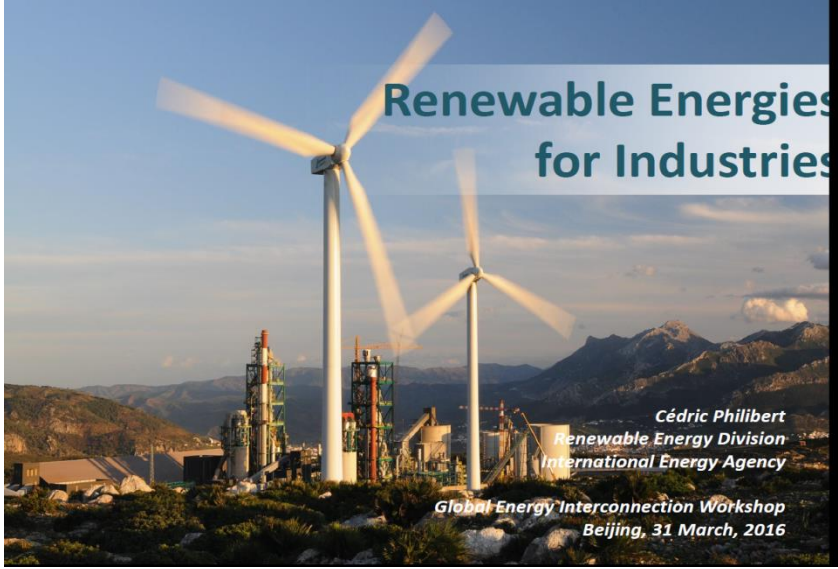


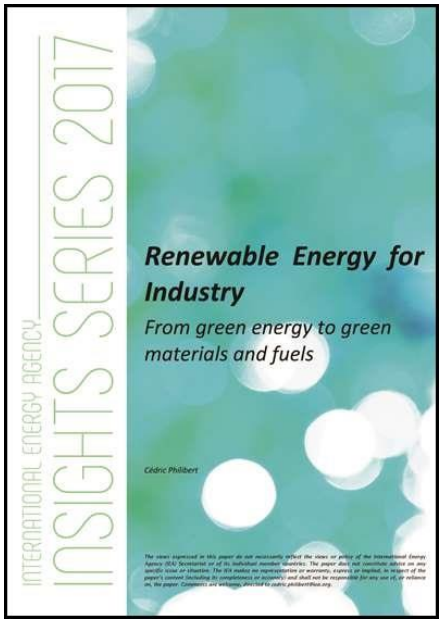
Renewable Energy for Industry: Offshore wind in Northern Europe

