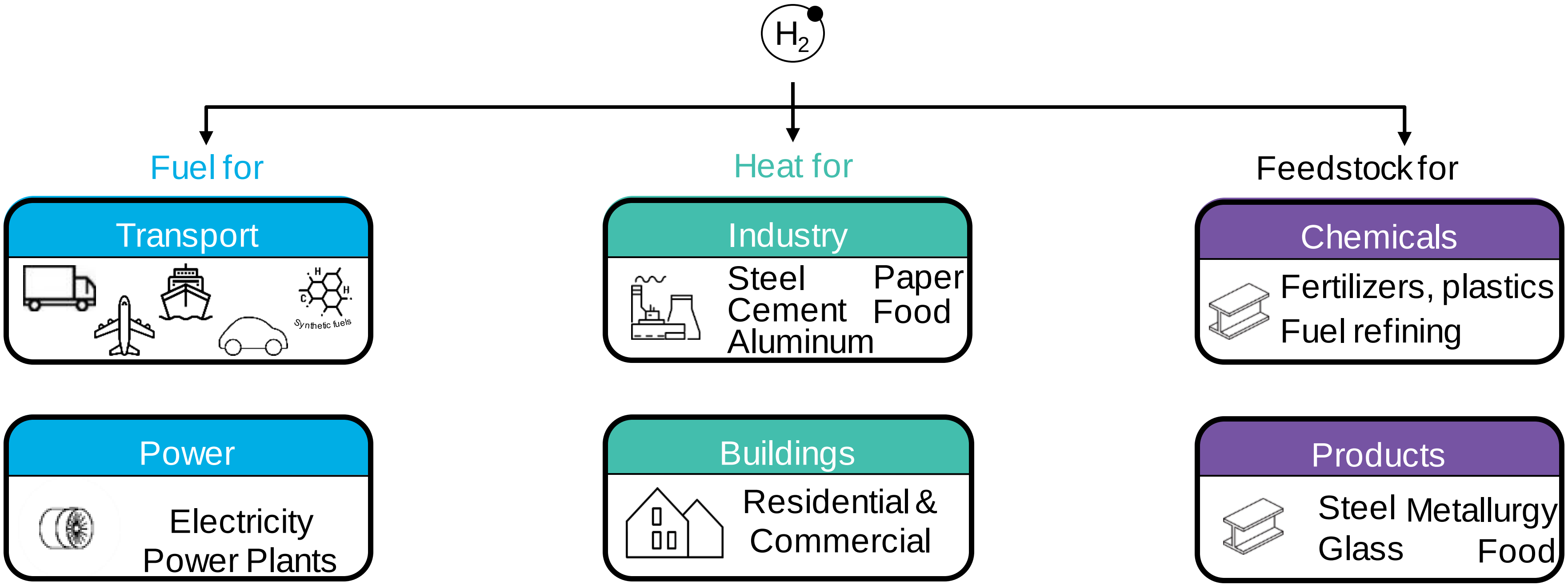
Projections for global final energy consumption in 2050



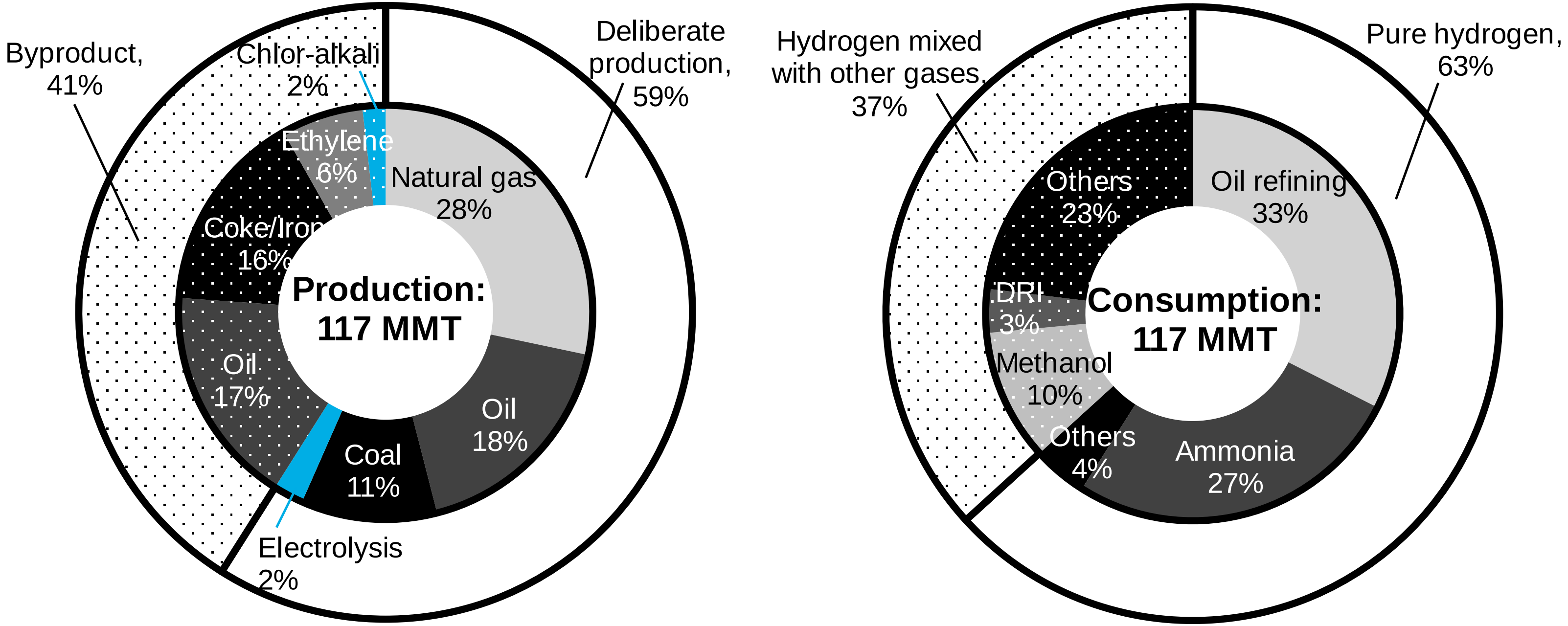
Source: BloombergNEF, IEA, IPCC.

Hydrogen has potential as a zero-carbon fuel



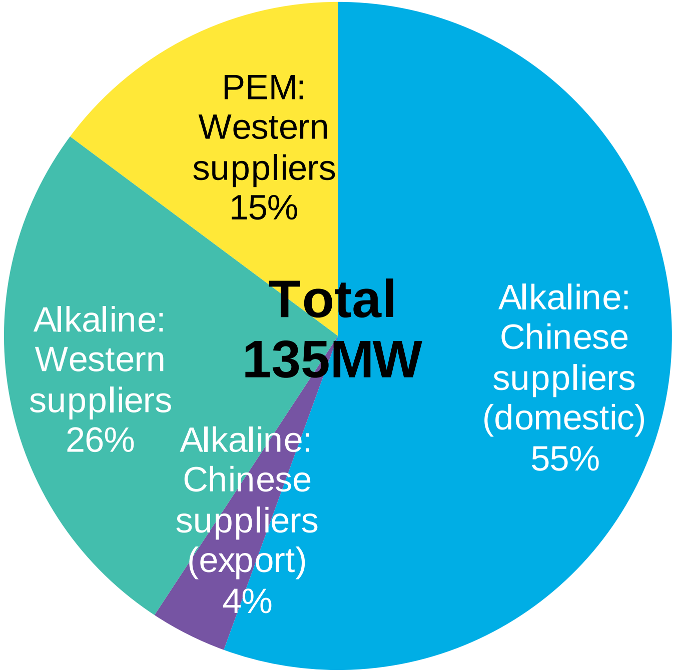
Source: BloombergNEF

Hydrogen production by source and application by sector, 2018



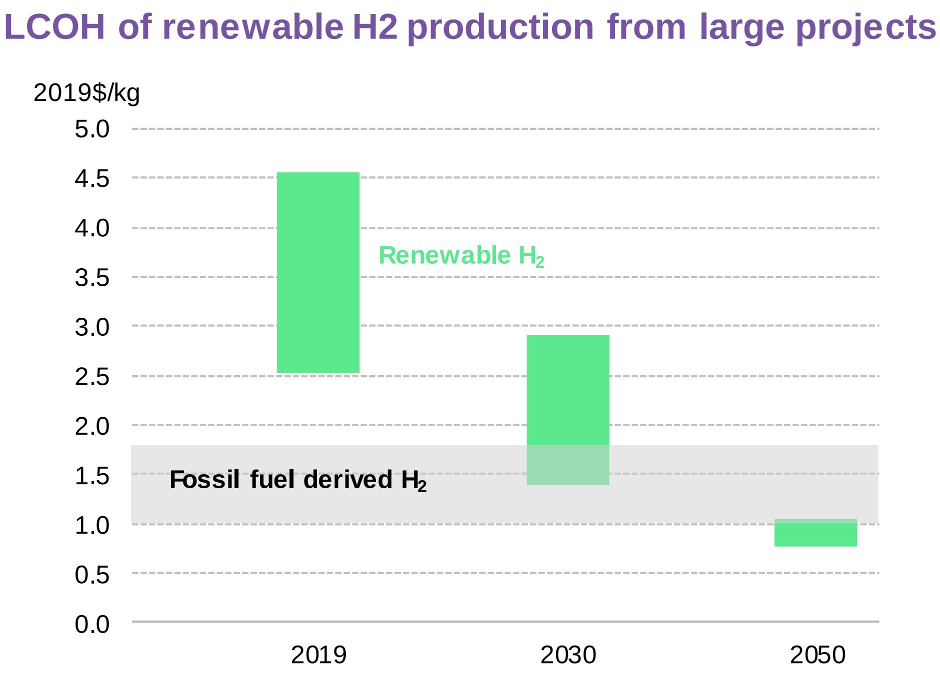
Source: BloombergNEF, International Energy Agency. Note: For deliberate production, the category terms indicate the source materials; for byproduct, the terms refer to the industries

