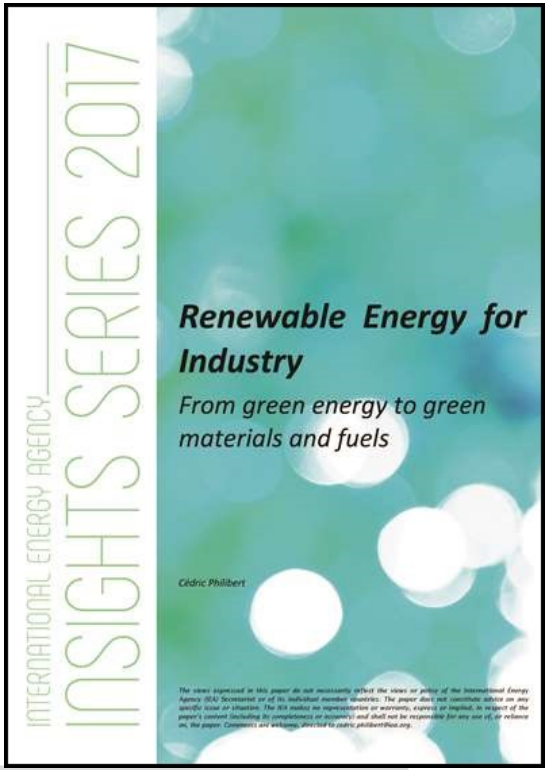
Download the report:
www.iea.org/publications/insights