Cédric Philibert, Renewable Energy Division, International Energy Agency

ETIP WIND, 21 February 2019

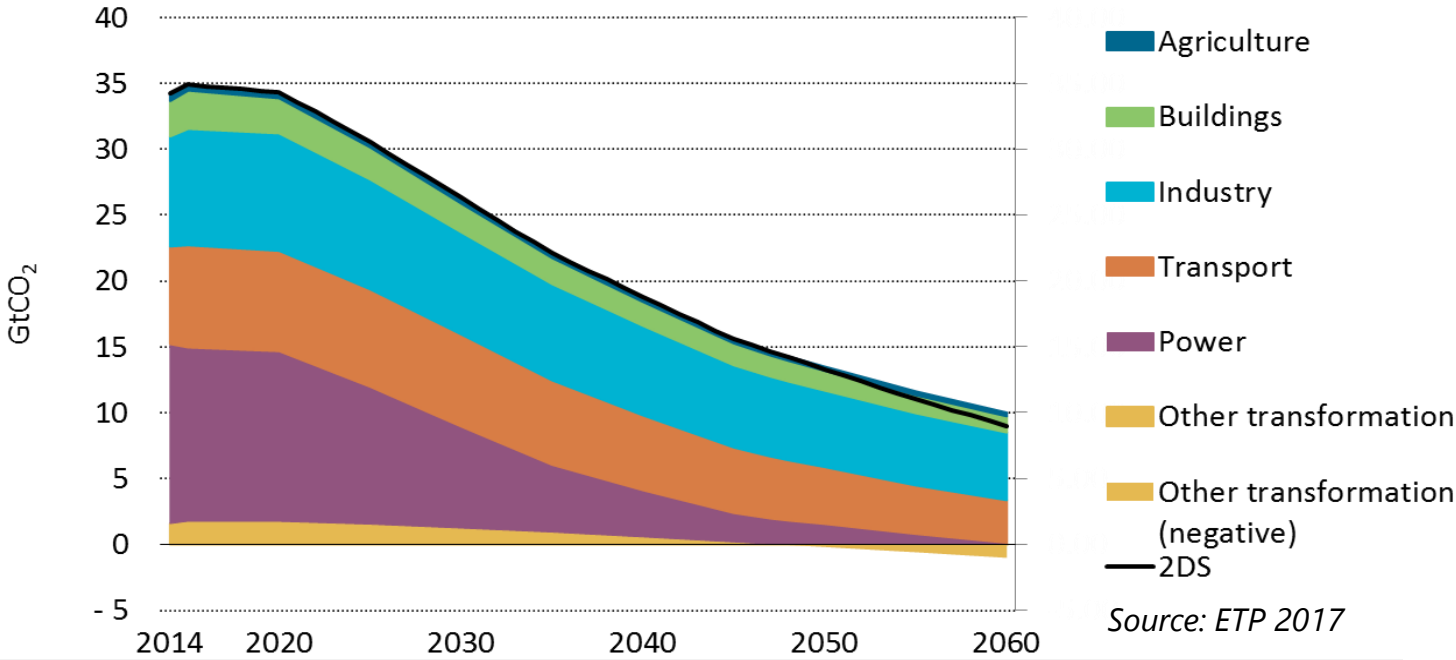
IEA

Industry and transports: the hard-to-abate sectors



https://bit.ly/2QaNlcv

CO_2 emissions in the 2 Degree Scenario

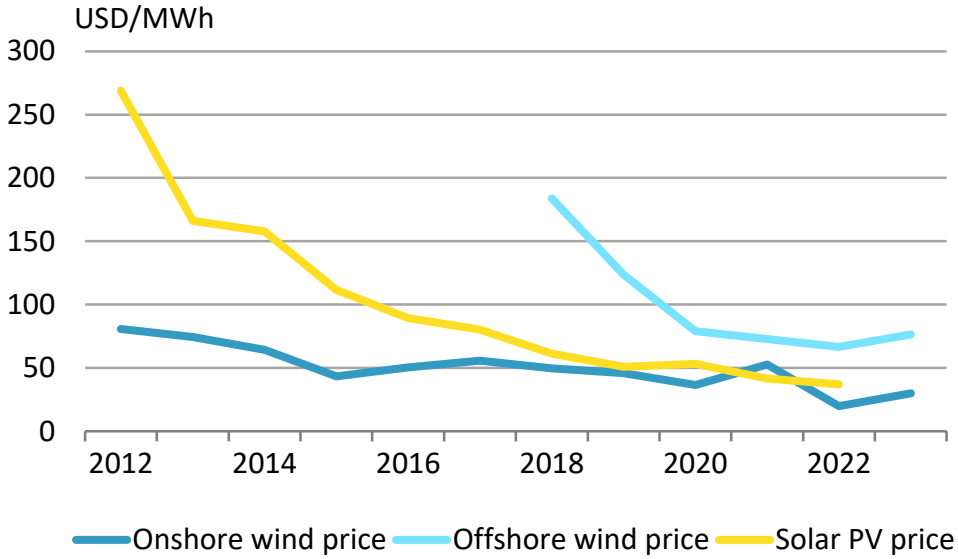


Source: ETP 2017

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

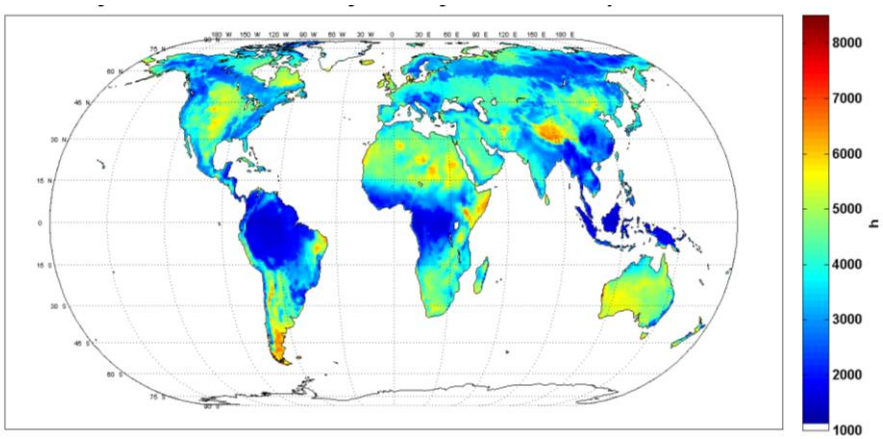
The emergence of low-cost renewable power is a game-changer

Average auction prices by commission dates



Source: IEA, Renewables 2017

Hybrid solar and wind full load hours adjusted for overlap



Source: Fasihi & Breyer, 2017

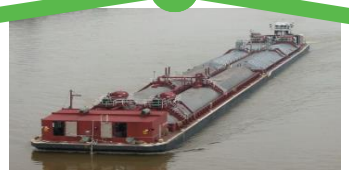
Capacity factors of combined wind and solar power exceeds 50% in vast areas, often remote from large consumption centers, potentially delivering huge amounts of power at less than $30/MWh