Estimated shipment of water electrolyzers, 2018



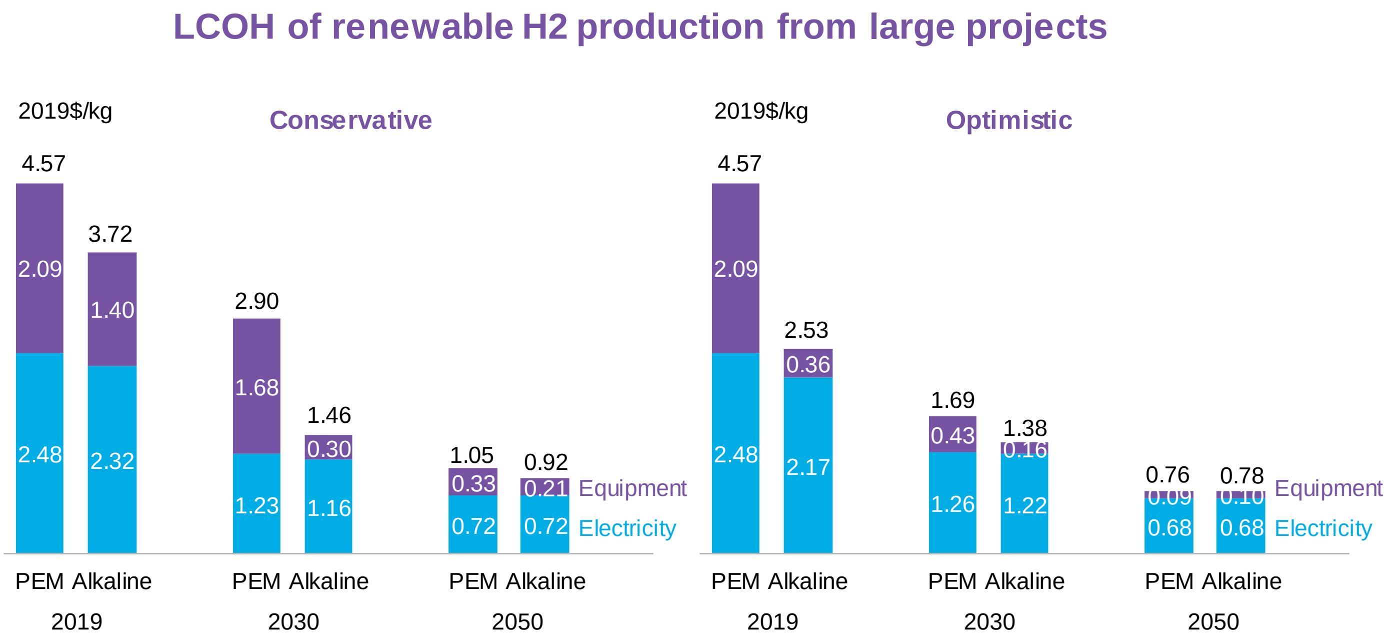
Source: BloombergNEF.

Forecast levelized cost of renewable hydrogen production from large projects



Source: BloombergNEF. Note: The range for fossil fuel derive hydrogen reflects current costs.

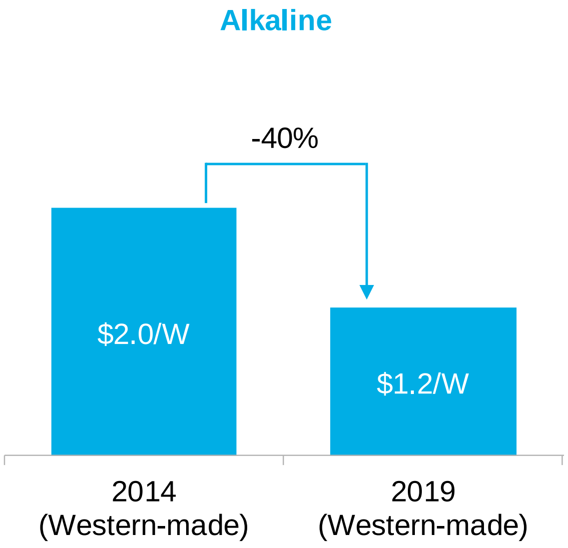
Both equipment and electricity will be cheaper

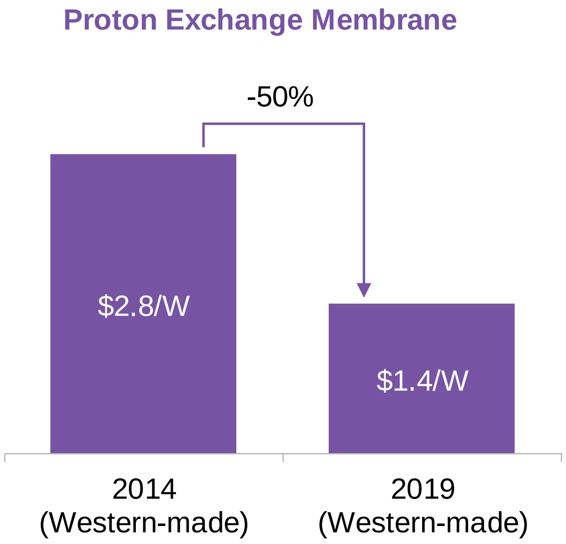


Source: BloombergNEF. Note: The project scale is assumed to be 2-3MW in 2019, 100MW in 2030, 400MW in 2050. The results in the conservative-scenario are based on electrolyzers powered by PV alone, while the optimistic results are based on a PV-plus-wind power source. In 2019, the conservative and optimistic cases for alkaline electrolyzers corresponds to projects adopting Western-made equipment and Chinese-made equipment, respectively.

The price of electrolyzers has been falling

Benchmark system capex based on large-scale electrolyzers, 2014 and 2019





Source: BloombergNEF

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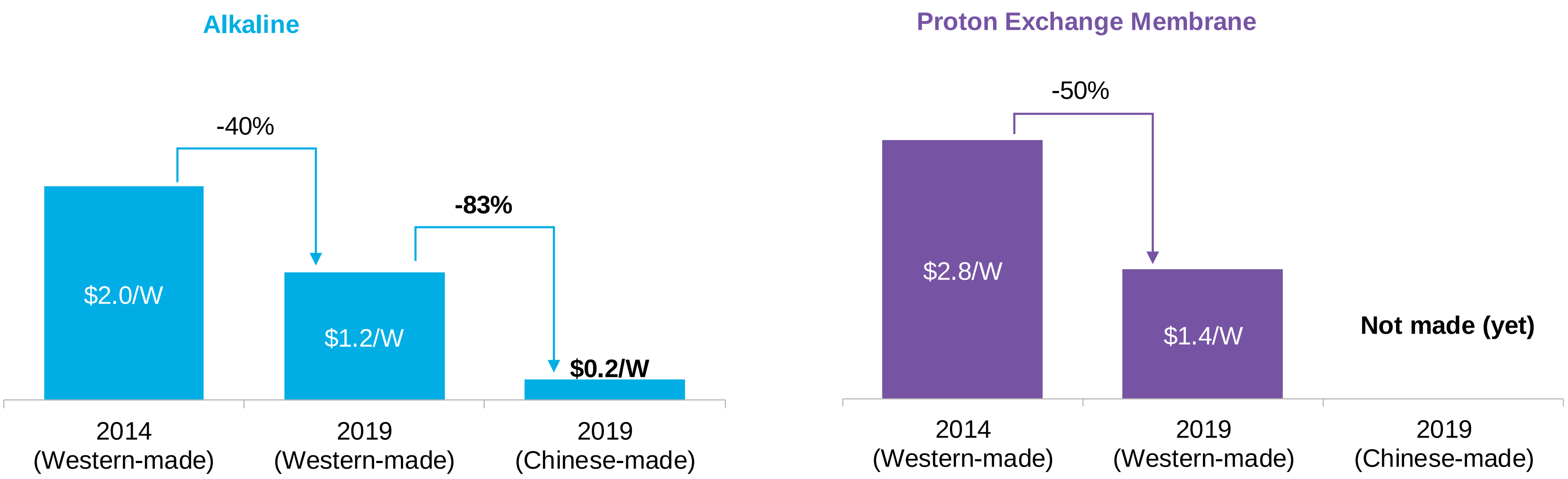
Electrolysis systems cost 83% less in China

