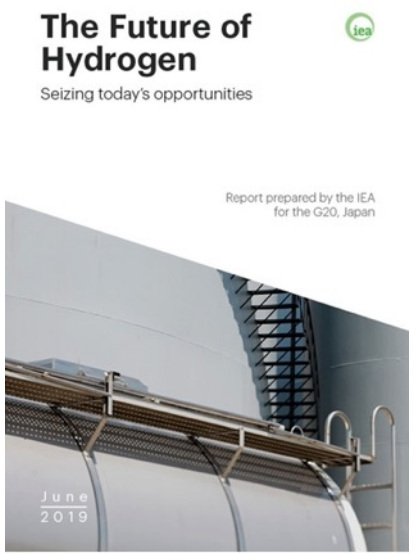
Hydrogen and ammonia: building global momentum

Cédric Philibert, *former International Energy Agency senior analyst*

Ammonia Energy Implementation Conference 2019, Orlando, FL

The Future of Hydrogen by F. Birol, Karuizawa, Japan, 14 June 2019

- Momentum currently behind hydrogen is unprecedented, with more and more policies, projects and plans by governments & companies in all parts of the world
- Hydrogen can help overcome many difficult challenges
  - ***Integrate more renewables***, including by enhancing storage options and "exporting sunshine & wind" from places with abundant resources
  - ***Decarbonize "hard to abate" sectors*** – steel, chemicals, trucks, ships & planes
  - ***Boost energy security*** by diversifying the fuel mix & providing flexibility to balance grids



- But there are challenges: ***costs*** need to fall; ***infrastructure*** needs to be developed; ***cleaner hydrogen*** is needed; and ***regulatory barriers*** persist

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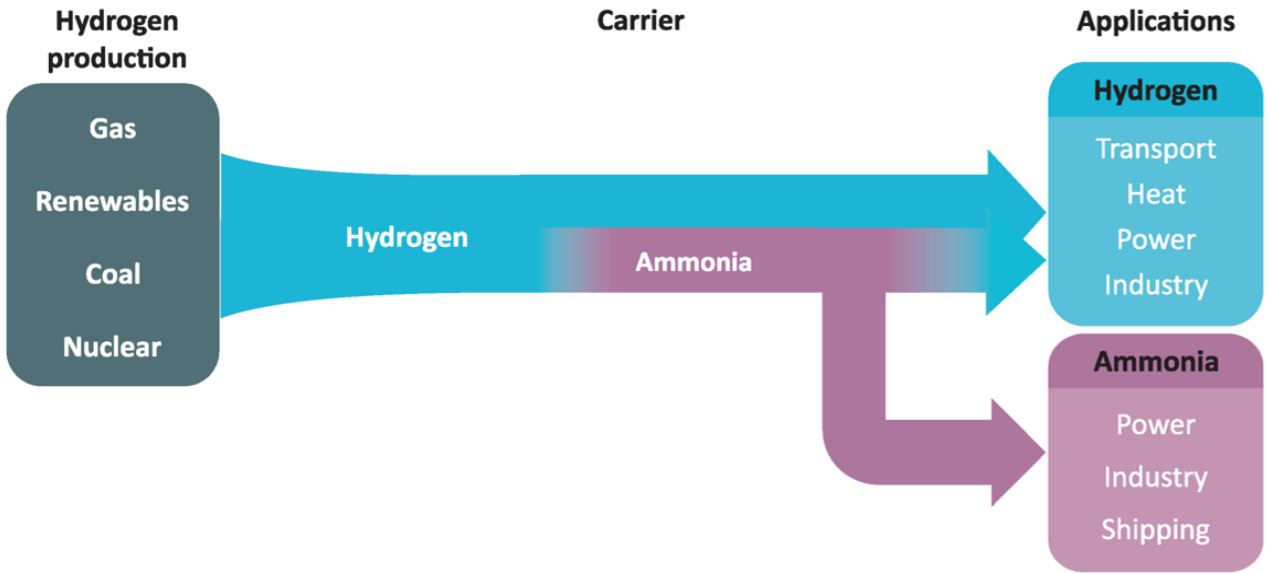
Ammonia part of the game as a chemical, carrier and fuel

Hydrogen has many production sources and applications



Hydrogen can be produced from different sources & has multiple applications, including in transport, industry, buildings & power generation; when produced from fossil fuels, coupling with CCUS maximises CO_2 benefits

Fatih Birol, Executive Director, IEA Hydrogen Energy Ministerial, Tokyo, 23 October 2018

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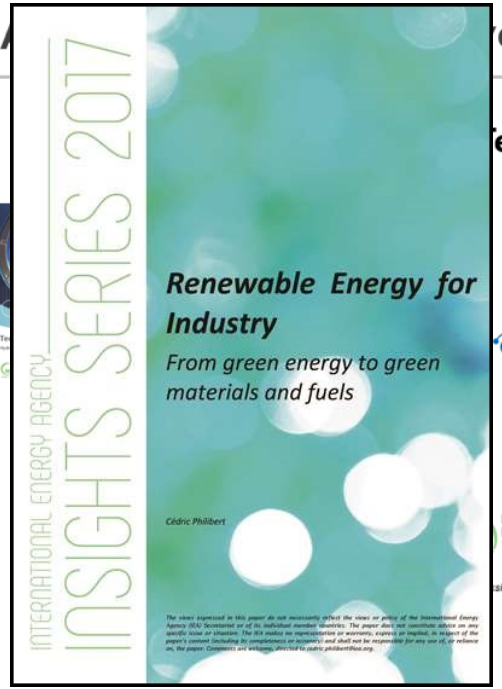
Appreciation of hydrogen had already changed at the IEA

IEA ydrogen



echnology Network

iea Energy Technology Network

iea hydrogen

Workshop

International Energy Agency Secure Sustainable Together

European Commission

shop by the International Energy Agency and the European Commission

Electrofuels

Date: Monday 10 September 2018

Business Network

Energy Business Council

IEA Ministerial Meeting (Nov 2017)

Secretariat

CLEAN ENERGY MINISTERIAL

Advancing Clean Energy Together

IEA has been active on the analysis of hydrogen for many years; our work will expand, collaborating closely with our extensive technology and business networks