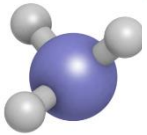
Renewable power can replace fossil fuels in many uses

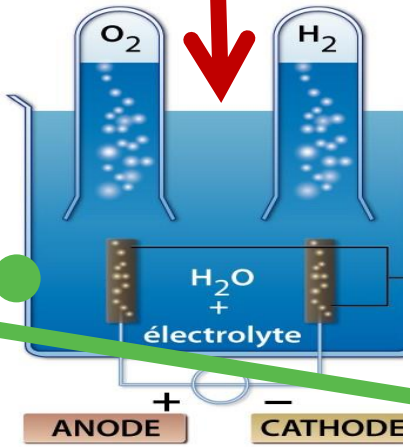
Buildings
Heating
Cooking
Lighting

Industry
Steam
Force
Electrolysis

Transports
EVs
H-rich fuels





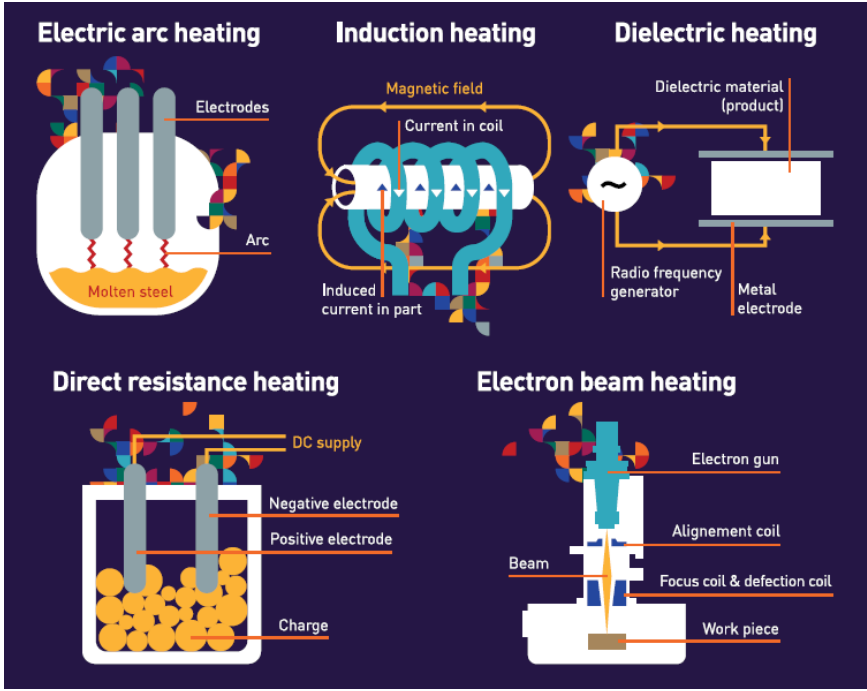


Feedstock, process agents, fuel

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

Direct electrification can take several forms

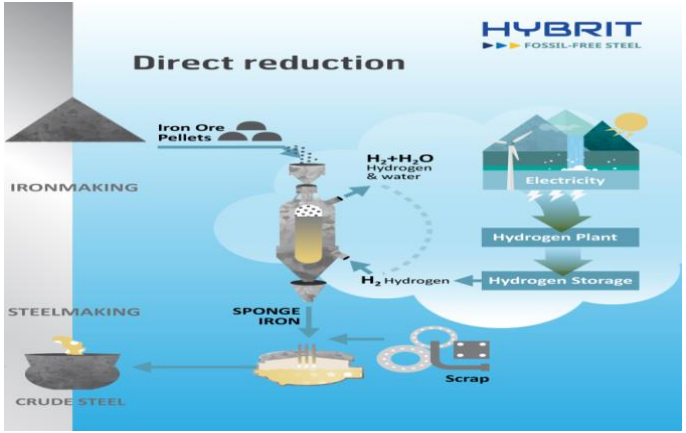
- Electro-magnetic technologies for heating, hardening, melting
- Heat pumps/mechanical vapour recompression
- Cheap resistances in boilers or furnaces taking advantage of cheap “surplus” power when available