Benchmark system capex based on large-scale electrolyzers, 2014 and 2019



Source: BloombergNEF

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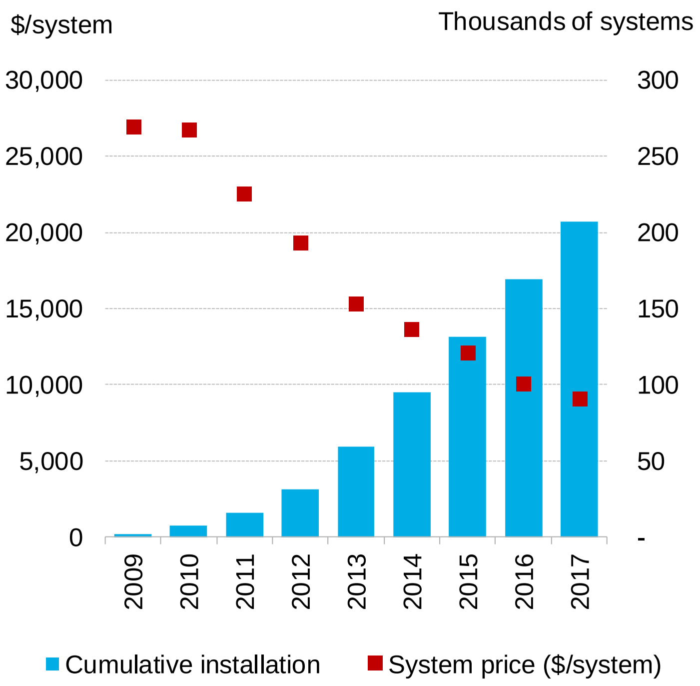
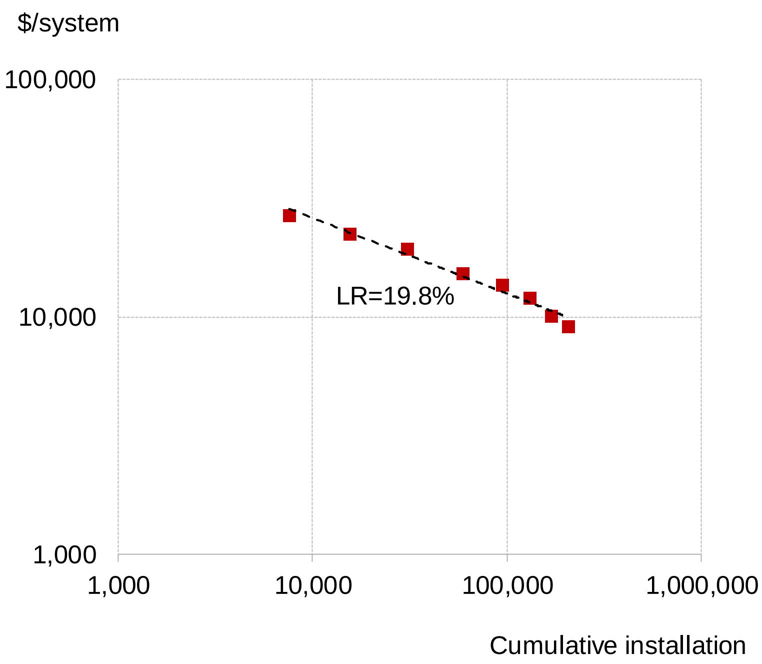
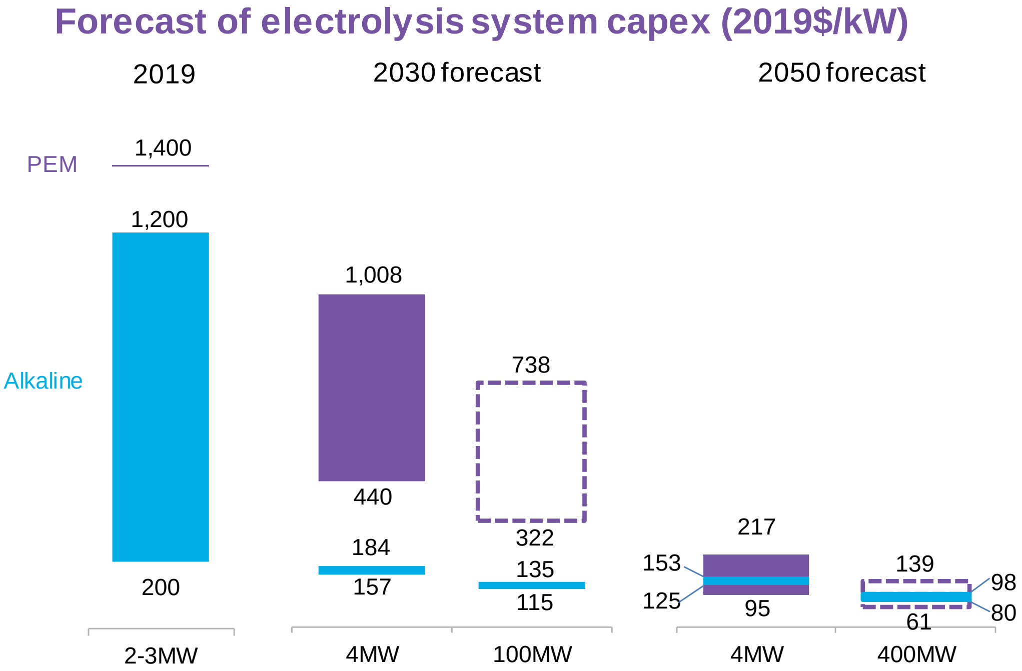
Installation volume and price of PEM fuel cell systems under Japan's Ene-Farm program





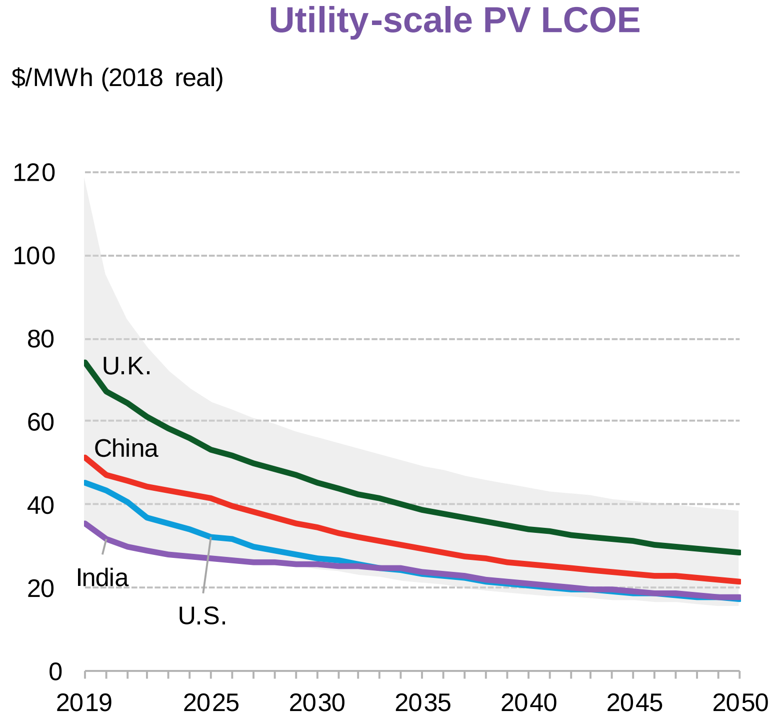
Source: Japan METI, BloombergNEF. Note: The power ratings of the systems are in the range of 700-1,000W.

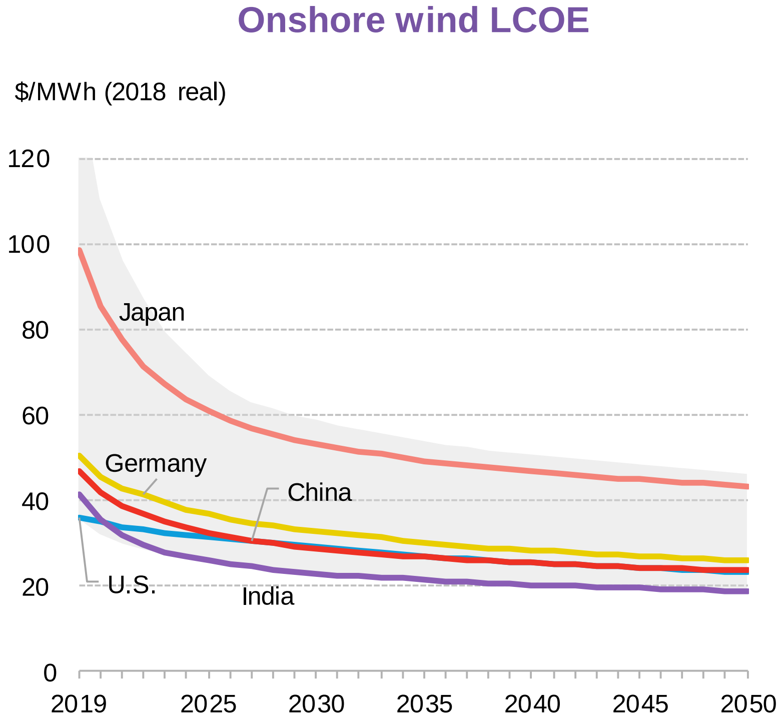
Great potential for further cost reduction of electrolyzers



Source: BloombergNEF. Note: The two dashed boxes indicate that PEM electrolysis system capex for large projects is derived from cost estimates for 4MW PEM systems, and should be considered as a hypothetical value