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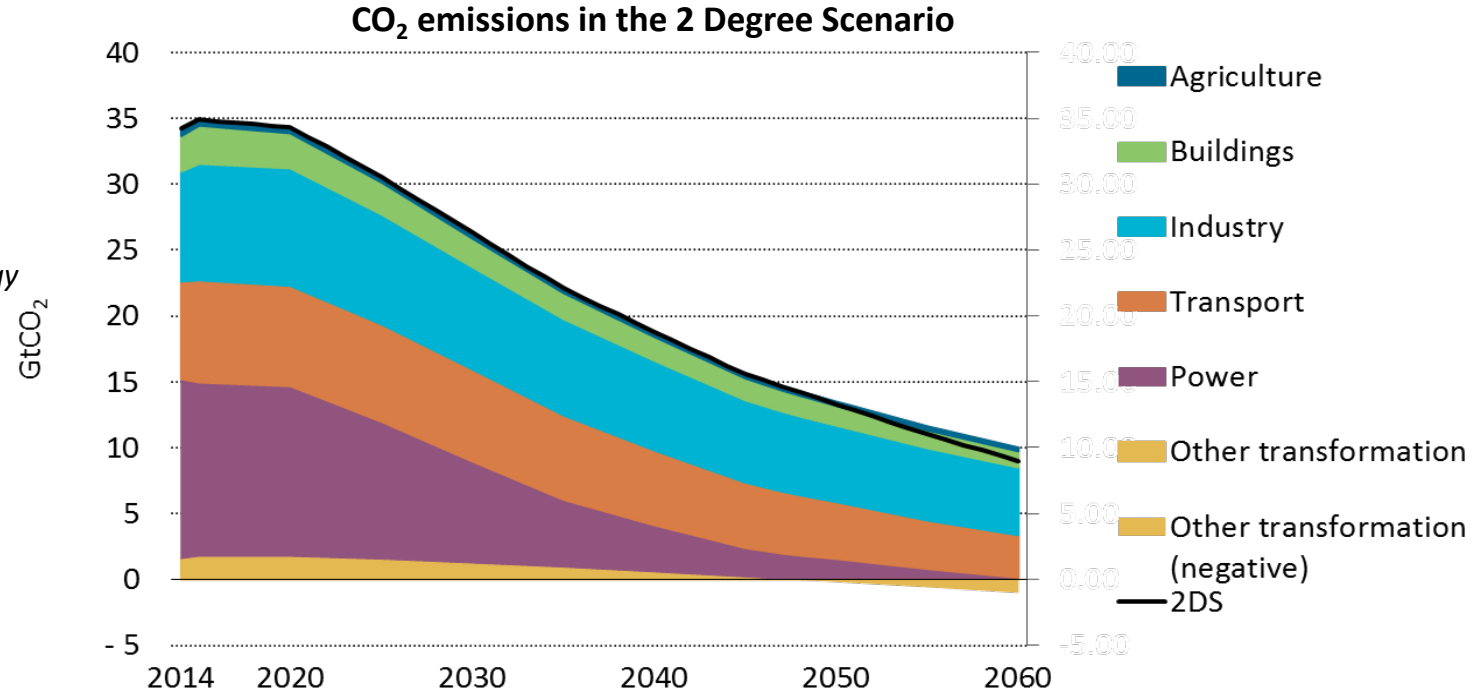
Industry and transports: the hard-to-abate sectors

Source: IEA 2017 Energy Technology Perspectives



Cement, chemicals, iron and steel… Aviation, road transports and shipping represent major challenges for climate change and air quality

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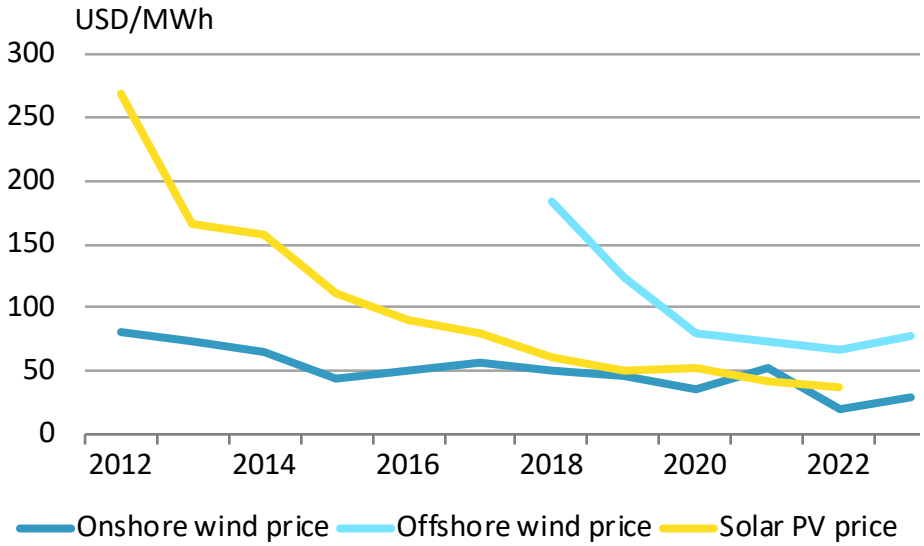
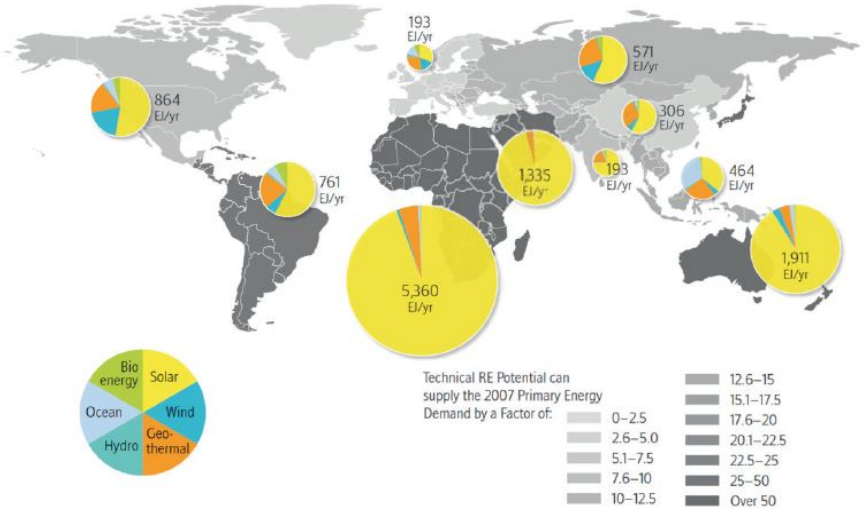
The emergence of low-cost renewable power is a game-changer