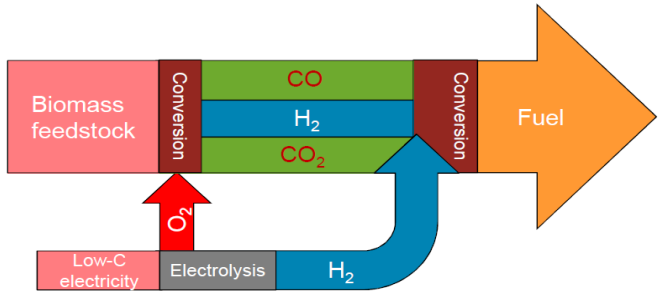


Electric technologies can prove cost-competitive when they are twice as efficient, thus filling the cost gap with direct fossil-fuel use – and helping integrate more renewables

Most relevant areas for green hydrogen use

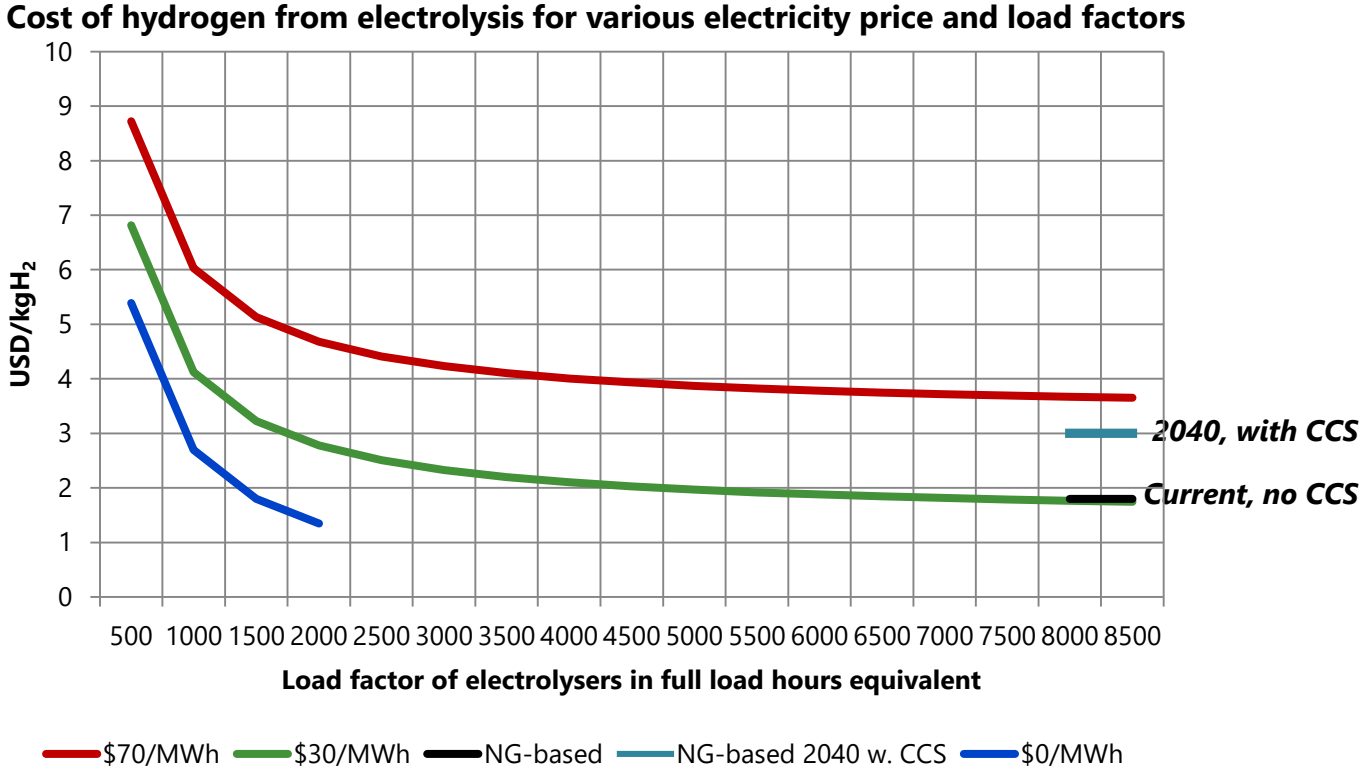
- Greening ammonia and methanol for their current industrial uses
- Refineries (contribute to cleaning fuels)
- Direct iron reduction in steelmaking
- NH_3 as a fuel (shipping, balancing power plants, industrial furnaces)
- H_2, CH_4, CH_3OH and synthetic HCs as electro fuels
  - *Better if the carbon is taken from the air*
- Enhancing biofuels/biogas production