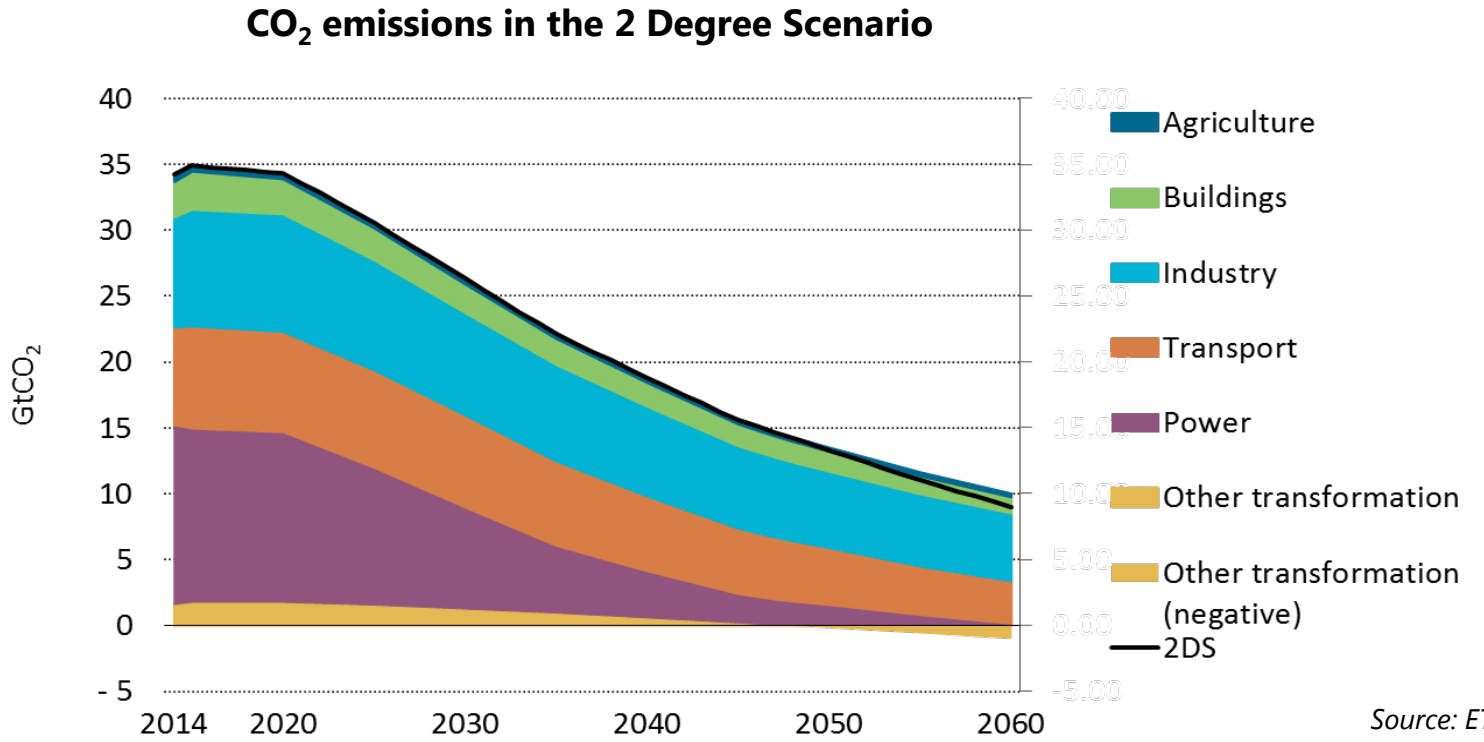
Renewable Energy for Industry

Cédric Philibert, Renewable Energy Division, International Energy Agency

JISEA Annual Meeting @ NREL, Golden, CO, 4 April 2018

IEA

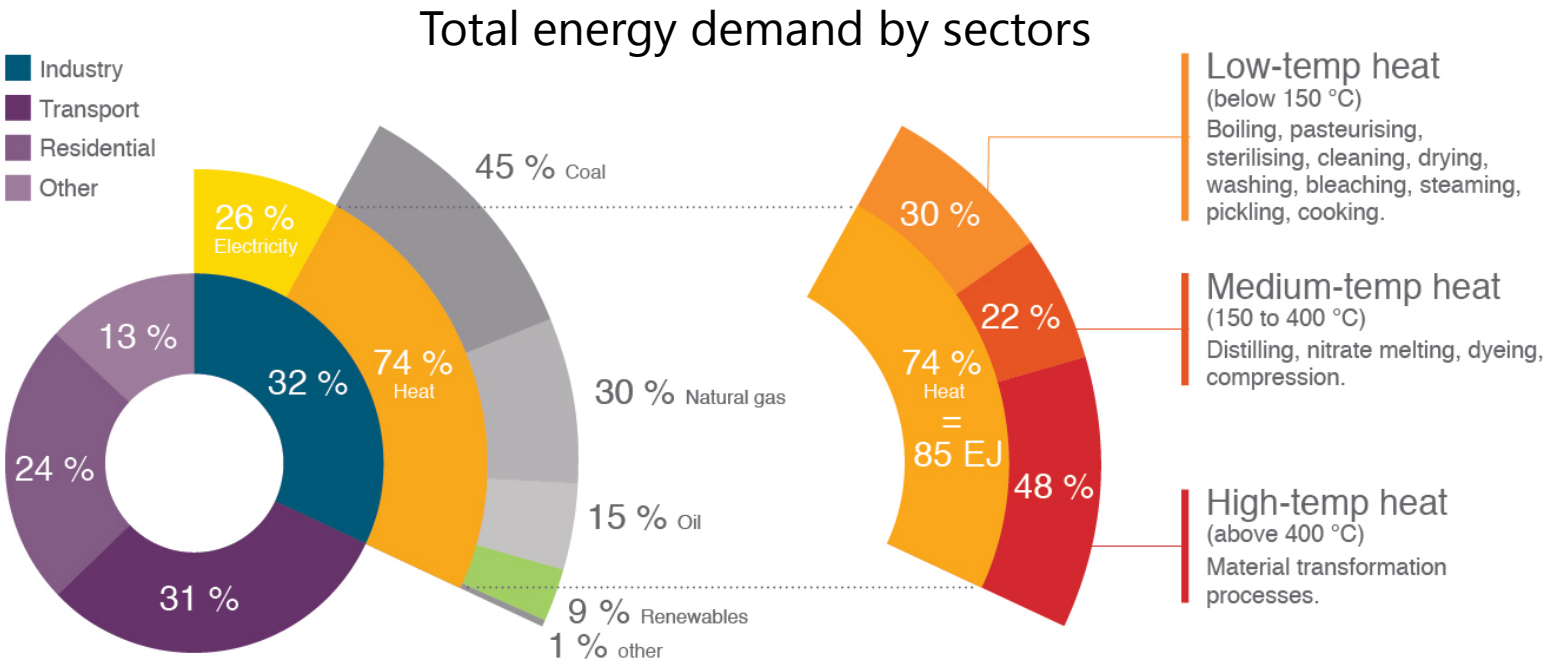
Industry represents a major issue for climate change



Source: ETP 2017

Cement, iron and steel, and chemicals responsible for the bulk of remaining industrial emissions in 2050.

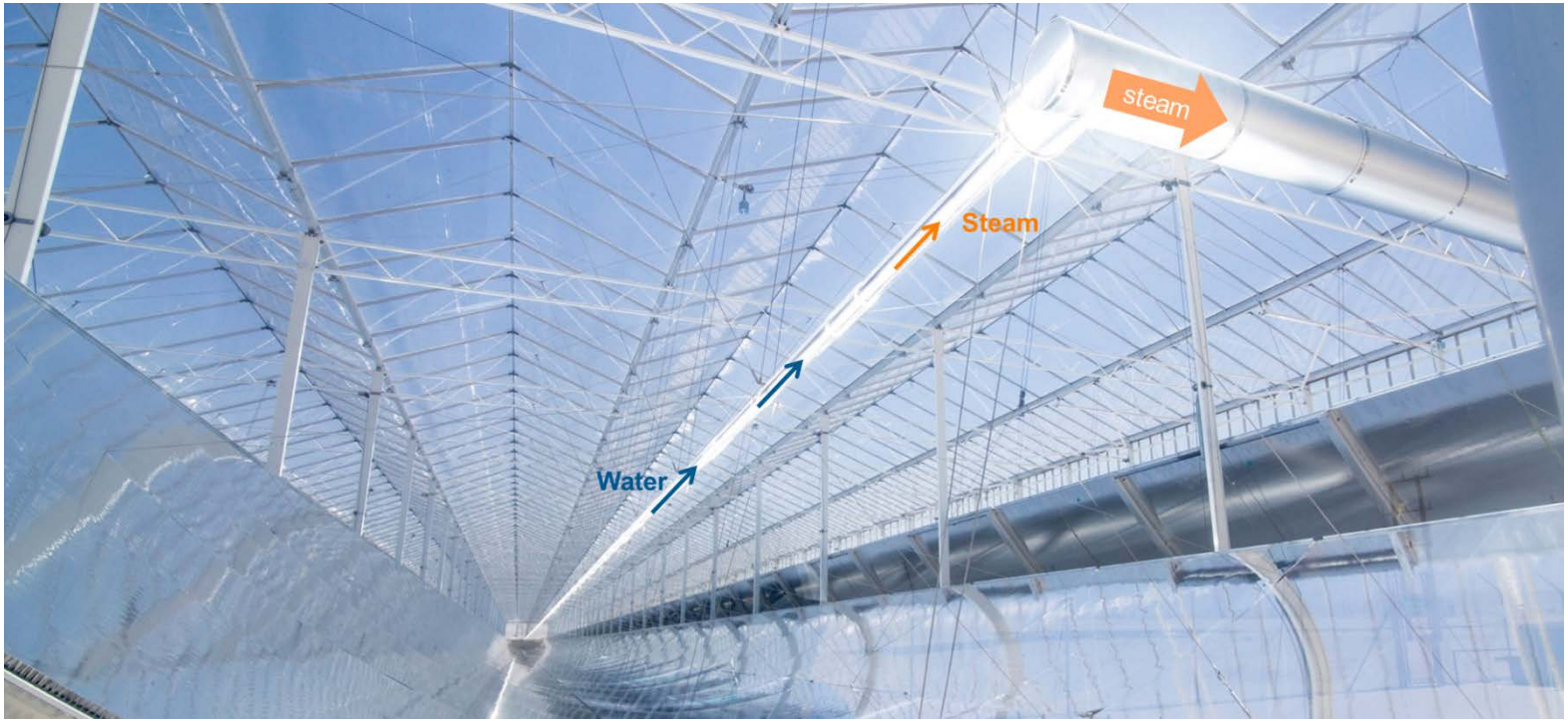
Industry remains dependent on fuel combustion for process heat