Average auction prices by commission dates



Source: IEA, Renewables 2017

Some areas have larger RE resources



Source: IPCC 2012, Renewable Energy Sources and Climate Change Mitigation

Capacity factors of combined wind and solar power exceeds 50% in vast areas, often remote from large consumption centers, potentially delivering huge amounts of power at less than $30/MWh

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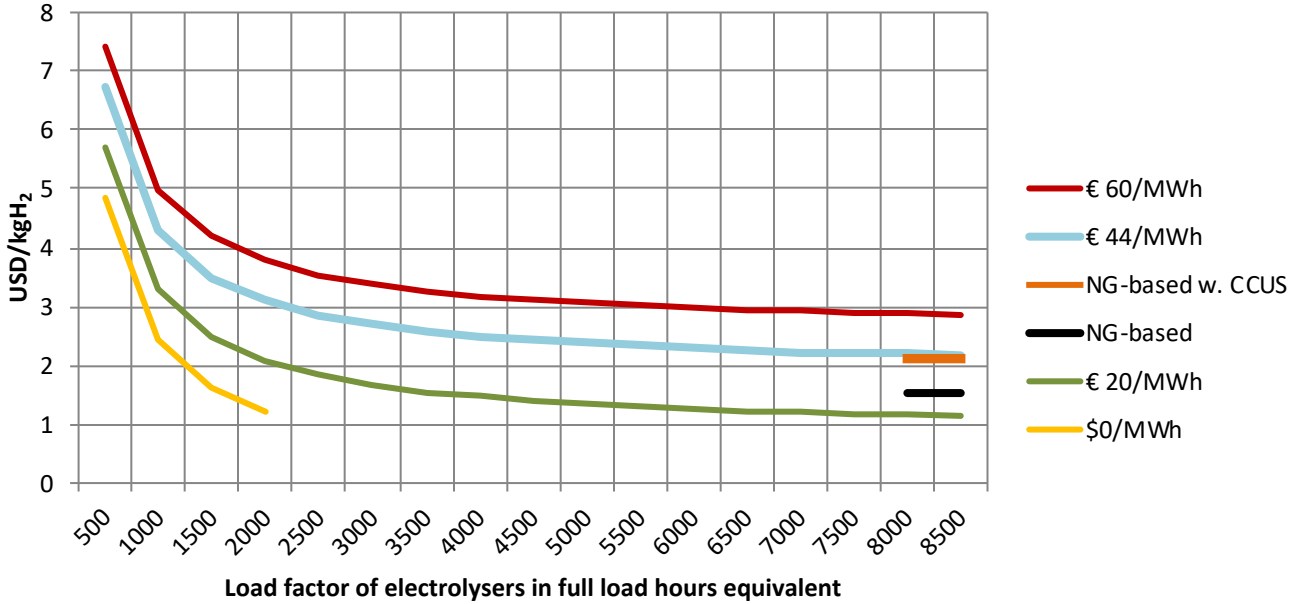
Green hydrogen from water electrolysis can compete…

Cost of hydrogen from electrolysis for various electricity price and load factors vs. natural gas-based in Europe



Beyond 20- 40% capacity factor the cost of electricity dominates the cost of hydrogen from electrolysis

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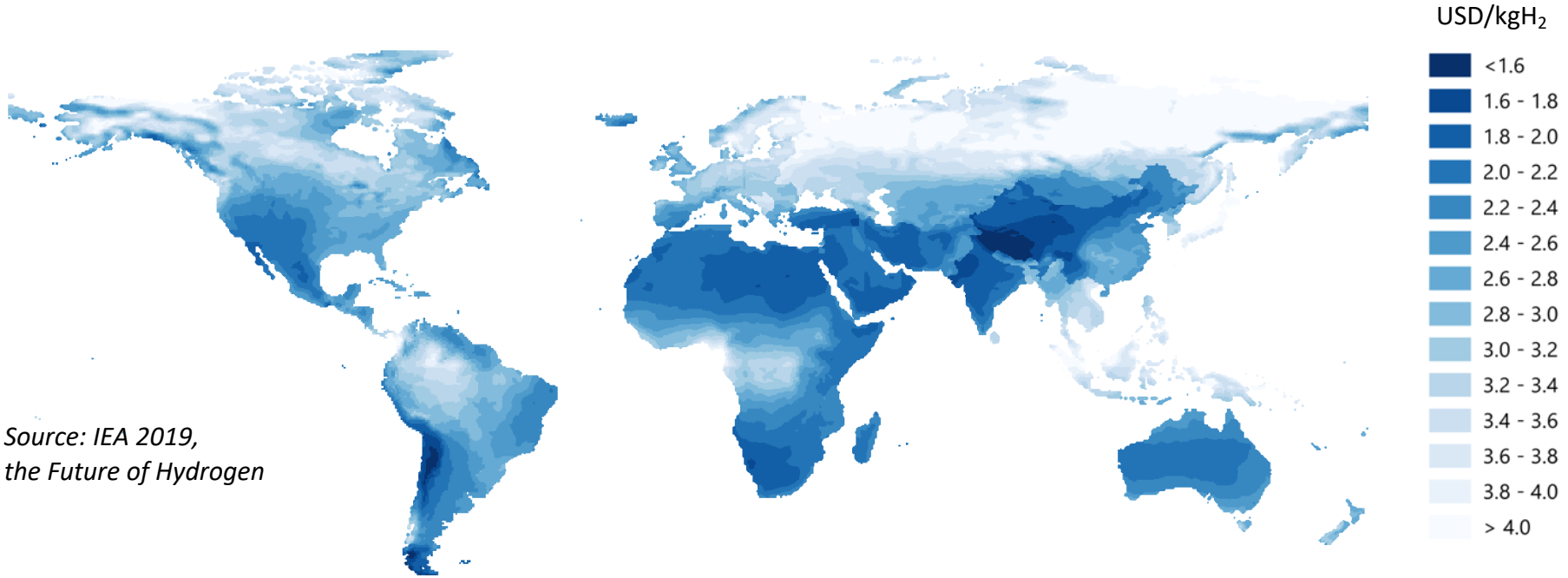
Renewables hydrogen costs are set to decline

Long-term hydrogen production costs from solar & wind systems



Source: IEA 2019, the Future of Hydrogen

Regions with most favourable renewable resources will likely export hydrogen-rich chemicals and fuels to consumption centres