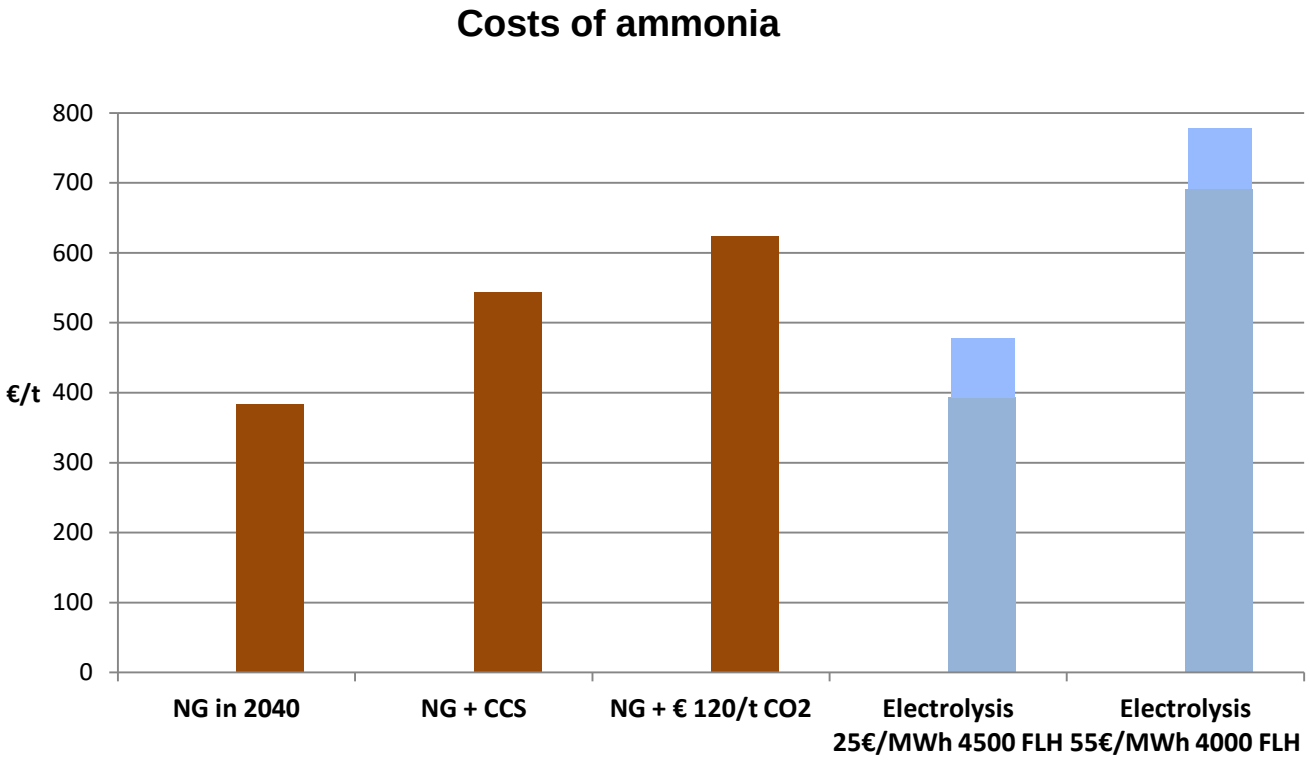
Renewable fuels and chemicals that are easy to ship and store will likely be traded from areas with vast resource to large consuming areas

Green hydrogen from water electrolysis can compete…



Beyond 20- 40% capacity factor the cost of electricity dominates the cost of hydrogen from electrolysis; With "surplus" electricity the cost of hydrogen increases rapidly if load factors fall below 3000 FLH

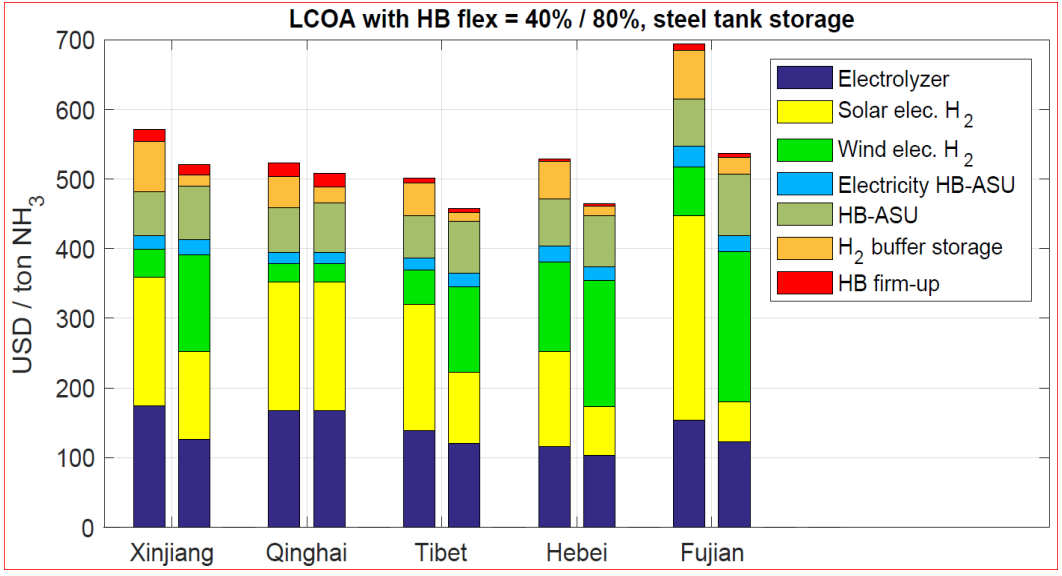
Green ammonia from NG reforming vs. water electrolysis