Renewable electricity cost continues to fall

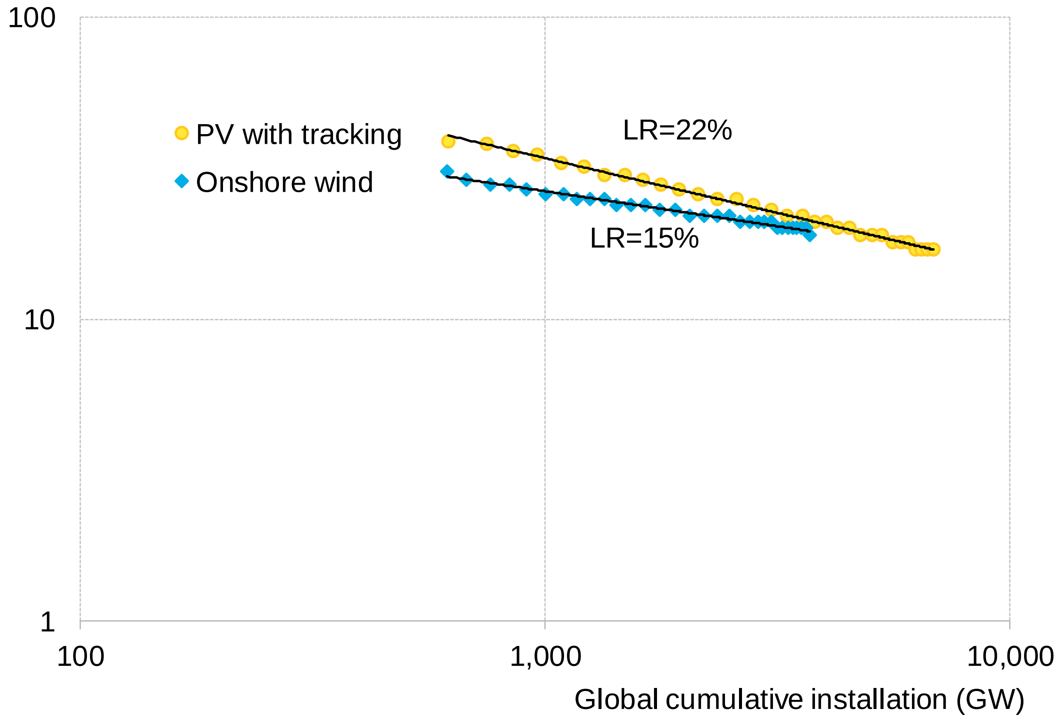




Source: BloombergNEF. Note: The gray range represents the global diversity of benchmark LCOEs. These figures exclude curtailment and subsidies.

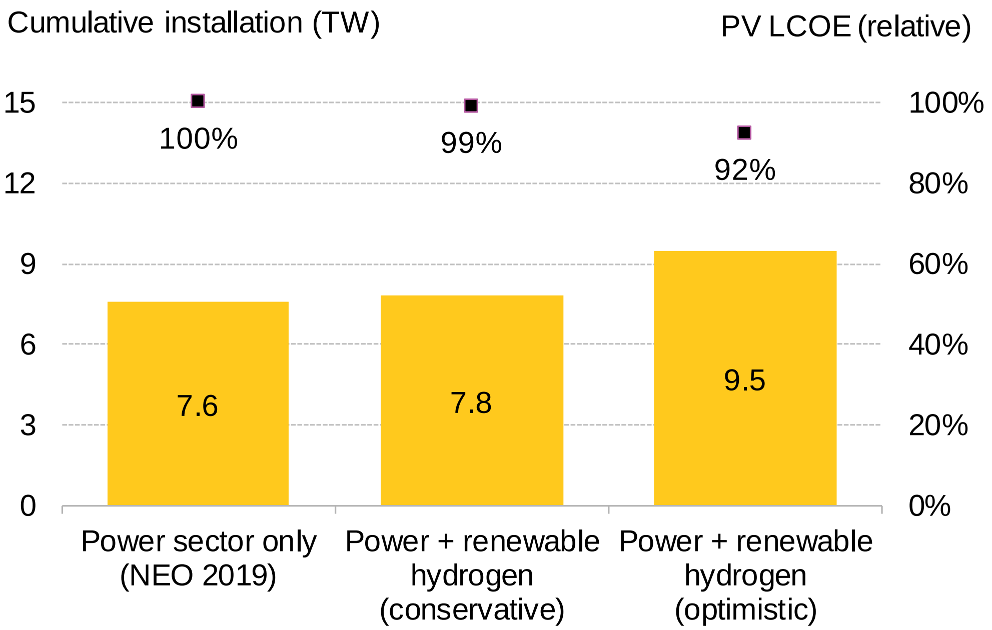
Learning rates of PV and wind LCOE

Lowest LCOE in the U.S. for PV and wind (2018$/MWh)



Source: BloombergNEF.

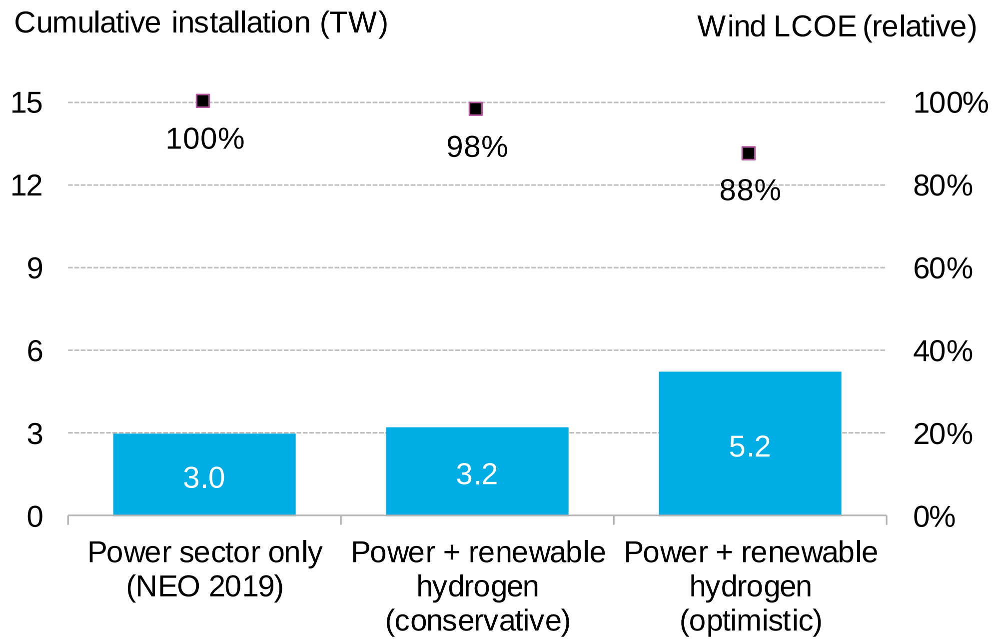
Increase in PV build and reduction in LCOE from demand for renewable hydrogen, 2050



Source: BloombergNEF. Note: PV capacity here in DC.

BloombergNEF

Increase in wind build and reduction in LCOE from demand for renewable hydrogen, 2050



Source: BloombergNEF. Note: Wind capacity here refers to onshore installation.