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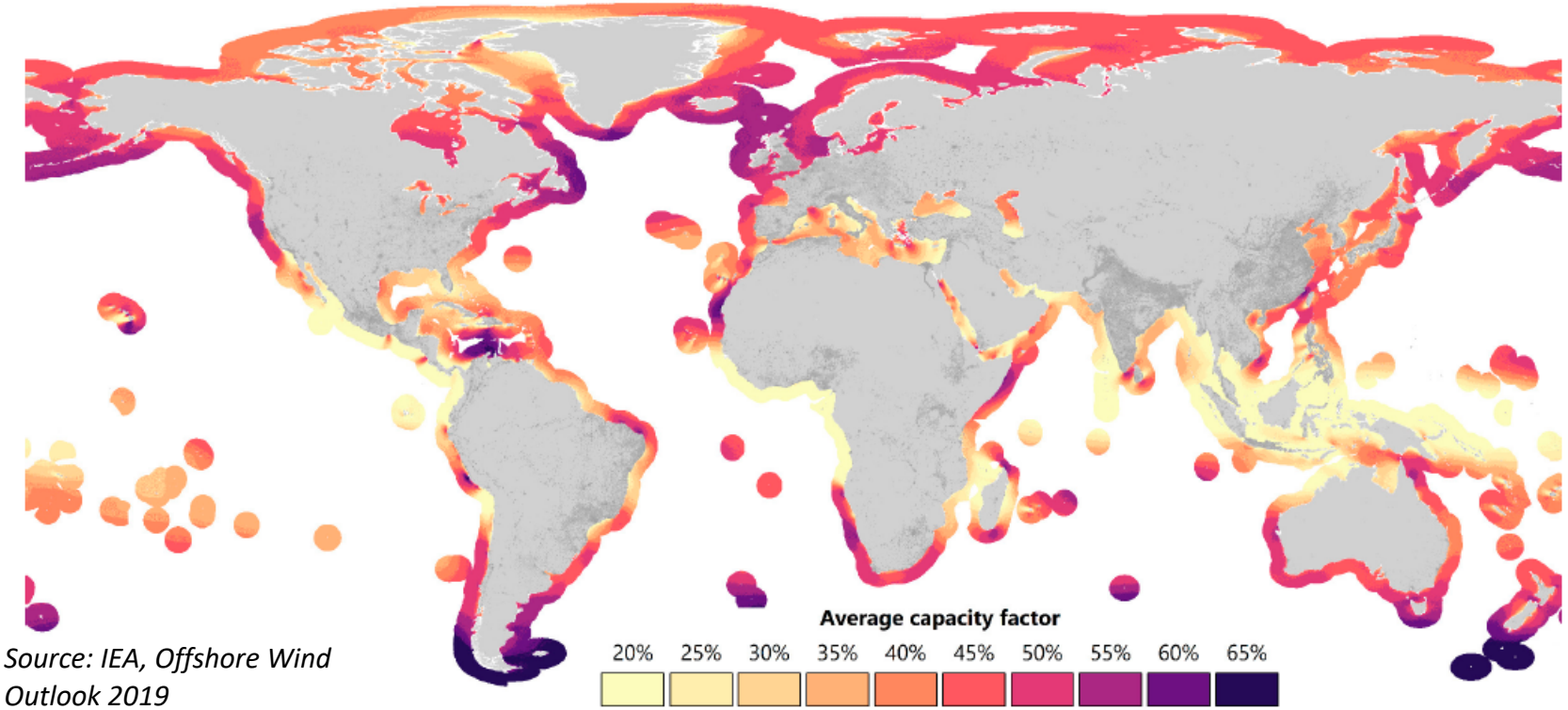
Offshore wind: a great potential of « variable baseload » power



Source: IEA, Offshore Wind Outlook 2019

High capacity factors of offshore wind turbines make them closer to baseload, though still variable

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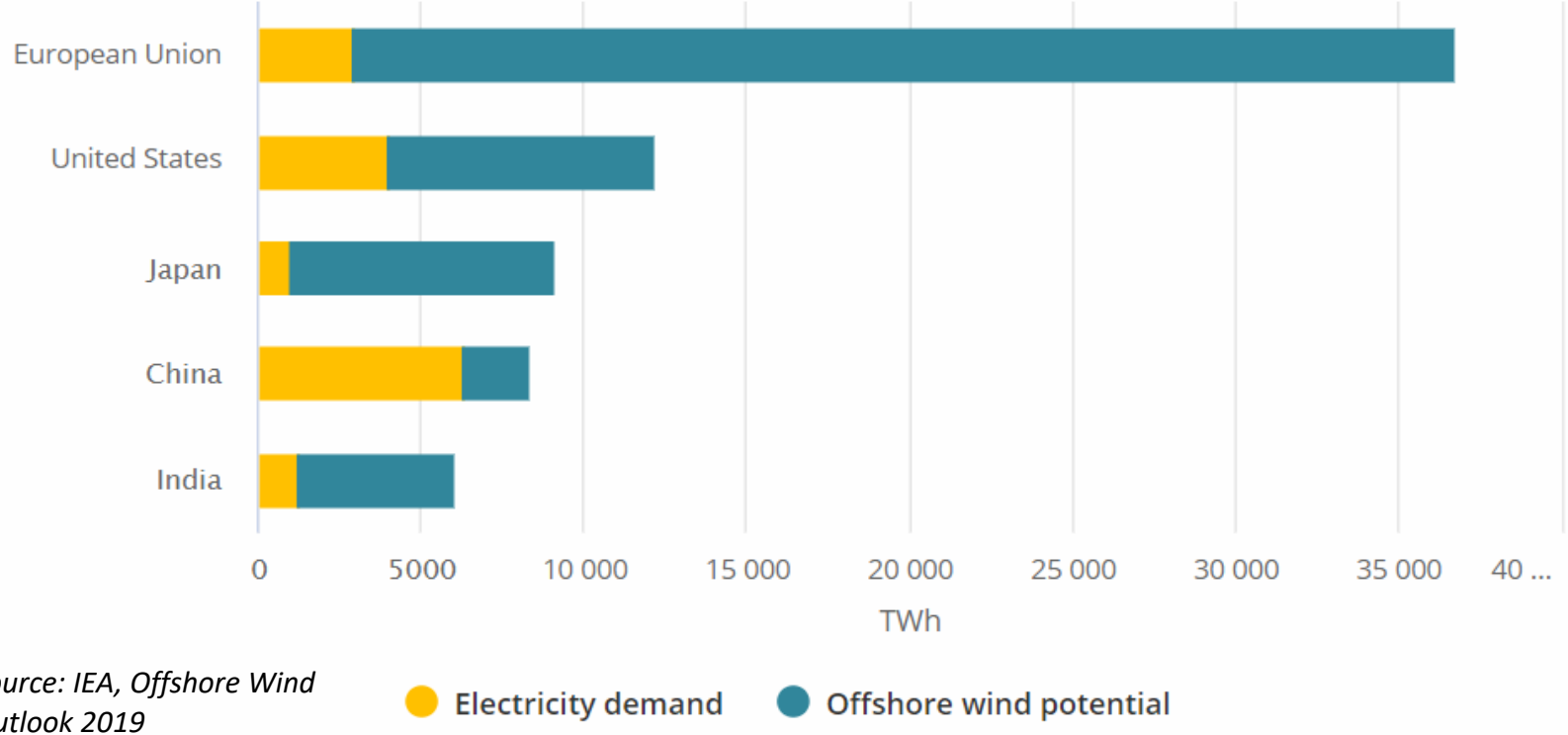
Offshore wind: a great potential of « variable baseload » power