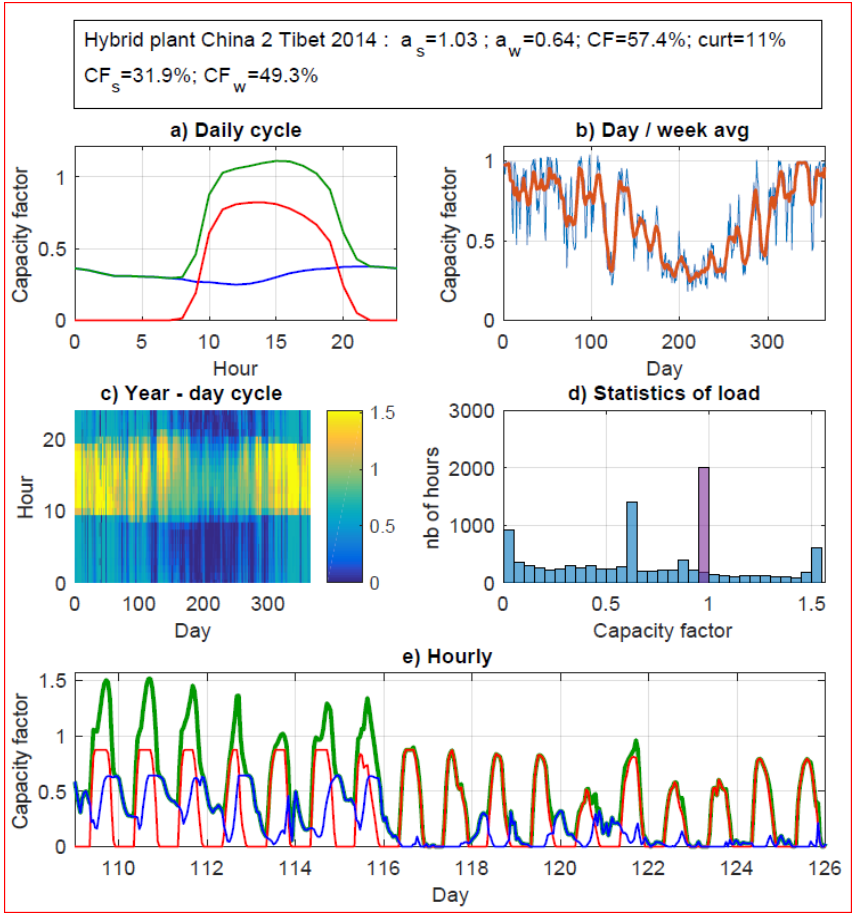


Producing green ammonia from renewables can compete with NG reforming with CCS in areas with excellent resources delivering low cost electricity with high capacity factors

Producing hydrogen and ammonia from variable solar and wind

- Optimising the production of hydrogen and ammonia from a combination of solar and wind power requires detailed hourly analysis
- Electrolysis of water and H.-B. process are flexible enough, but some H_2 buffer storage is necessary and potentially costly