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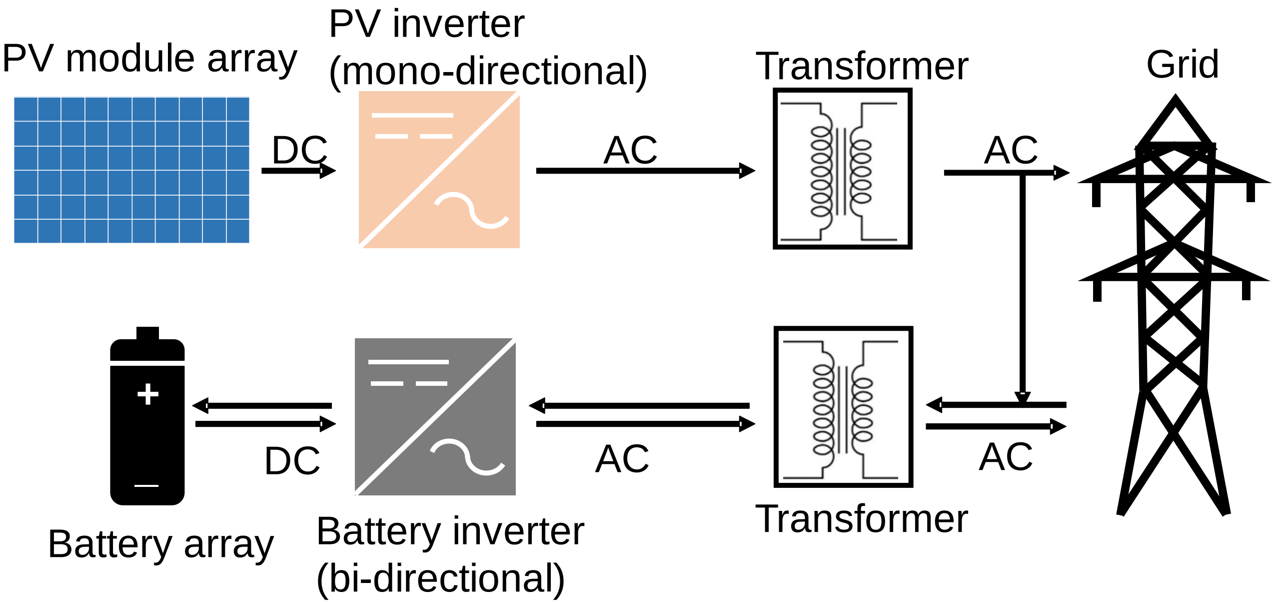
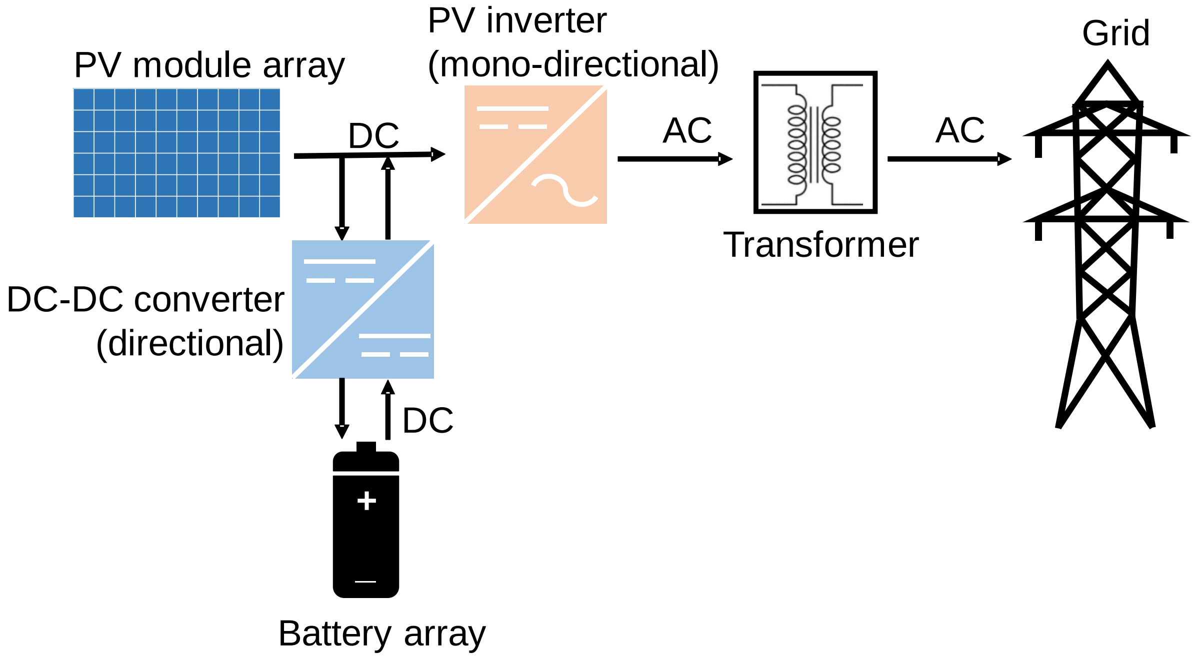
A system with storage AC-coupled with PV



Source: BloombergNEF.

A system with storage DC-coupled with PV



Source: BloombergNEF.

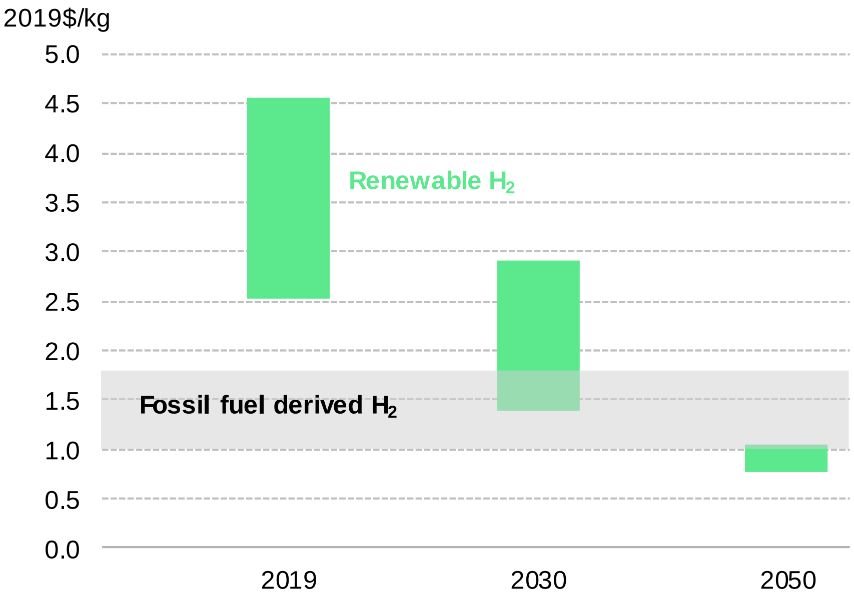
LCOE forecast for electrolyzers, 2030 and 2050 (2019$/MWh)

	PV	Wind	PV+wind
2030	24.1-25.6	25.8-27.9	25.5-27.4
2050	14.8-15.9	14.9-16.9	15.0-17.0

Source: BloombergNEF. Note: The electricity cost is for captive renewable power plants designed for electrolyzers.

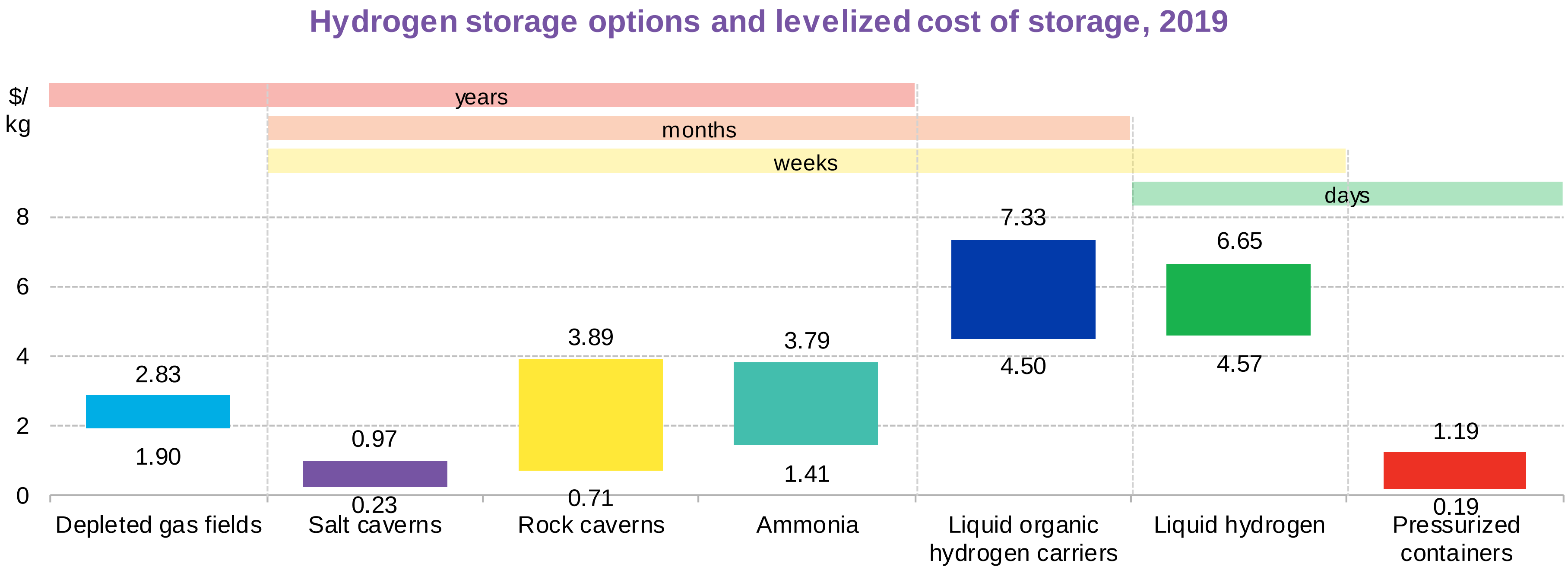
Green hydrogen will be cheaper than grey hydrogen

LCOH of renewable H2 production from large projects



Source: BloombergNEF. Note: The range for fossil fuel derive hydrogen reflects current costs.

A variety of storage options exist



Source: BloombergNEF.