Source: IEA, Offshore Wind Outlook 2019

The global potential of offshore wind is ten times greater than current electricity consumption

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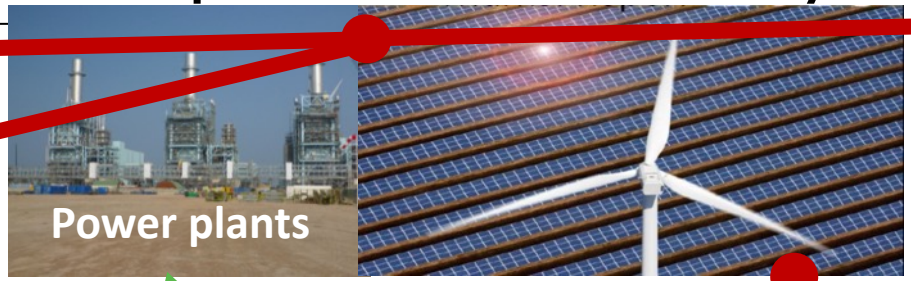
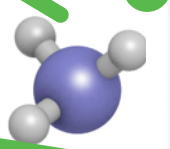
Renewable power can replace fossil fuels in many uses

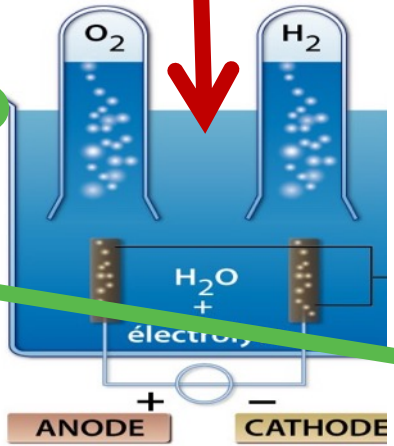
Buildings
Heating
Cooking
Lighting



Industry
Steam
Force
Electrolysis

Transports
EVs
H-rich fuels





Feedstock, process agents, fuel

Beyond current uses, renewable electricity can replace fossil fuels in direct uses in buildings, industry and transports, directly or through electrochemistry/electrolysis

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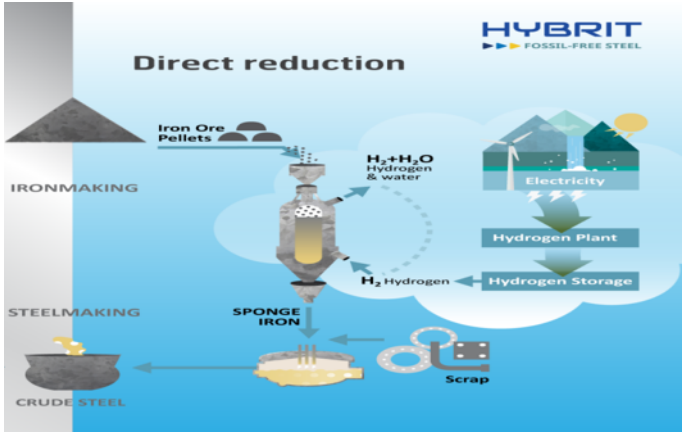
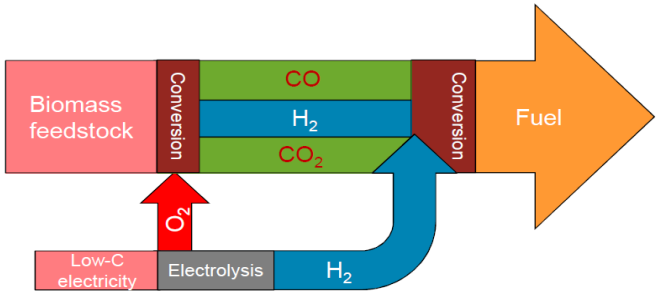
Most relevant areas for green hydrogen use

- Green ammonia & methanol for their industrial uses
- Refineries (to upgrade and clean fuels)
- Direct iron reduction in steelmaking with H_2 (or NH_3?)
  - Electrowinning would be more efficient& flexible
- H_2/NH_3 storable/shippable fuels in power systems
- H_2/syn CH_4 in gas grids & trucks and other vehicles?
- NH_3 as fuels (shipping, industrial furnaces…)
- CH_3OH and synthetic HCs as electro fuels/feedstocks
  - To chemical industry and aviation
  - Sustainable if the carbon is taken from the air
  - Combining with the production of biofuels





Where possible, direct electrification is preferred for being significantly more efficient