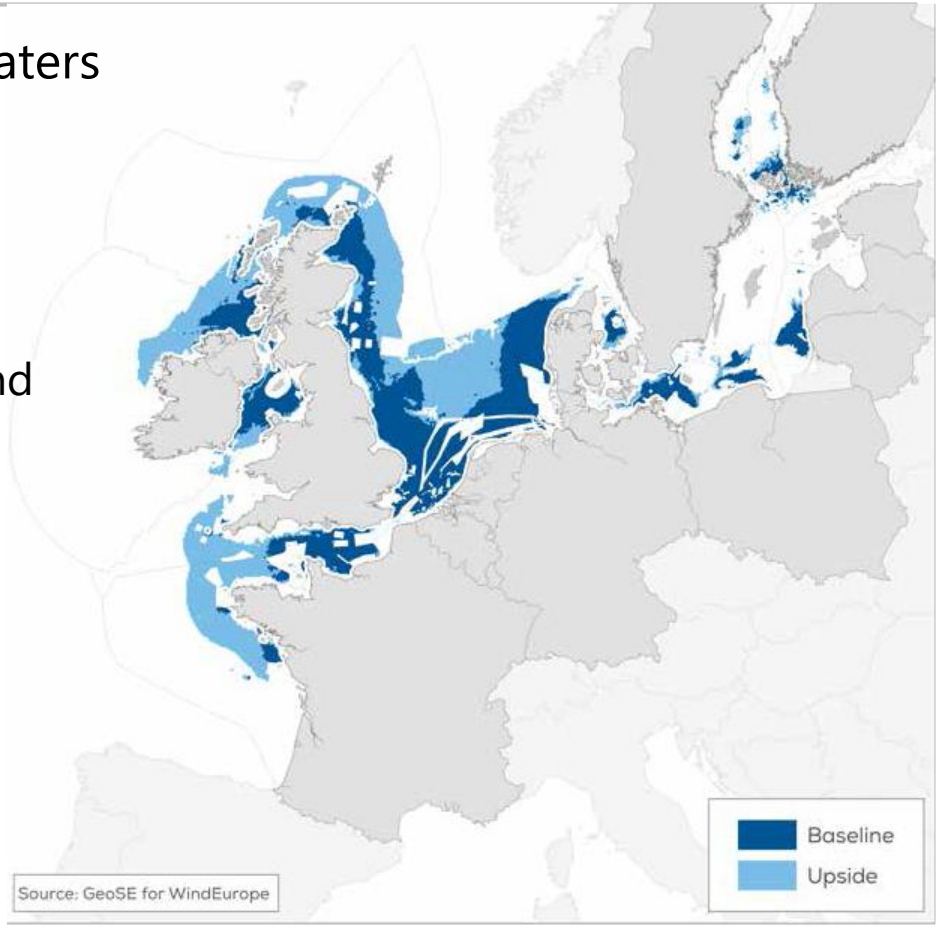




Offshore wind in Northern Europe: a large affordable potential

- Wind offshore potential in European waters is 2600 – 6000 TWh
- @ € 55 to 70/MWh (*WindEurope*)
- 80% to 180% of current elec. demand
- Possible additional uses:
  - Electrification of buildings, transport, and industries
    - Steelmaking: electrowinning or H_2-DRI
    - Chemicals – 1900-4900 TWh (Dechema)
    - Cement and others
  - Balancing power plants?
  - Heating and transport fuels?

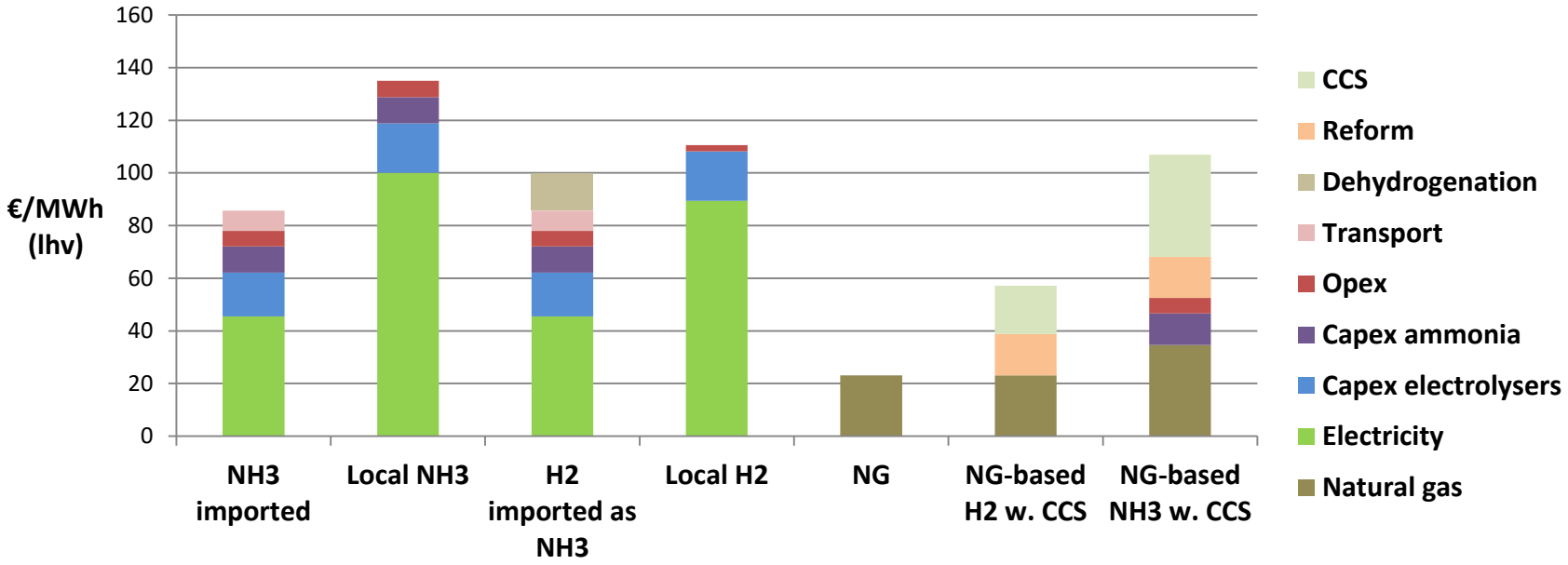
More: https://bit.ly/2XlR1Mn



Source: Hundleby and Freeman (2017)