Source: Solrico, 2017

Heat represents three quarters of the energy demand of industries world-wide, and half of it is low to medium temperature heat, more easily supplied by direct renewable heat

Direct renewable heat is improving on various fronts

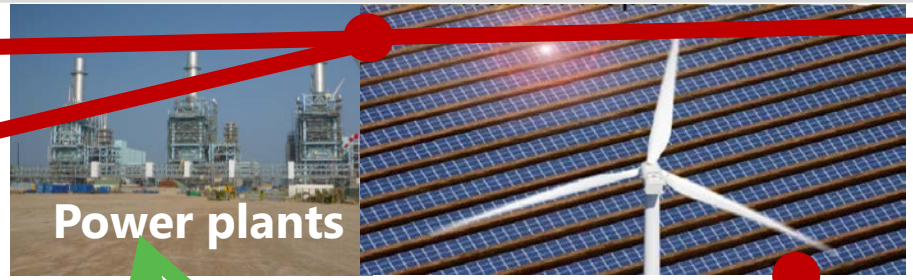


Source: Glasspoint, 2017

Enclosed troughs technology delivers significant cost reductions to solar heat, opening new applications such as enhanced oil recovery in Oman and California

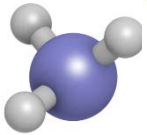
Renewable power can replace fossil fuels in many uses