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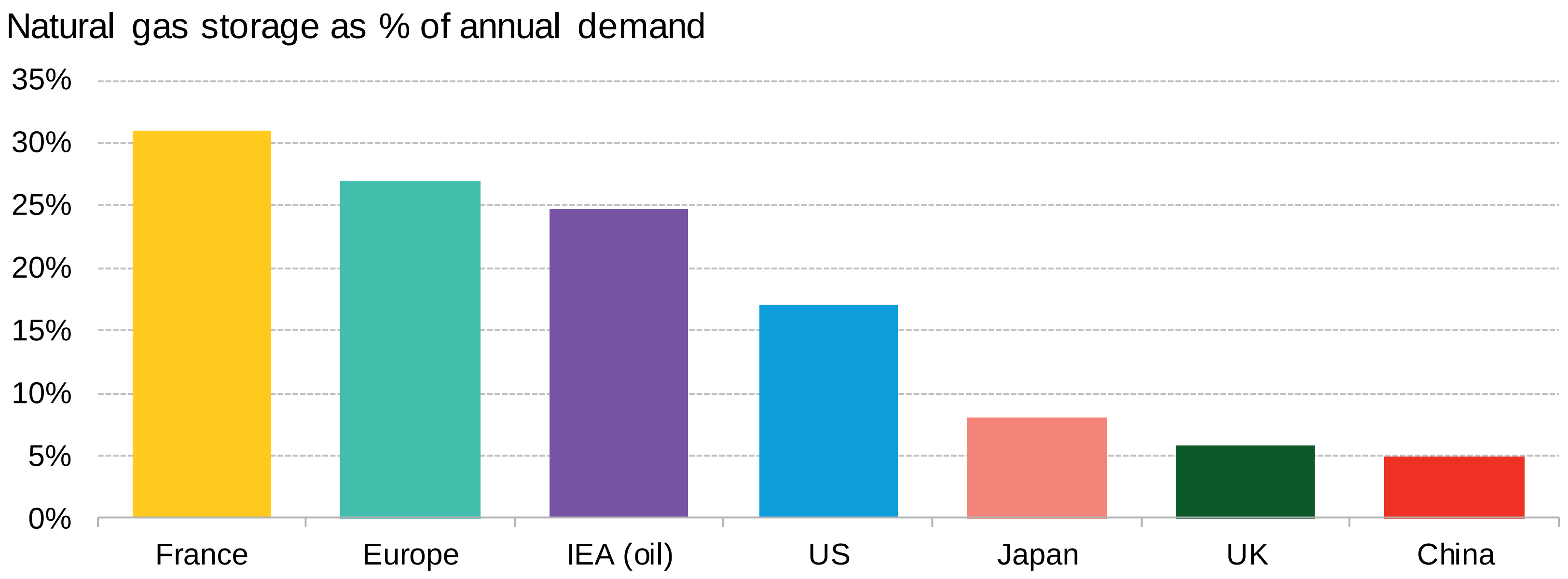
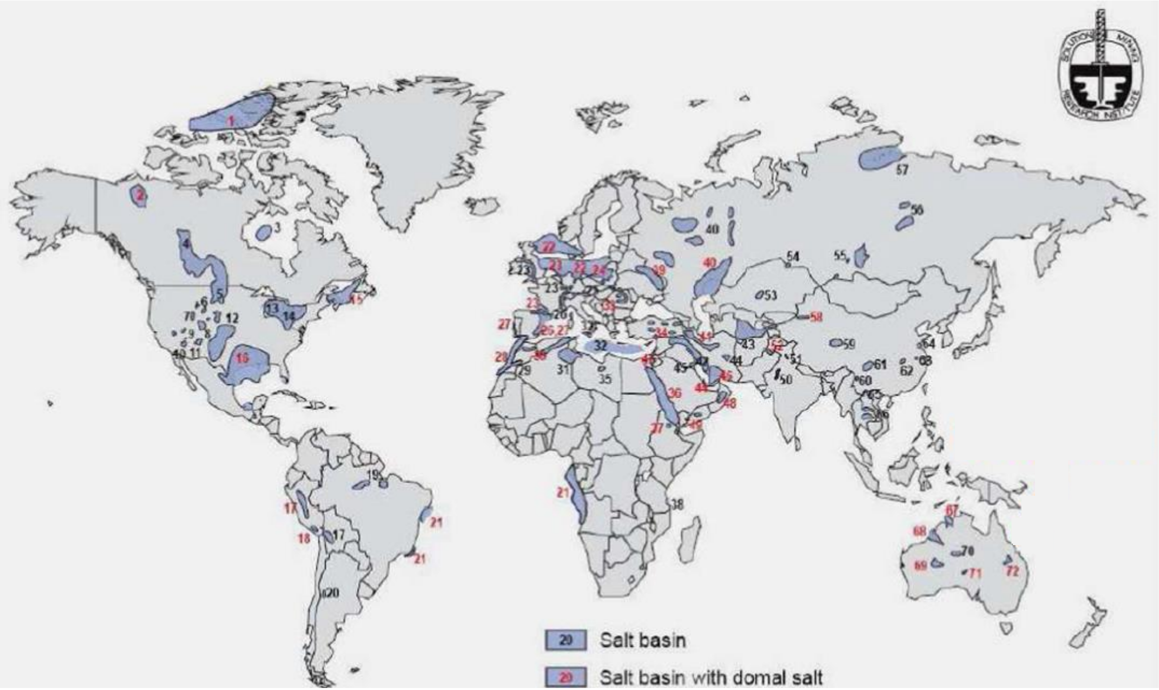
Hydrogen will need to be stored at similar scales to natural gas



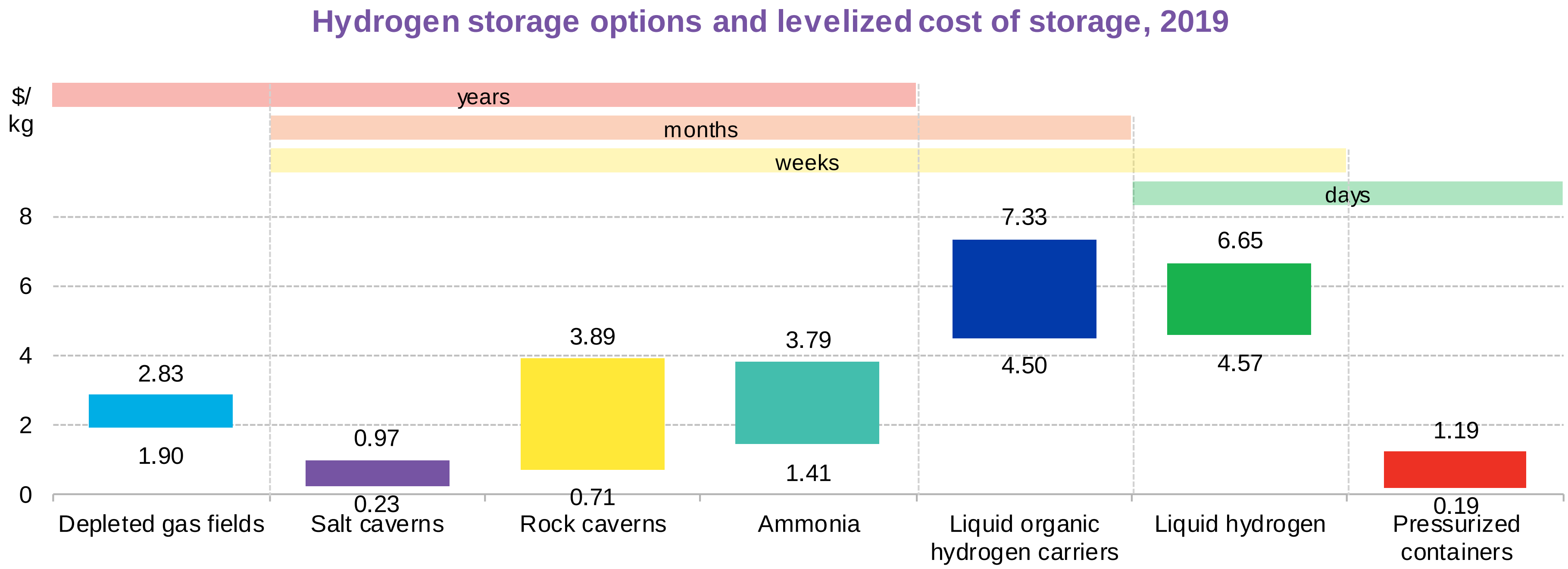
Source: Oxford Institute for Energy Studies, Bloomberg, International Energy Agency (IEA), Japan Ministry of Trade Economy, Trade and Industry

Major world salt deposits



Source: Solution Mining Research Institute, published in Blanco and Faaij 2018, A review at the role of storage in energy systems with a focus on Power to Gas and long-term storage, Renewable and Sustainable Energy Reviews Journal

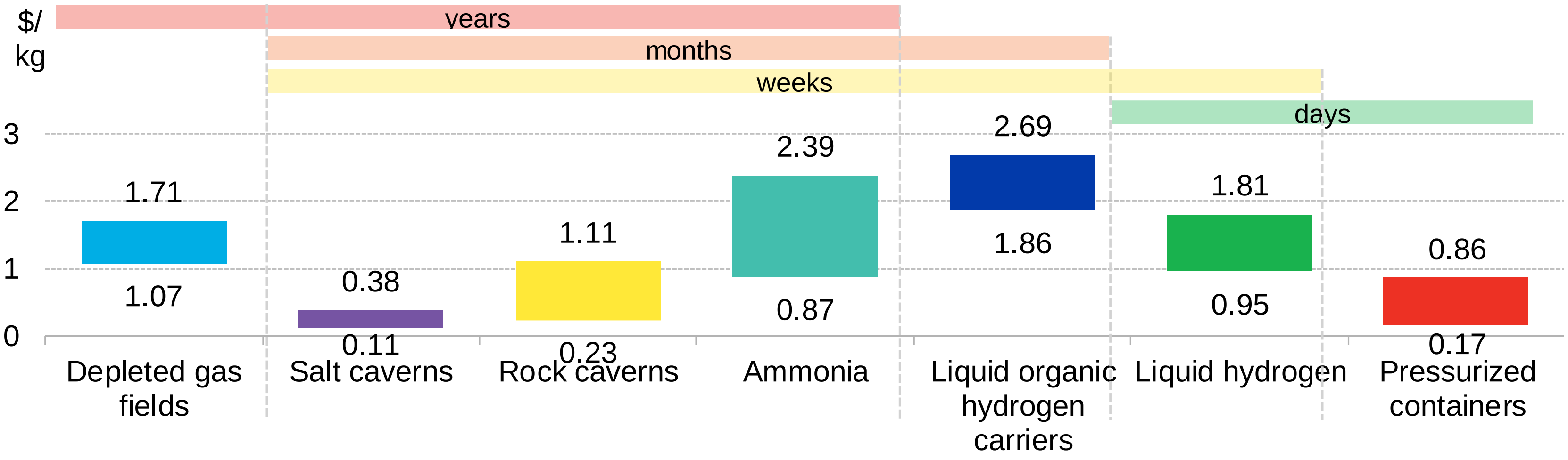
A variety of storage options exist



Source: BloombergNEF.