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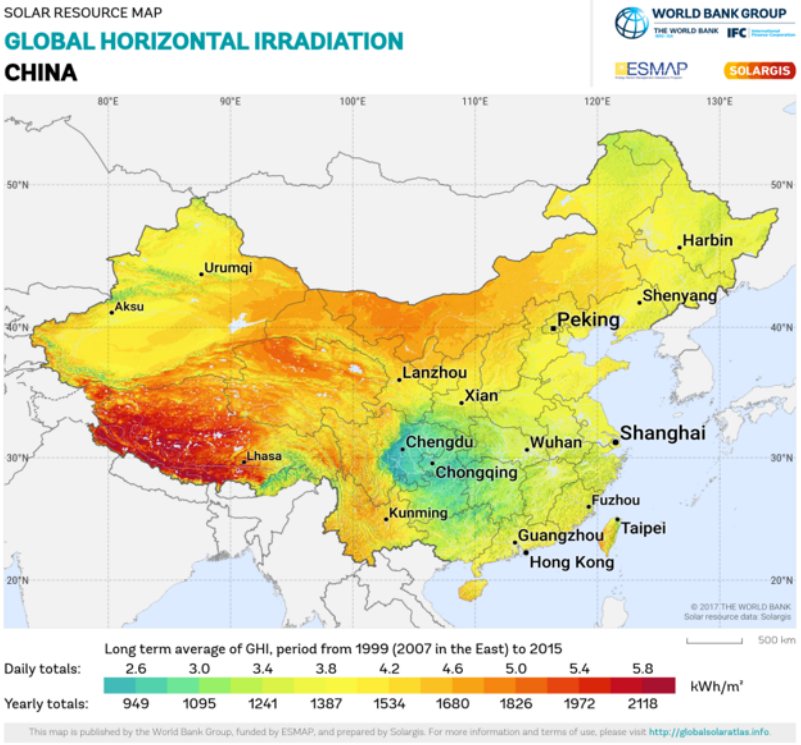
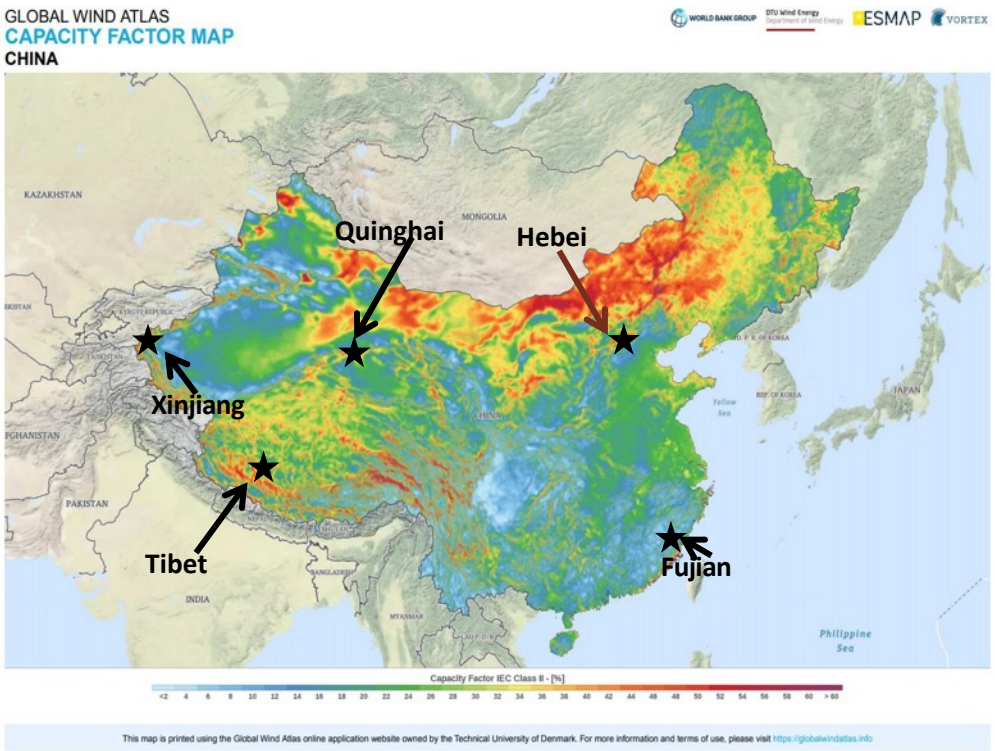
Case study: Hydrogen and ammonia production in China





North and West China have the best solar & wind resources; ammonia and other liquids could be pipelined eastward to consumption centres and industrial facilities

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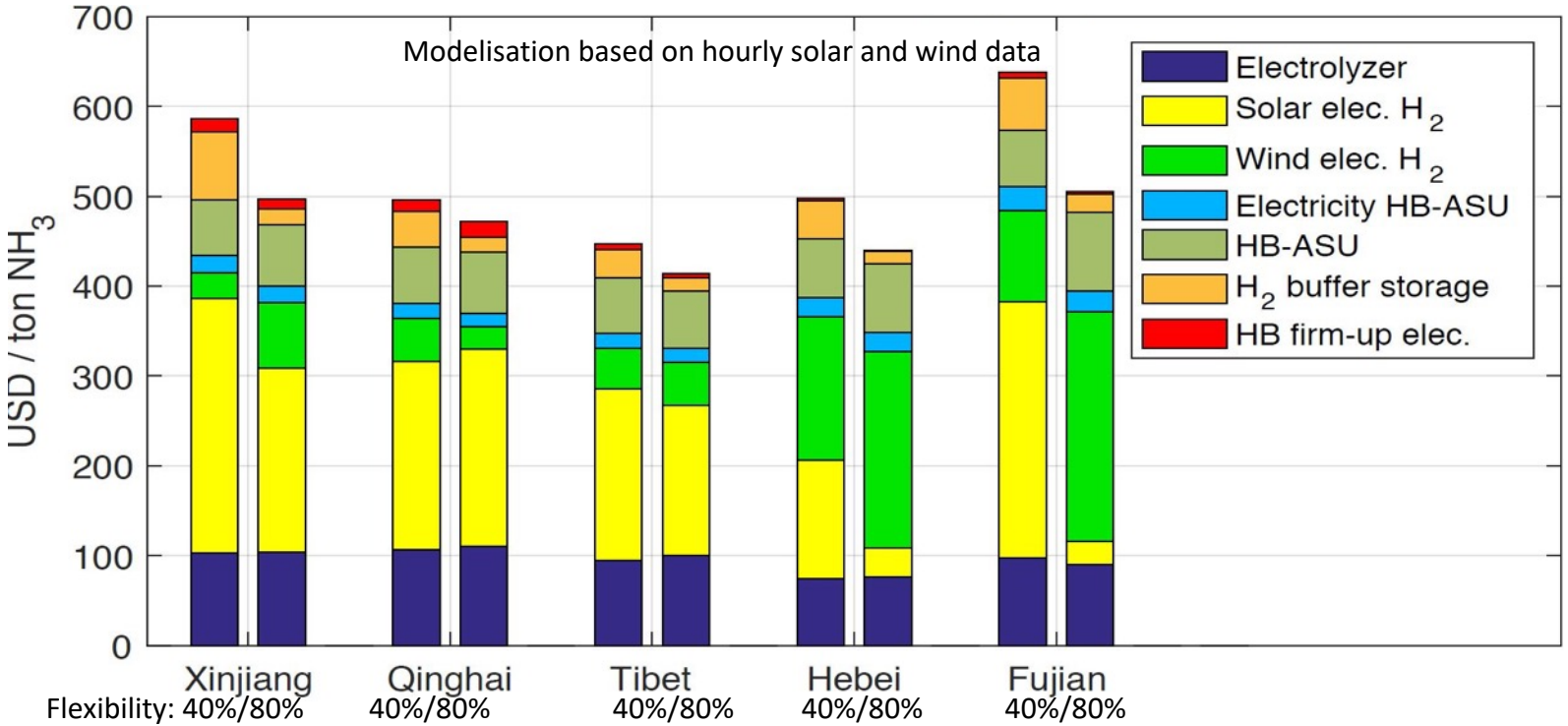
Green NH3 offers large affordable emission reduction potential in China



Electricity represents the major component of ammonia cost. Solar dominates in Qinghai, wind dominates in Hebei, Tibet uses a more even mix.