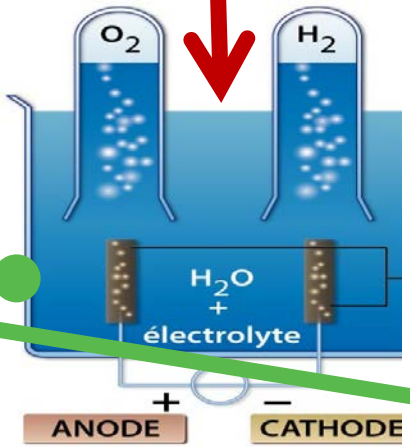
Buildings
Heating
Cooking
Lighting



Industry
Steam
Force
Electrolysis

Transports
EVs
H-rich fuels

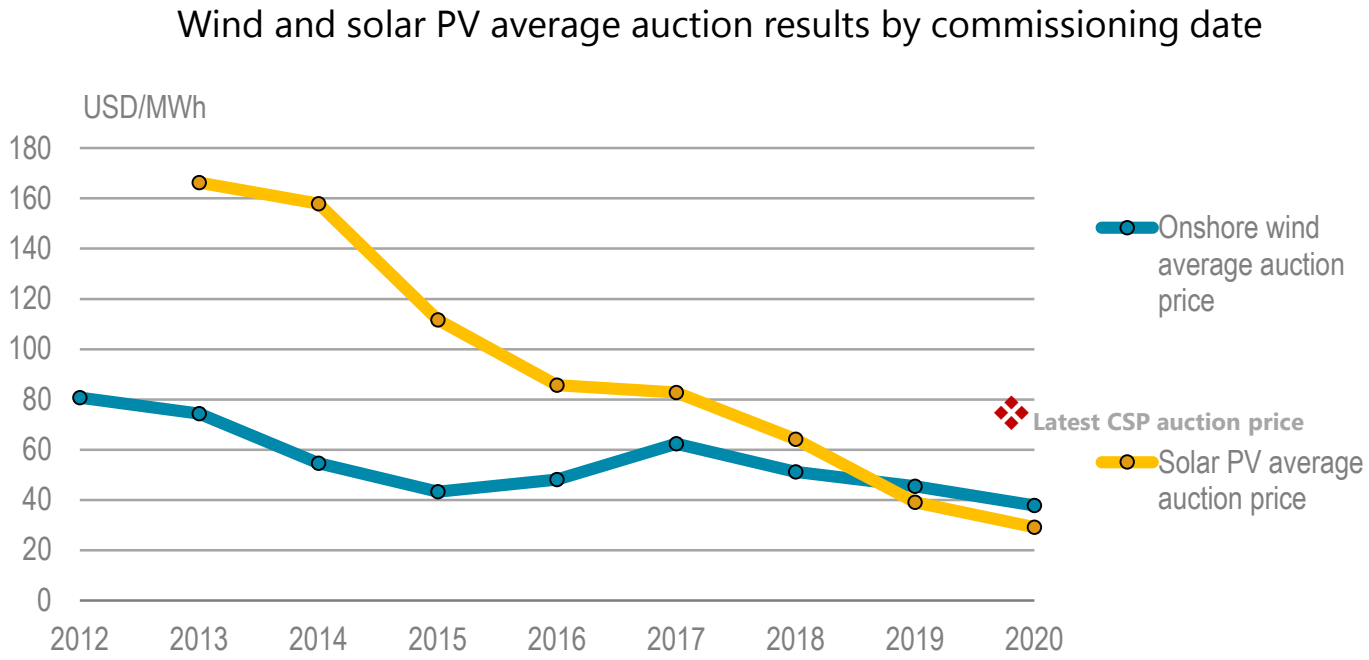




Feedstock, process agents, fuel

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

Wind and solar PV costs being driven down by competition



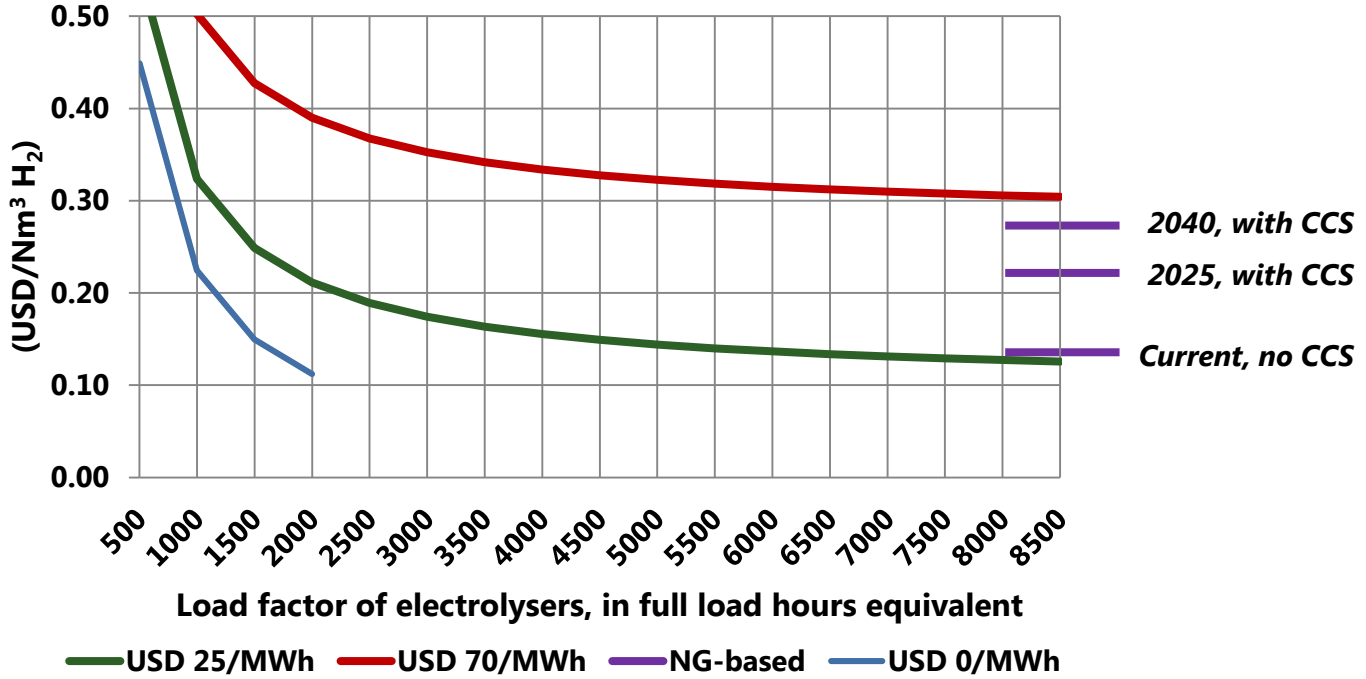
Source: Renewables 2017

The cost of wind and solar PV have fallen sharply, with further reductions expected;
Cost-optimal integration requires interconnections, flexible generation, storage & demand response

Hydrogen from electrolysis can be competitive

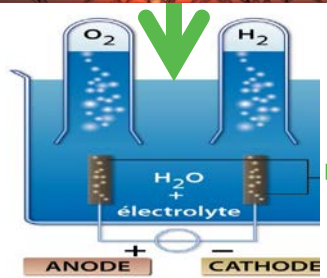
Assumptions: Capex electrolysers USD 450/kW$_{in}$ + 30% install. +20% Opex; lifetime 30 y; WACC 7%; efficiency 70%; H_2 from NG reforming based on gas prices in Europe (WEO 2017)

Cost of hydrogen from electrolysis for various electricity price and load factors



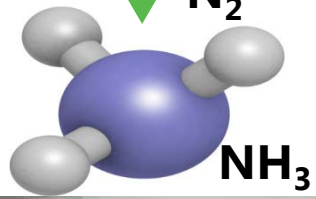
Beyond 4000 FLH the cost of electricity dominates the cost of hydrogen from electrolysis; With "surplus" electricity the cost of hydrogen increases rapidly if load factors fall below 2000 FLH

Ammonia: the other hydrogen, and a low-hanging fruit



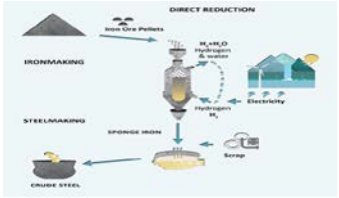
H_2

N_2



Precursor fertilizers industry

Process agent steel industry



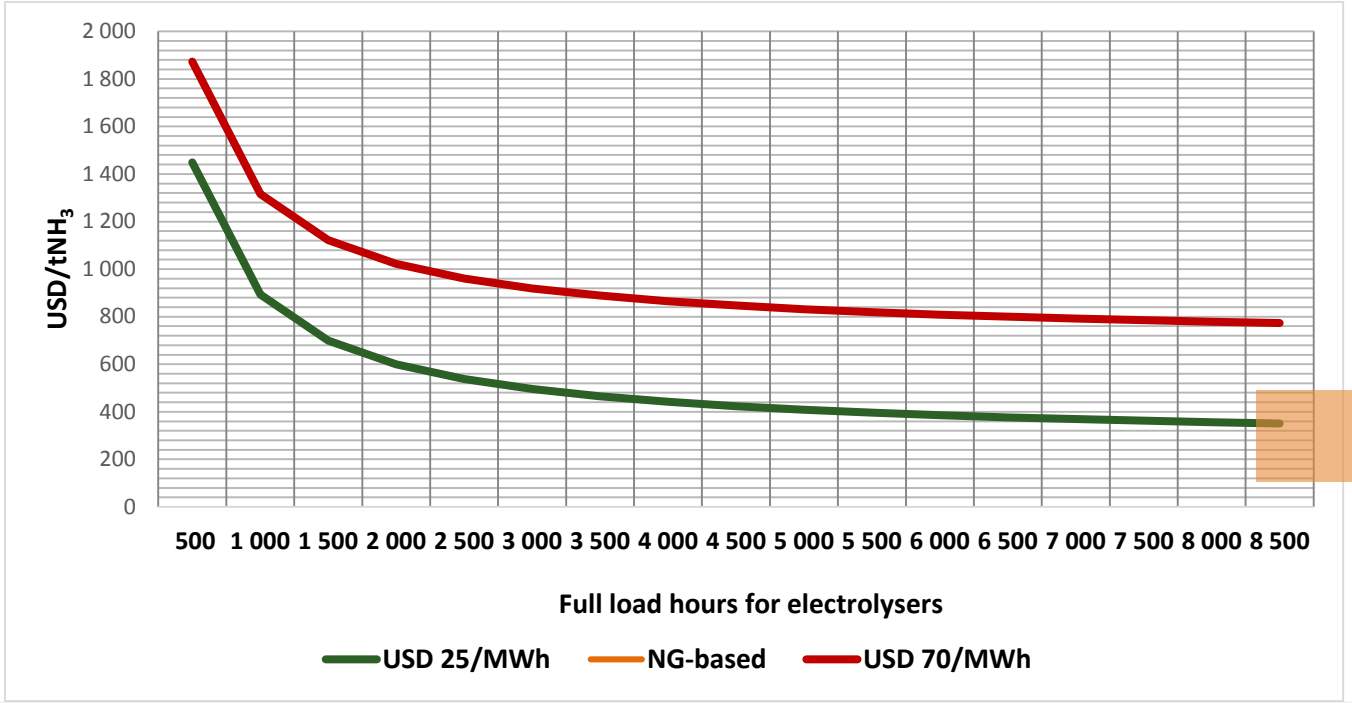
Fuel

Ammonia may have multiple uses in industry as feedstock, process agent and fuel

Renewables can compete with natural gas in producing ammonia

Additional assumptions: Capex NH_3 plant USD 382 million 500,000 t/y. Opex USD 14 to 37/tNH_3 (plus electricity).