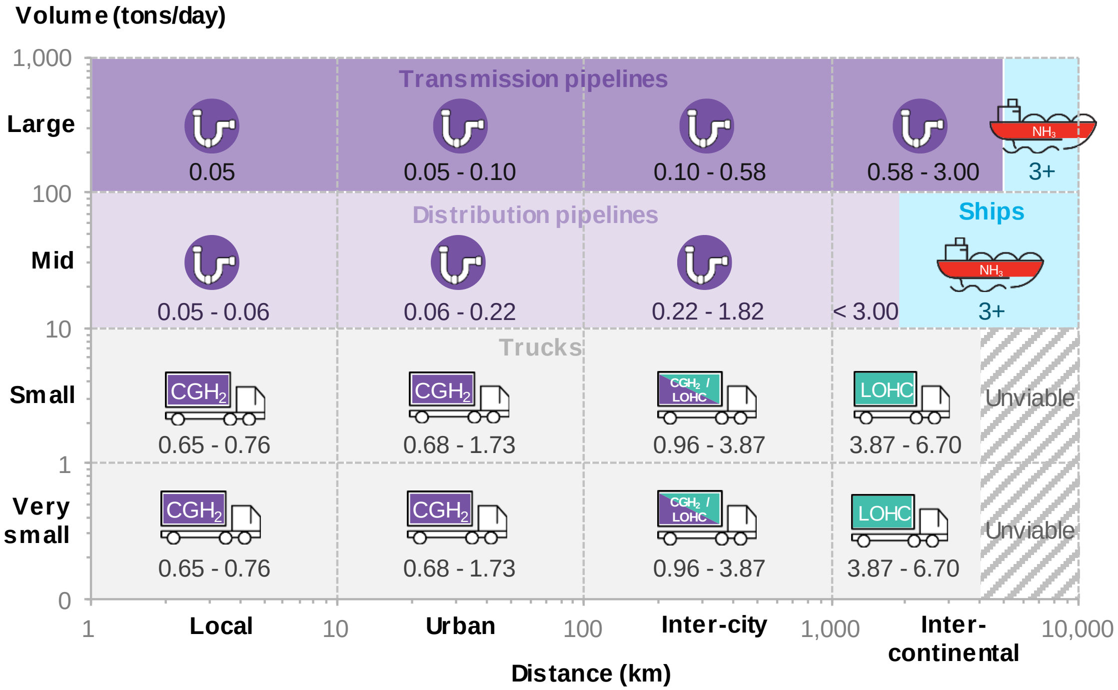
Prices across the board should fall in future

Hydrogen storage options and levelized cost of storage, future best case



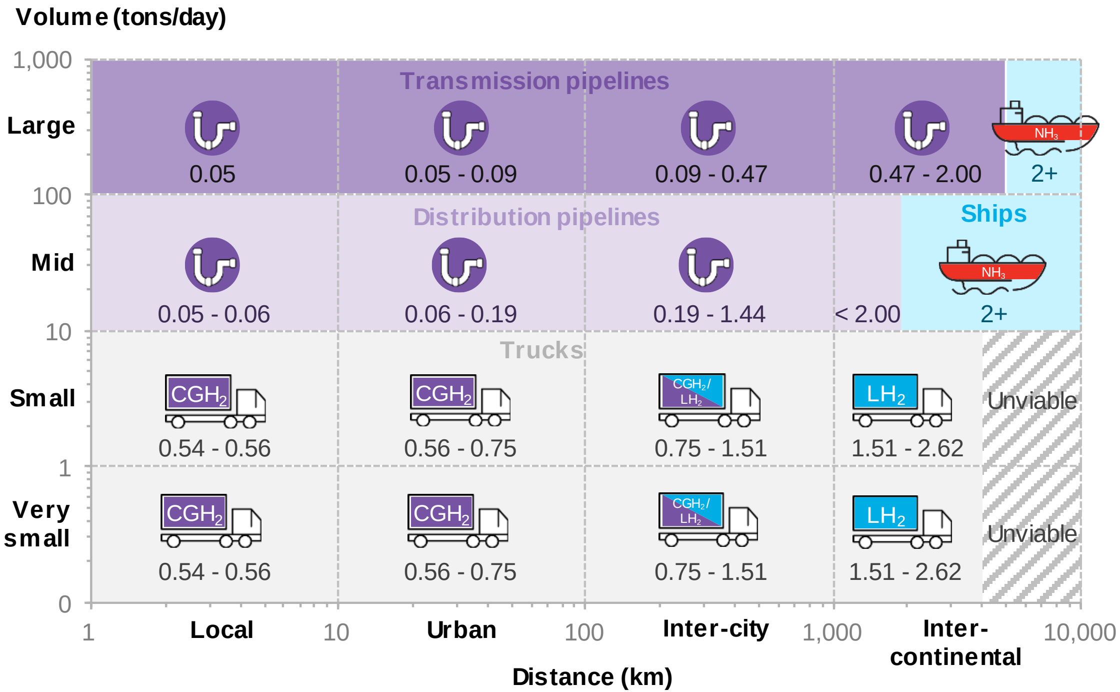
Source: BloombergNEF.

H_2 transport costs based on distance and volume, $/kg, 2019



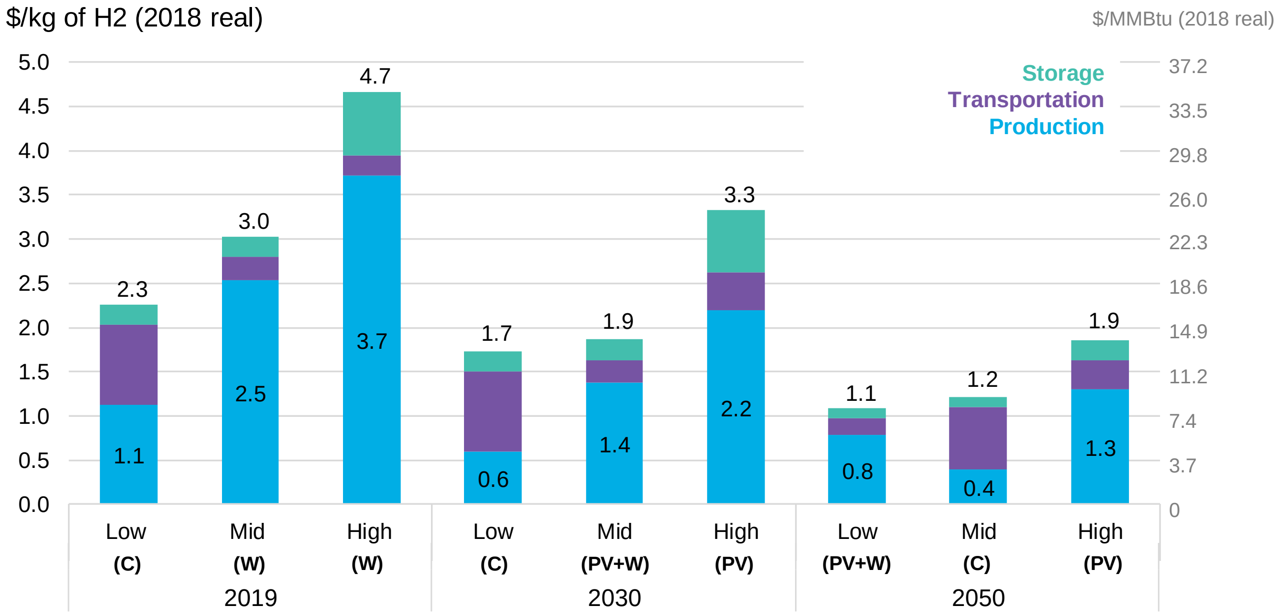
Source: BloombergNEF. Note 1: Ammonia assumed unsuitable at small scale due to its toxicity. Note 2: While LOHC is cheaper than LH_2 for long distance trucking, it is less likely to be used than the more commercially developed LH_2. Note 3: assumes salt cavern storage for pipelines.

H_2 transport costs based on distance and volume, $/kg, future best case



Source: BloombergNEF. Note 1: Ammonia assumed unsuitable at small scale due to its toxicity. Note 2: While LOHC is cheaper than LH_2 for long distance trucking, it is less likely to be used than the more commercially developed LH_2. Note 3: assumes salt cavern storage for pipelines.