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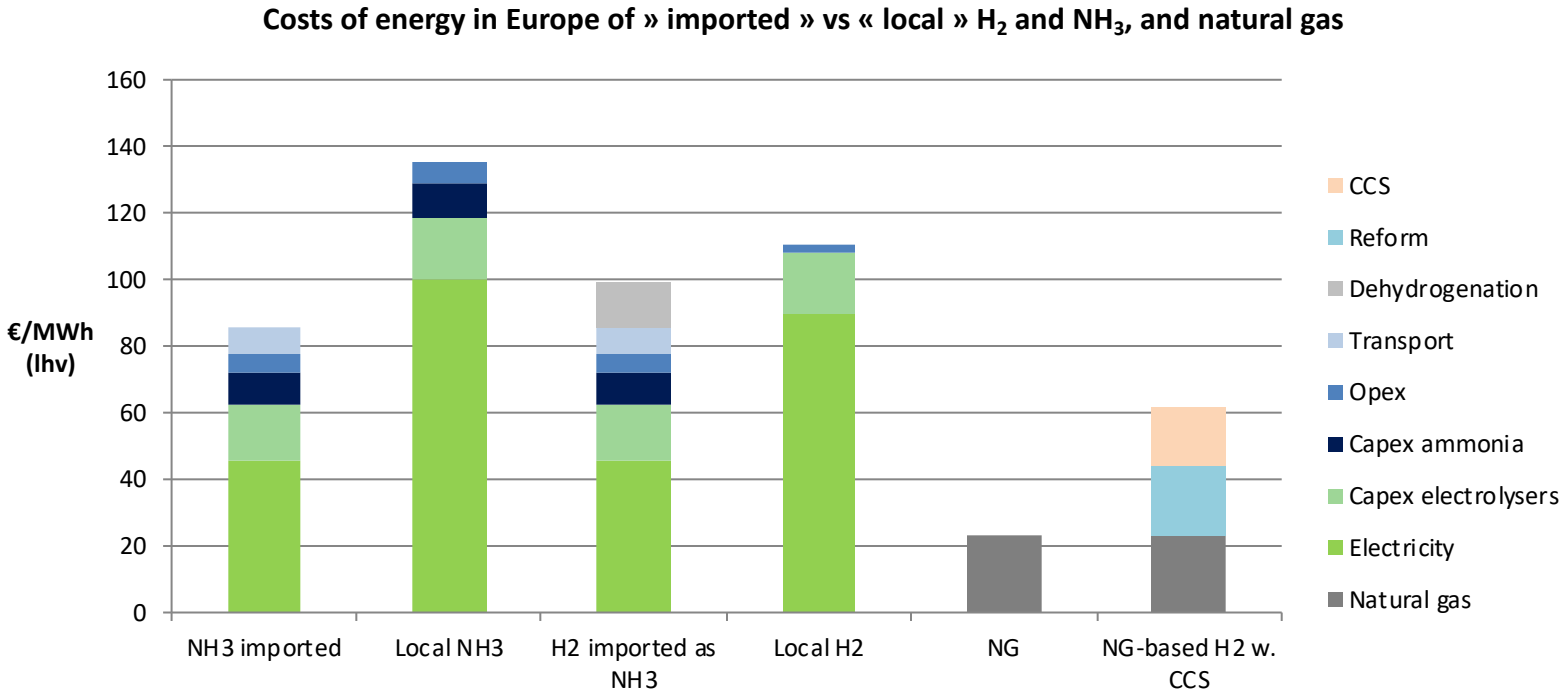
Ammonia hardly competes with natural gas as a fuel



NH_3 imported from areas with power $30/MWh competes with NH_3 produced in areas with $60/MWh but cannot compete with natural gas, even with CCS if (it hold its promises)

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Three ways of isolating hydrogen

- Steam reforming of natural gas and partial oxidation of naphta and coal

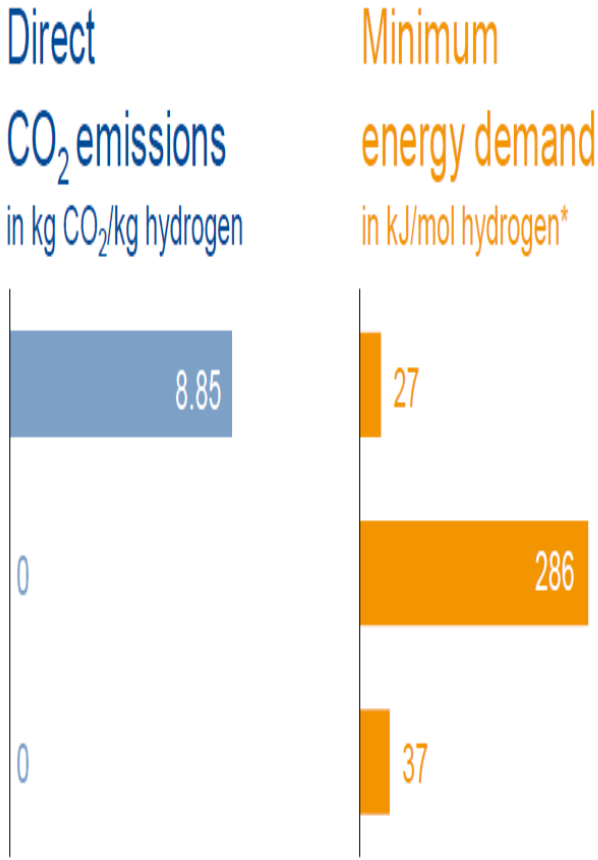
$$CH_4 + 2H_2O \xrightarrow[heat]{} CO_2 + 4H_2$$