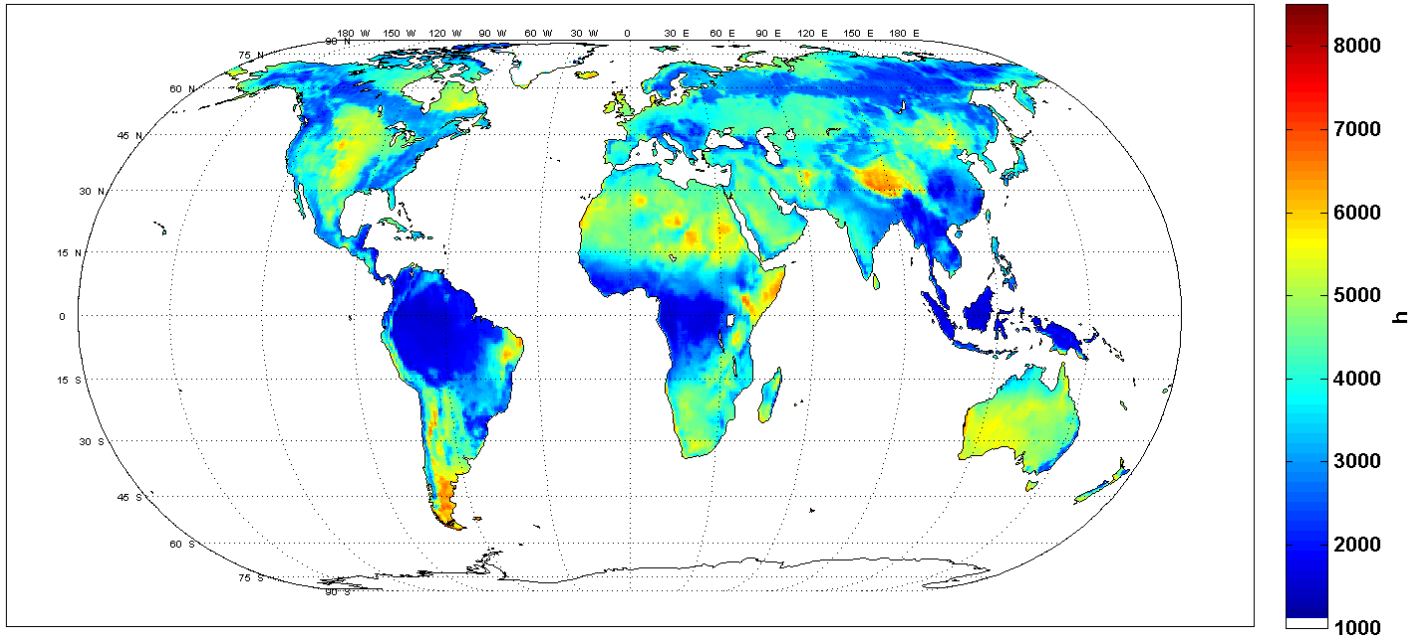
Cost of ammonia in all-electric plants for various electricity price and load factors



Below USD 30/MWh and with high capacity factors, renewables can run all-electric ammonia plants at competitive costs

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

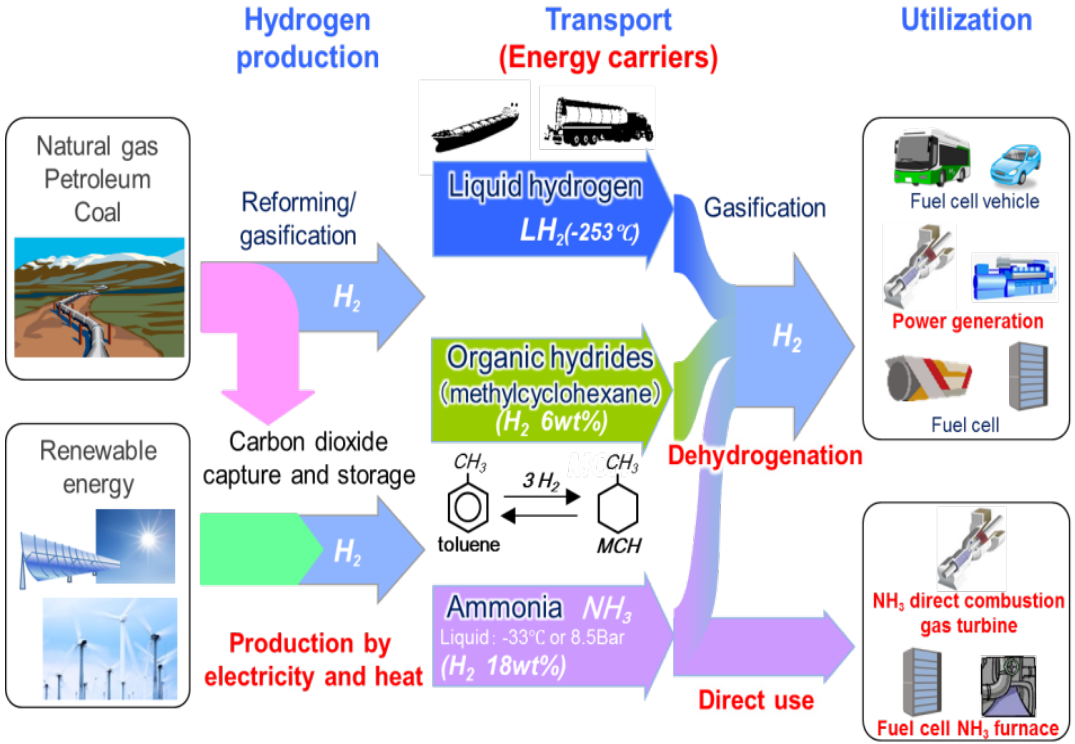
Hybrid solar and wind full load hours adjusted for overlap