Hydrogen delivery fuel cost scenarios, 2019-2050

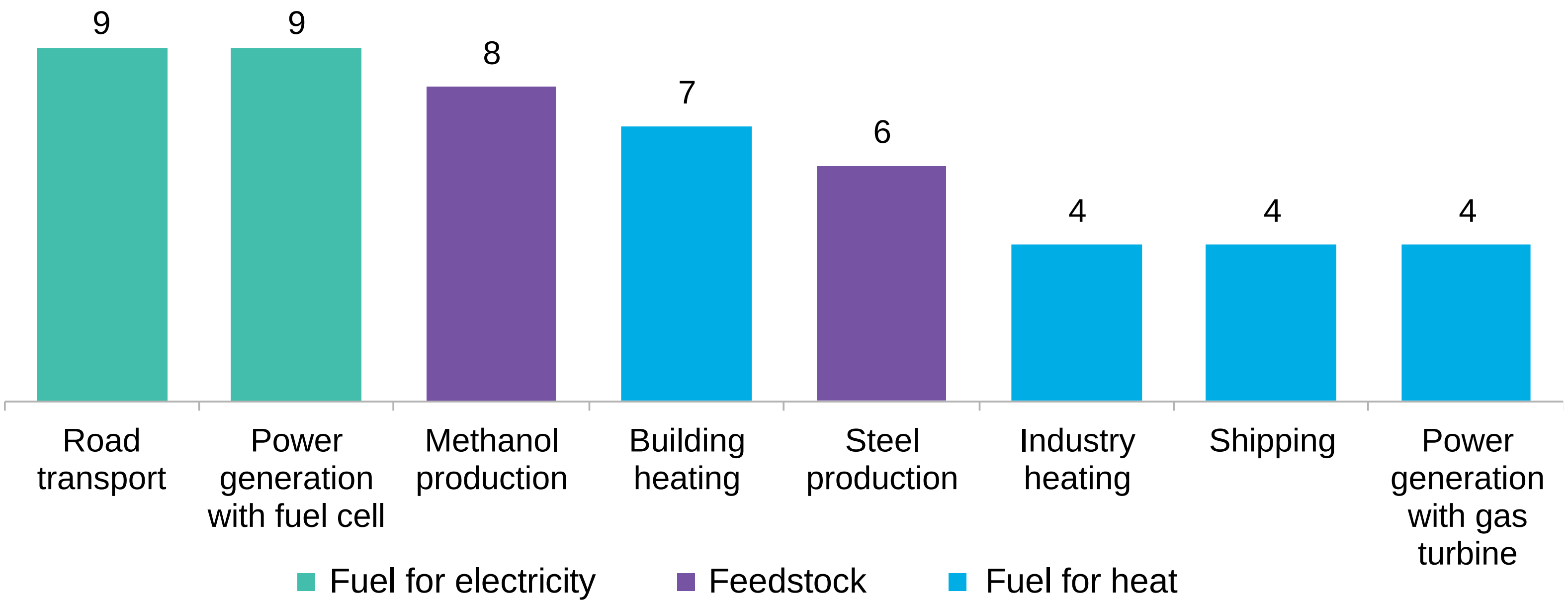


Electricity source for the electrolysis reaction

(C) Curtailment
(PV) Utility-scale PV
(W) Onshore wind
(PV+W) PV-plus-onshore wind

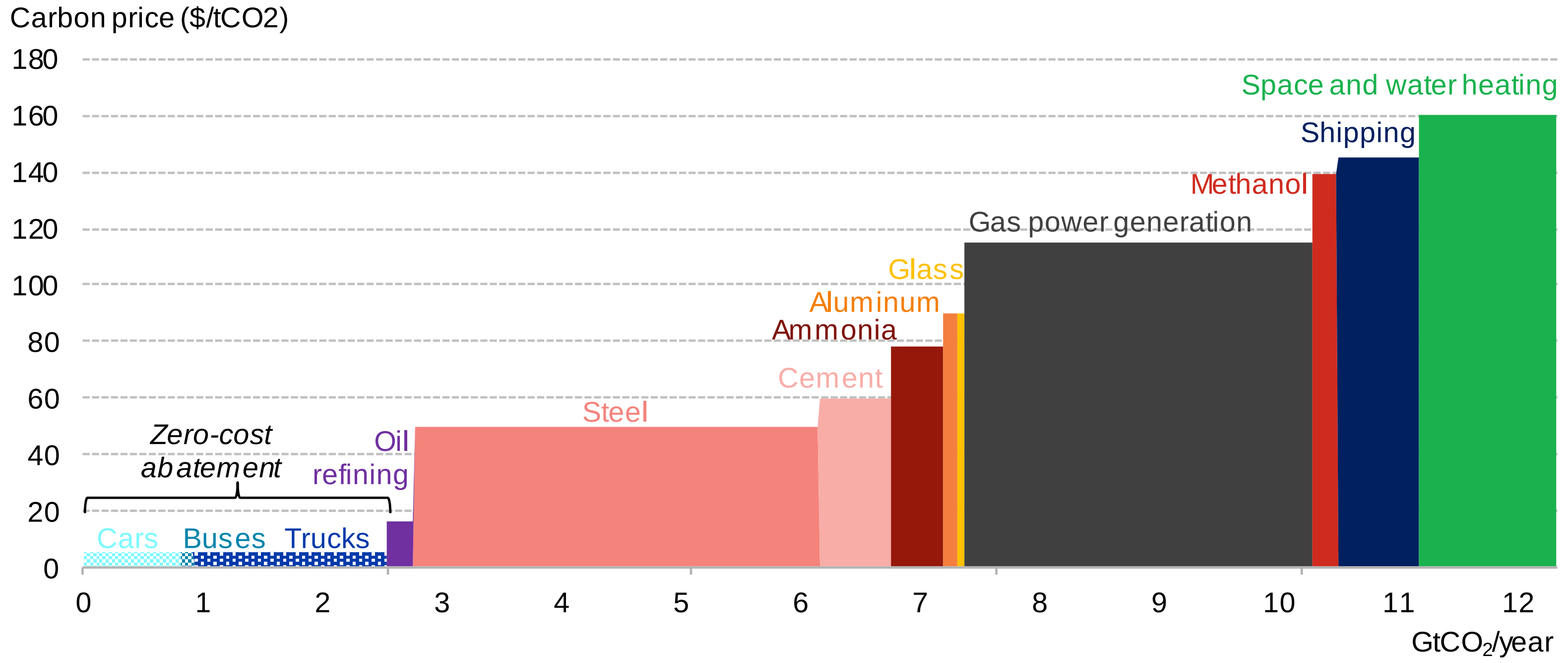
Source: BloombergNEF. Note: The assumptions are detailed for each component in the tables below. Stack based on levelized costs of production, transportation and storage. These fuel prices scenarios are all available in the 'Market' tab of EPVAL, BNEF's project finance model.

Technical readiness level of using hydrogen in various applications



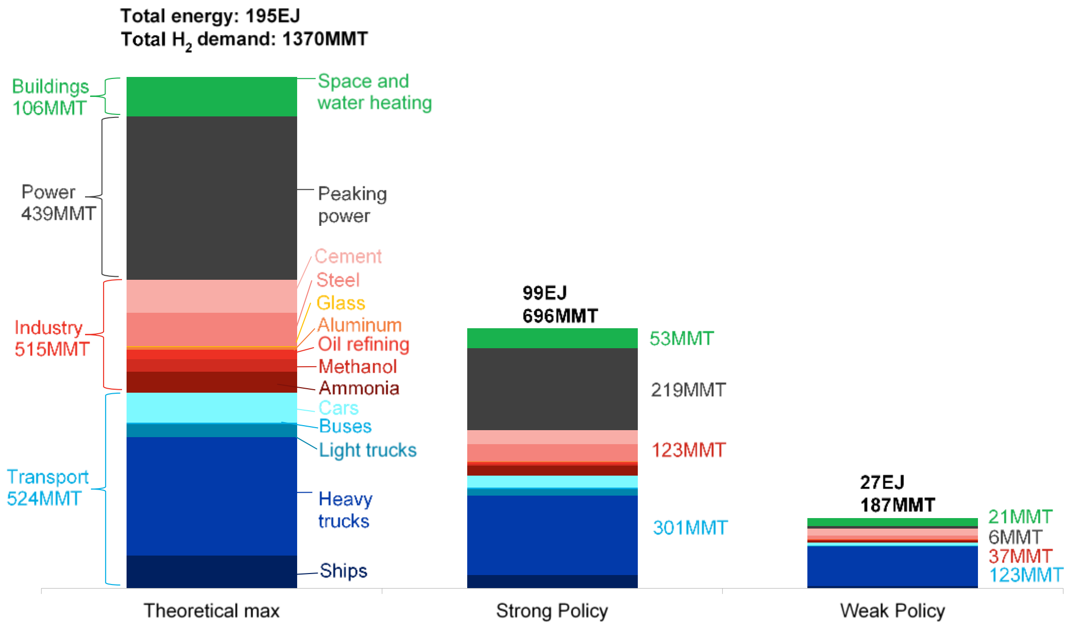
Source: BloombergNEF, CSIRO. Note: Technology readiness level is measured on a scale of 1 (basic research) to 9 (proven in an operational environment).

Marginal abatement cost curve from using $1/kg hydrogen for emission reductions, by sector in 2050



Source: BloombergNEF. Note: sectoral emissions based on 2018 figures, abatement costs for renewable hydrogen delivered at $1/kg to large users, $4/kg to road vehicles.

Potential demand for hydrogen in different scenarios, 2050



Source: BloombergNEF. Note: Aluminum demand is for alumina production and aluminum recycling only. Cement demand is for process heat only. Oil refining demand is for hydrogen use only. Road transport and heating demand that is unlikely to be met by electrification only: assumed to be 50% of space and water heating, 25% of light-duty vehicles, 50% of medium-duty trucks, 30% of buses and 75% of heavy-duty trucks

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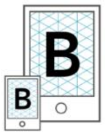

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