- Electrolysis of water - with low-carbon electricity

$$2H_2O \xrightarrow[elec]{} O_2 + 2H_2$$

- Pyrolysis of methane

$$CH_4 \xrightarrow[elec]{} C + 2H_2$$



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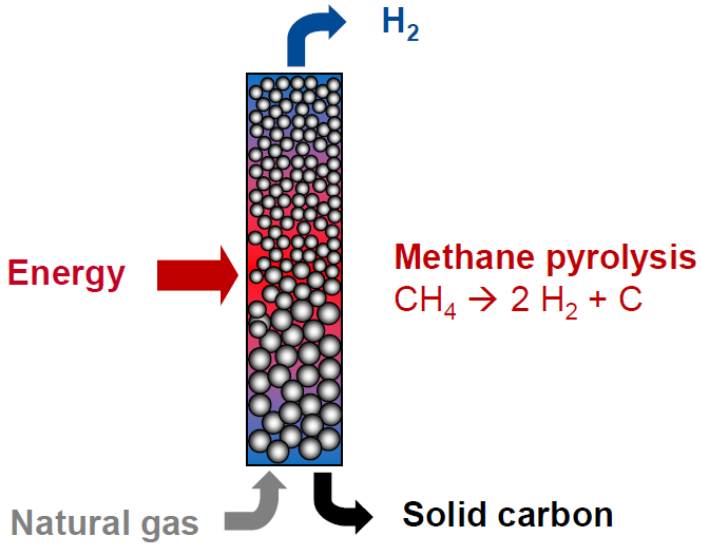
The value of methane pyrolysis

- Proven at commercial scale (*Kvaerner Hydrogen Plasma Black Reactor*, 1998-2007)
- Does not generate CO_2, a waste to store, but solid carbon, easier to valorise
  - Carbon black, graphene, fibers, tubes…
- Preserves stranded costs in natural gas production and transport infrastructures
  - CH4 easier to transport than H2, decarbonisation would likely take place close to consumption
- Allows to increase more rapidly the production of low-carbon hydrogen
- Monolith Materials is currently building a commercial plant in Nebraska
  - Plasma furnace developed at Mines Paristech

- TNO is developing its proprietary process
- BASF is building its third pilot plant



See Pöyry report *Hydrogen from natural gas – the key to deep decarbonisation*

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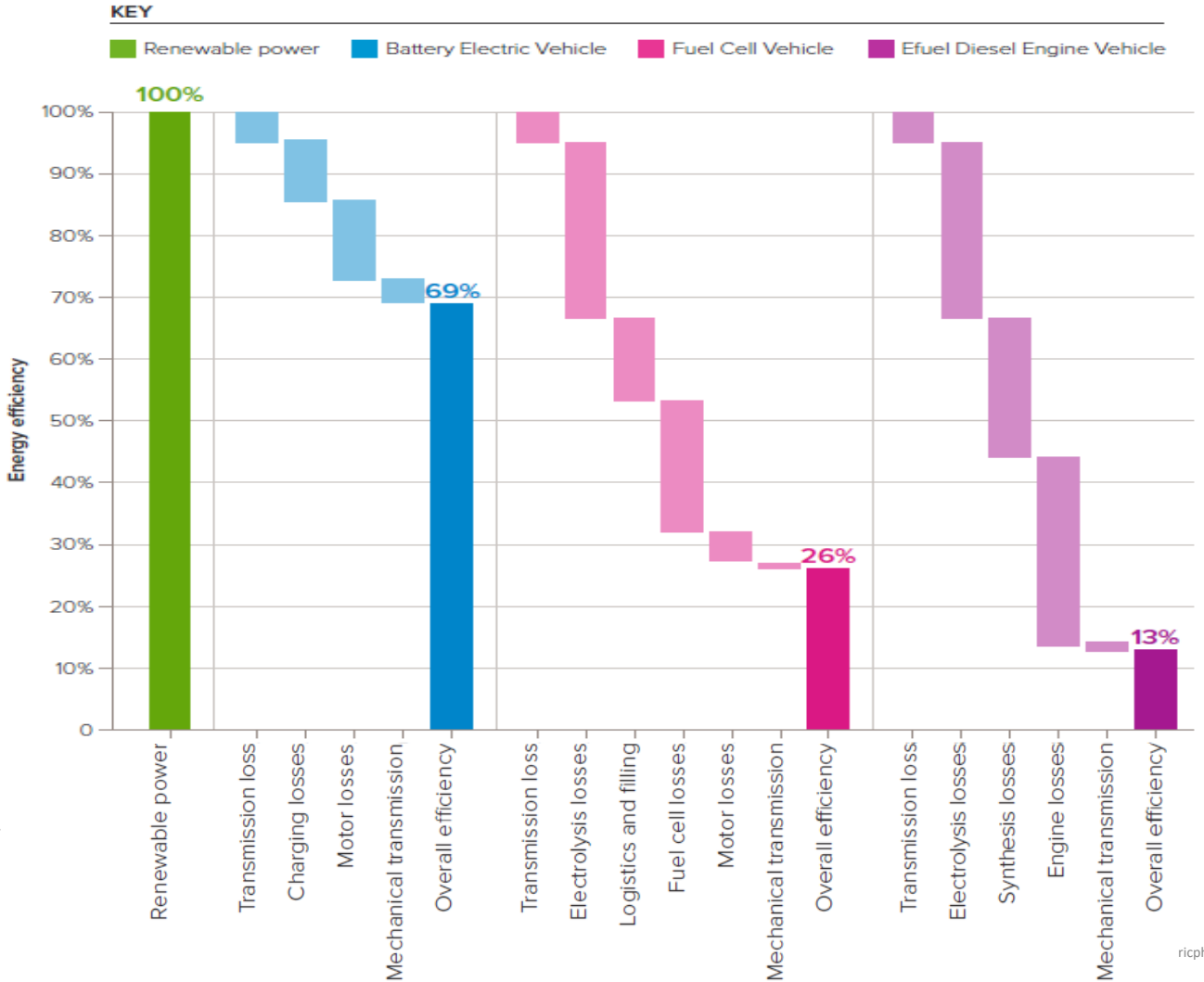
Direct electrification is more efficient



Source: The Royal Society, 2019, Sustainable synthetic carbon based fuels for transport

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To sum up

- Power sector, industry, aviation and shipping, some trucking need renewable, carbon-neutral electro fuels
- Chemical industries also need atmospheric carbon
- Sustainable biofuels only offer only a partial solution
- Carbon-free H_2 gas and ammonia can deliver to maritime transportation, steelmaking
- Biomass & Power-to-Liquid fuels can deliver to aviation and chemical industries
- Total electricity required for producing these fuels and chemicals may exceed current global generation
- Renewables can deliver, methane pyrolysis can accelerate delivery
- Direct electrification is more effective whenever possible

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