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

Exploiting cheap RE will require massive trade



Source: Japan's Energy Carriers Program, 2017

Ammonia is rich in hydrogen, easy to store and ship, and may prove the most versatile carrier of renewable energy

Ammonia is also a fuel

- Works in combustion engines, turbines, fuel cells, directly/cracked
- 100-y safe handling in industry
- Stationary applications in power and industry sectors
- A possible fuel for boats
- Other vehicles: acceptability issues
- Power-to-power efficiency better than other fuels for long-term storage
  - Pumped-storage hydropower and batteries more efficient short-term storage options

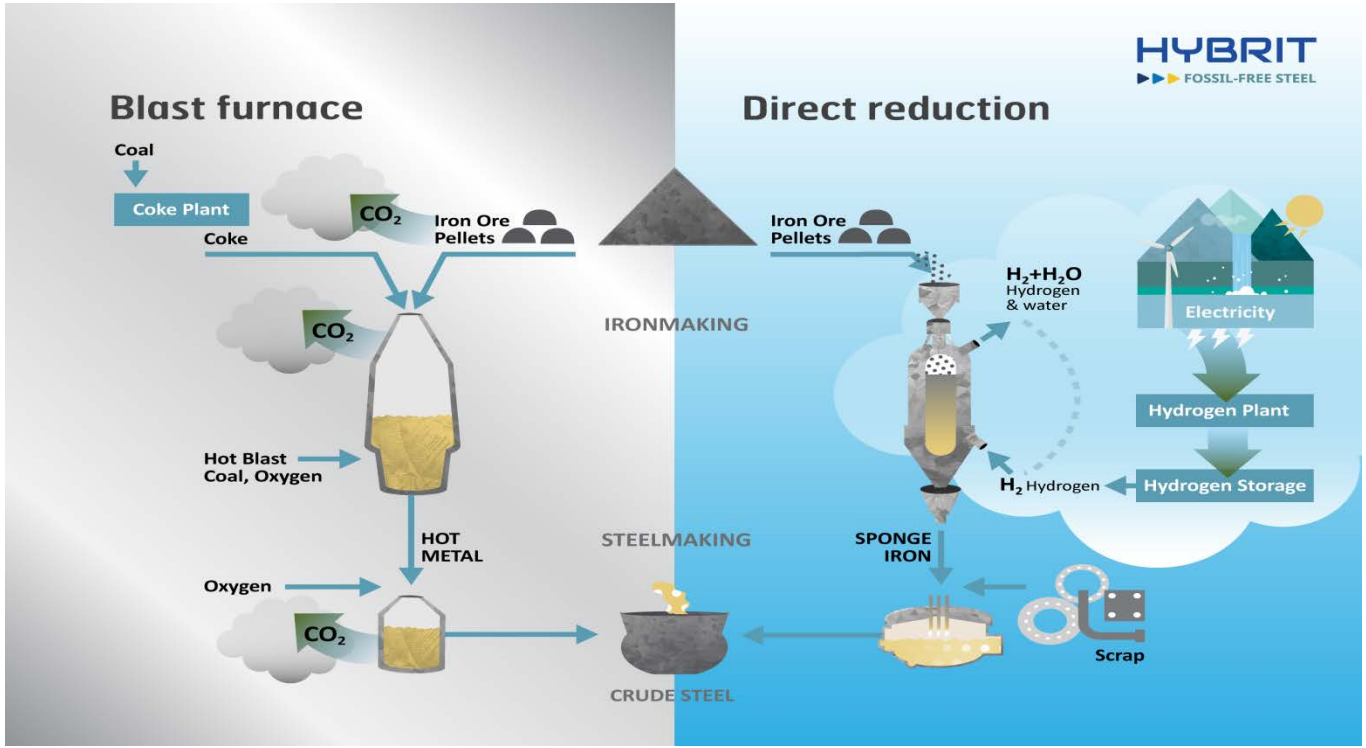
Power to power efficiency

Fuel	PtP efficiency CO_2 from air	PtP efficiency CO_2 from fumes
CH_4	27%	31%
MeOH	27%	32%
DME	23%	28%
NH_3	35%	
NH3 PEM	*29%*	
NH3 SOEC	*39%*	

Sources: Grinberg Dana et al, 2017

Ammonia can be used as a carbon-free fuel in various ways, which must be further developed