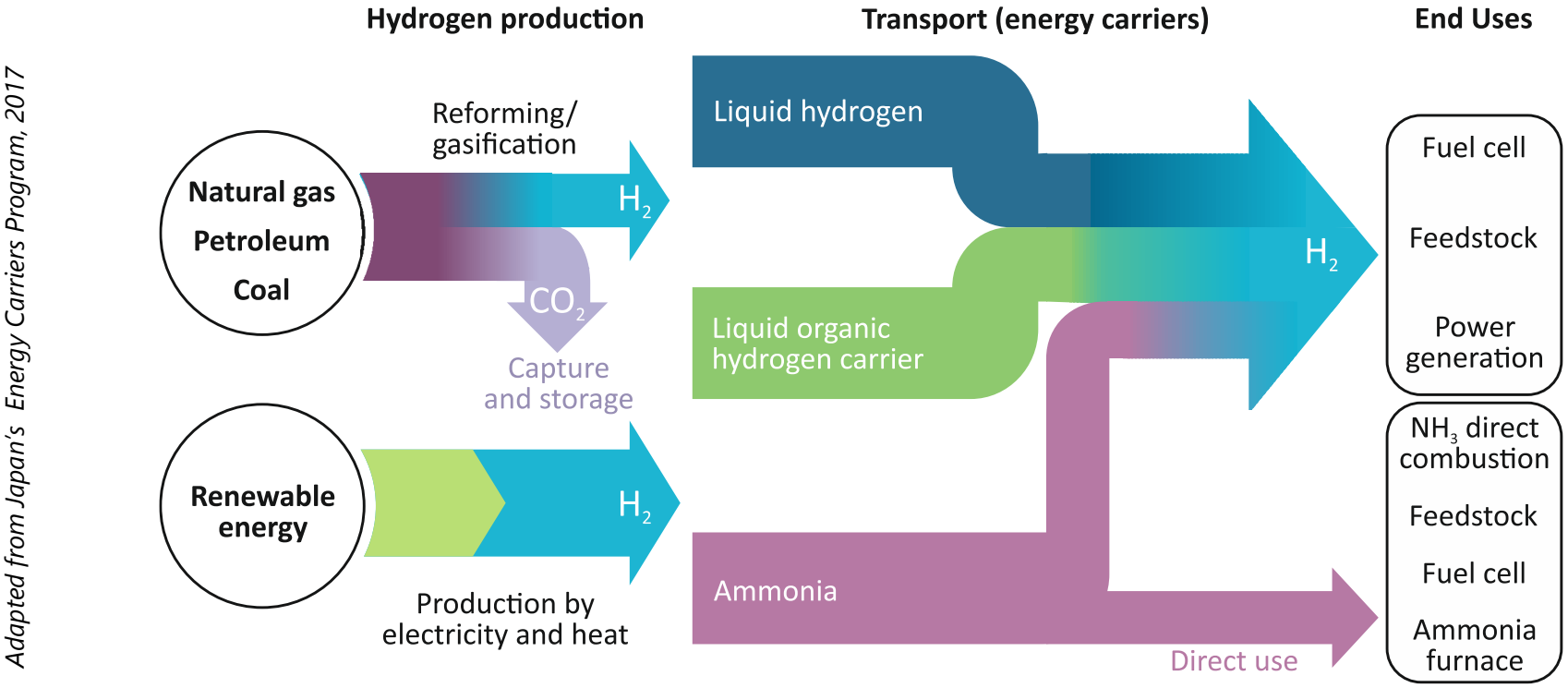
Low carbon NH_3 and H_2 energy options compared with NG

Costs of energy (lvh) in hydrogen from various sources and in natural gas, in Europe



If NH_3 is needed for as such, imports from best resource areas are cheaper; if pure H_2 is needed, SMR w. CCS is cheaper

Exploiting cheap RE will require massive trade



Adapted from Japan's Energy Carriers Program, 2017

Various hydrogen-rich feedstocks and fuels will likely be traded internationally, including ammonia, methanol, Fischer-Tropsch fuels… Other options may be relevant for dihydrogen