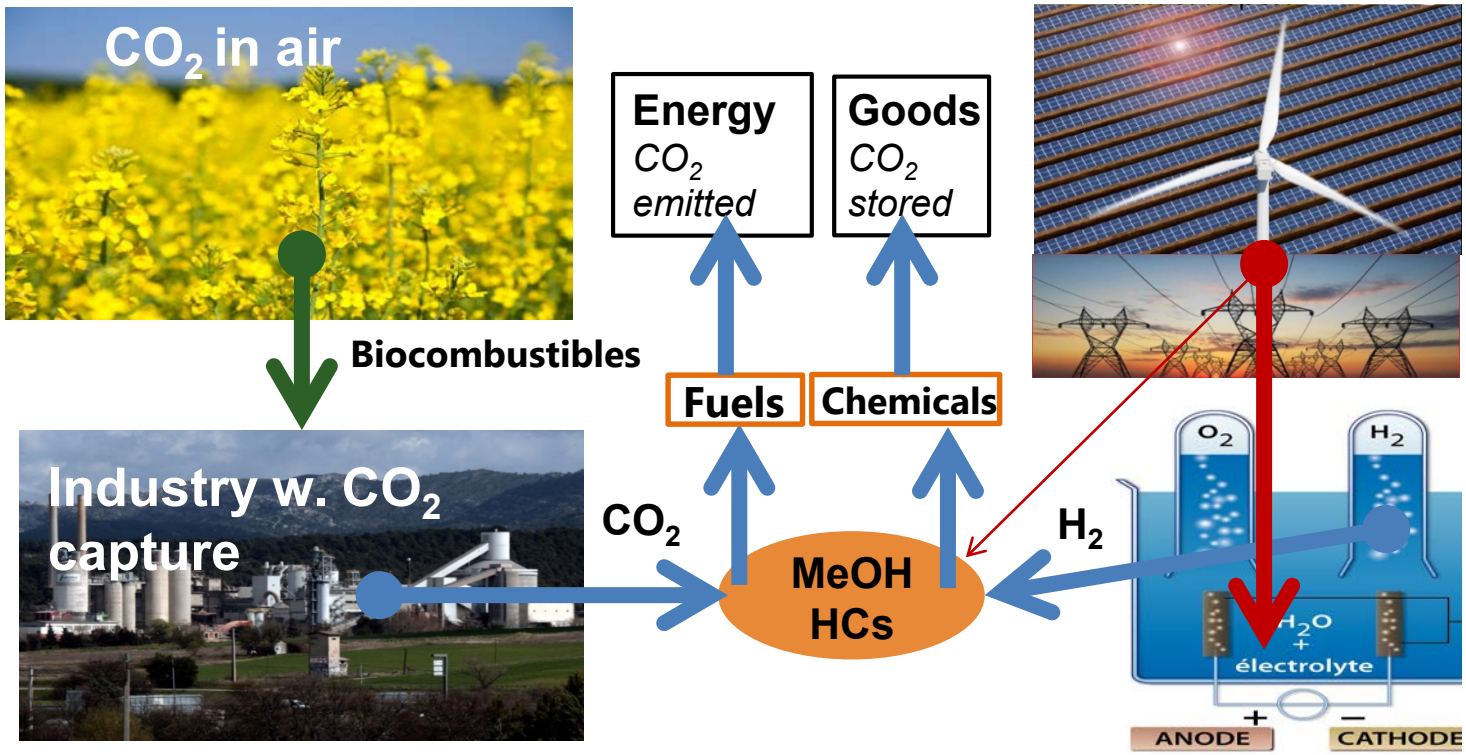
Renewable power can make CO_2-free iron and steel



Sources: Hybrit Projekt, 2017

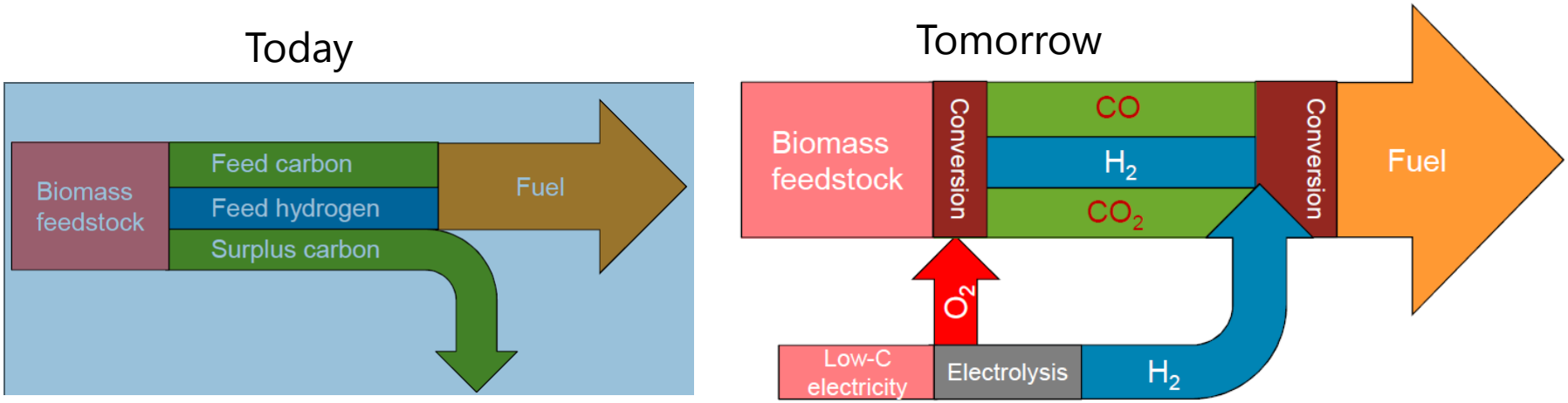
Substituting sync. gas with hydrogen for direct iron reduction may be phased in gradually; electrowinning is another, less mature option

Renewable hydrogen can be combined with recycled CO_2



Manufacturing methanol from renewables-based water electrolysis and recycled CO_2 would strongly reduce life-cycle CO_2 emissions and could drive negative emissions

Multiplying the use of constrained biomass feedstock

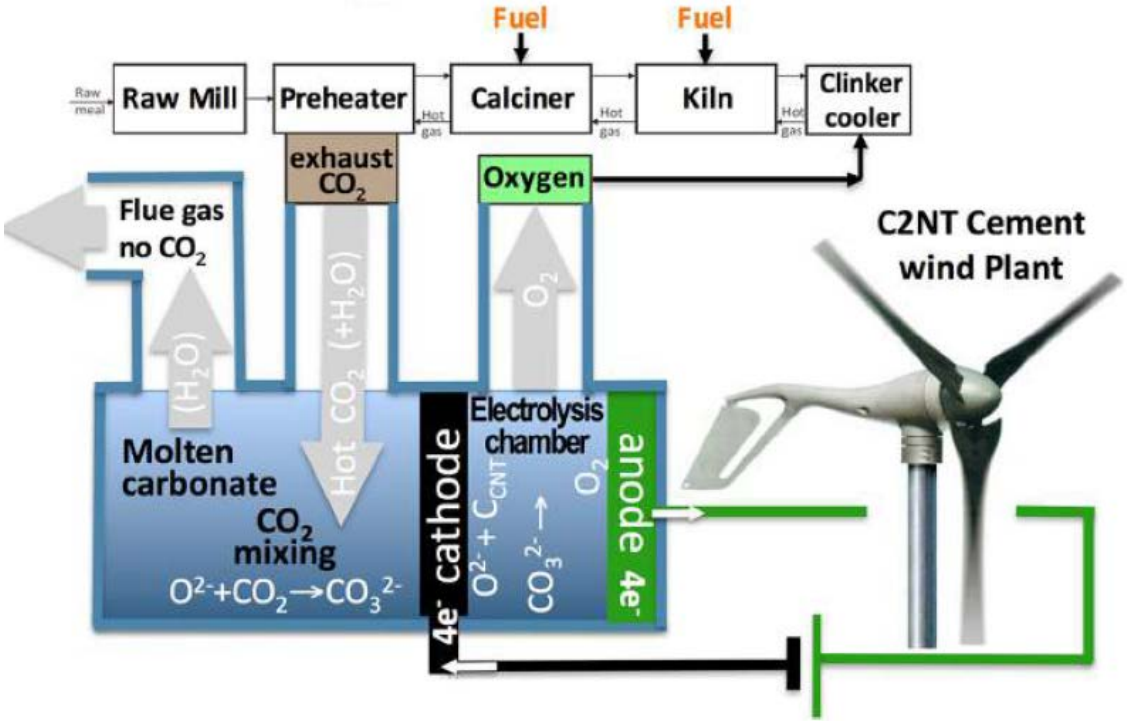


Source: Hannula, 2016

Using hydrogen and oxygen from renewable-based water electrolysis can augment the potential of biomass in converting CO_2 into fuel

Electrolysis might allow for CO_2-free cement manufacturing

Concept scheme of co-production of cement and carbon nanotubes



Source: Stuart Licht, Journal of CO_2 utilization, 2017

Still at lab-scale, molten carbonate electrolysis run on solar and wind could be coupled with an oxyfuel cement factory and produce high-value carbon nanotubes instead of CO_2

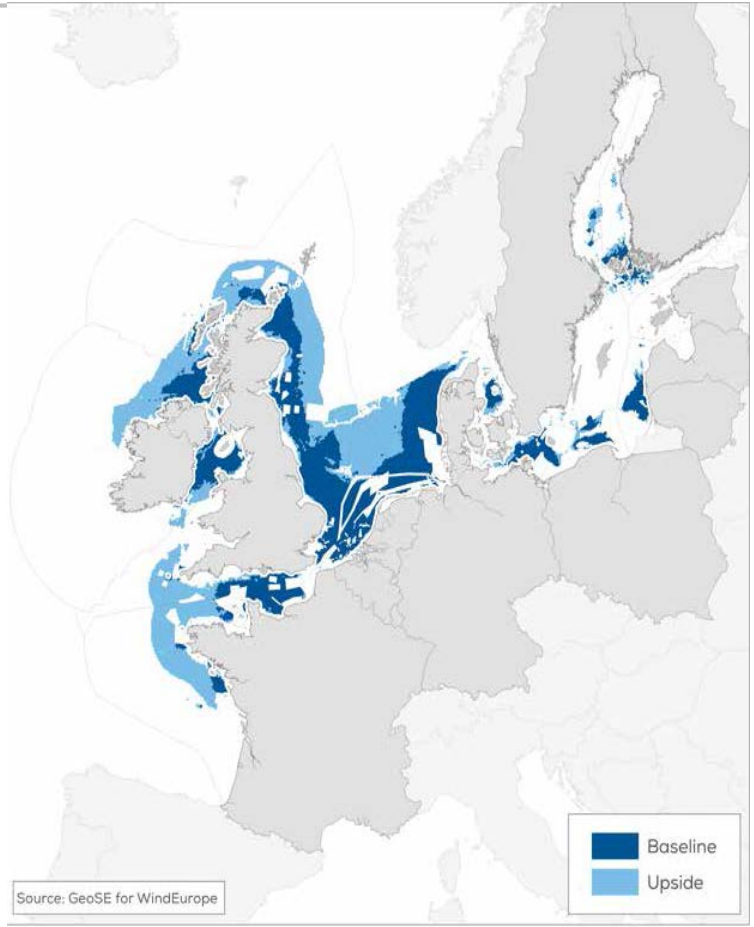
Policy options

- De-risking investment is key – as always
- Carbon pricing would improve competitiveness
- Risks of carbon leakage for heavily-traded commodities
  - Reconsidering the carbon leakage issue and identifying win-win strategies will help fostering RE deployment in most favourable areas - and vice-versa
  - Global sectoral agreements?
  - Border carbon adjustments? Standards?
- Procurement of green materials could help jump-start deployment
  - Private by Business-to-Consumer companies, public for infrastructures

A new era of international collaboration is required to foster global decarbonisation of industry

Forthcoming: REfI from offshore wind in Northern Europe

- Wind offshore potential in European waters is 2600 – 6000 TWh @ € 50 to 65/MWh (*WindEurope*)
  - = 80% to 180% of EU power demand by 2030
- Possible additional uses:
  - Steelmaking: electrowinning, H_2-DRI
  - Partial electrification of cement making?
  - Chemicals – 1900-4900 TWh (Dechema)
    - CCU or biomass to provide carbon feedstock
  - Balancing power plants (~800 TWh)
  - Heating and transport fuels: many more TWh
- Costs higher than NG+CCS in most cases but:
  - Reduced price volatility
  - Increased energy security
- Storable and transportable products may rather be imported from North Africa



Source: Hundleby and Freeman (2017)

Concluding remarks

- Industrial air pollutants and CO_2 emissions must be addressed
- The recent rapid cost reduction of solar PV and wind power opens new possibilities for greening the industry
  - Directly with electricity
  - With hydrogen-rich chemicals, including ammonia, as feedstocks, process agents and fuels
- Electrification of industry can help integrate variable renewables.
- RE for industry creates new Terawatt-scale market opportunities for PV and wind
  - International collaboration should facilitate new forms of international energy trade

Breaking news!

Offshore wind to power Chinese petrochemical industries

- TIANJIN, March 29 (Xinhua) -- Tianjin Economic and Technological Development Area (TEDA) has signed a contact to build an offshore wind power station to power its petrochemical industries.
- The TEDA signed the contract with China Three Gorges New Energy Co., Ltd on a 18-billion-yuan power base with an annual generation capacity around 2.4 billion kilowatt hours, enough to power ten medium-sized petrochemical factories.
- The project requires approval from the central planners and construction is expected to begin in 2020.
- The first phase of the project will cover around 20,000 square meters offshore in the the Nangang Industrial Zone in Tianjin.
- "The potential of offshore wind power is huge. Such big project will attract high-end manufacturers," said Li Bin, director of Three Gorges New Energy.
- Wang Junming, deputy director of TEDA management committee, said the power generated will greatly reduce reliance on coal and gas.