Electro fuels – an introduction

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EC-IEA Workshop on Electro fuels, Brussels, 10 Sept 2018

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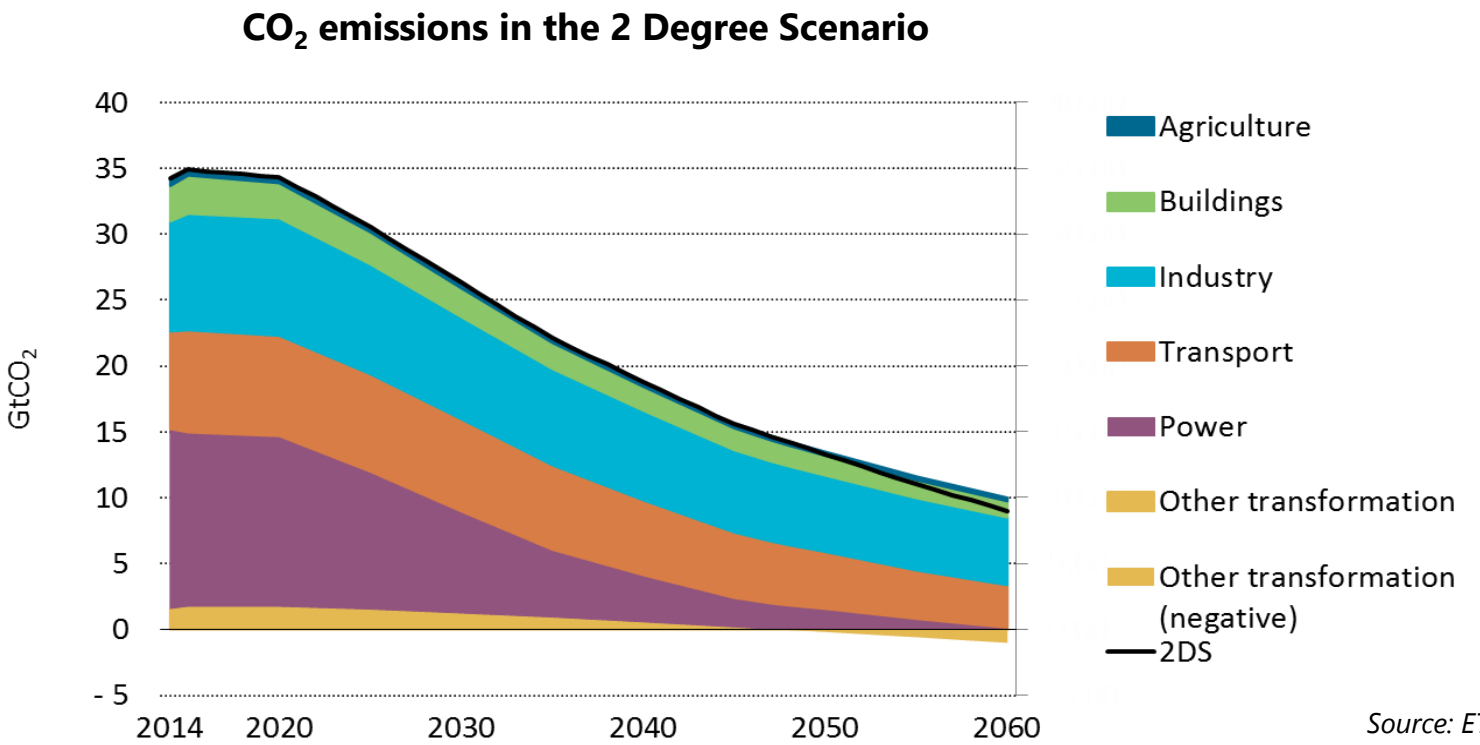
Industry and transports: the hard-to-abate sectors



Source: ETP 2017

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

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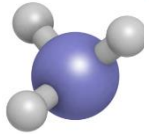
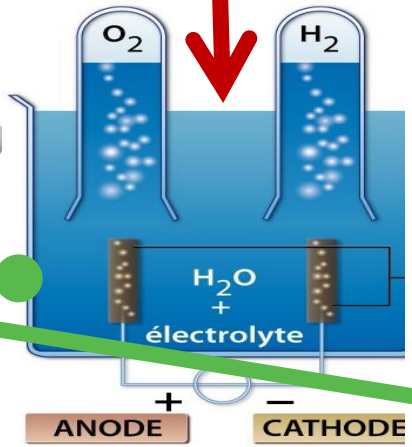
Renewable power can replace fossil fuels in many uses

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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Electro fuels: a broad definition

	Without carbon	Containing carbon
Gaseous	Hydrogen gas (H_2)	Methane (CH_4)
Liquids	Ammonia (NH_3)	Alcohols (C_xH_yOH) Hydrocarbons (C_xH_y)

There is a great diversity of options for electro fuels, all based on hydrogen, which may correspond to different needs and uses

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Different ways of producing hydrogen

- **Steam methane reforming /Coal or oil gasification - dominant**
  - $CH_4 + 2H_2O \xrightarrow[heat]{} CO_2 + 4H_2$
- **Electrolysis of water – coming back with renewables?**
  - $2H_2O \xrightarrow[elec]{} O_2 + 2H_2$
- **Methane splitting with green power - emerging**
  - $CH_4 \xrightarrow[elec]{} C + 2H_2$

Electro fuels

Over 95% of hydrogen today is produced from fossil fuels with large CO_2 emissions

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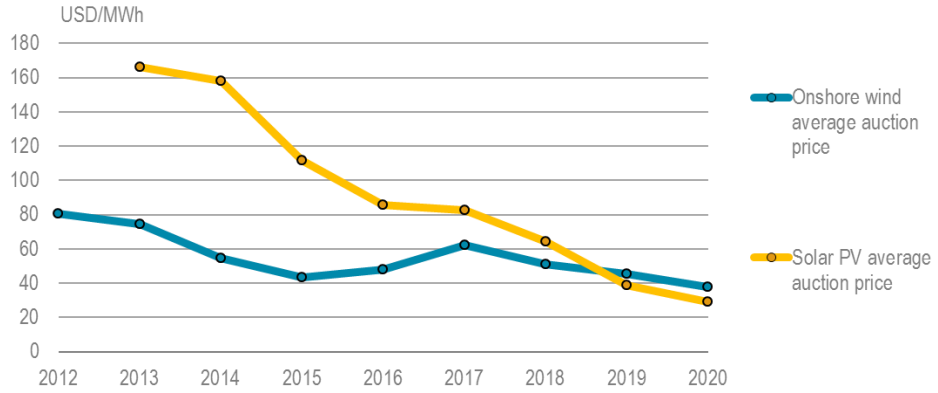
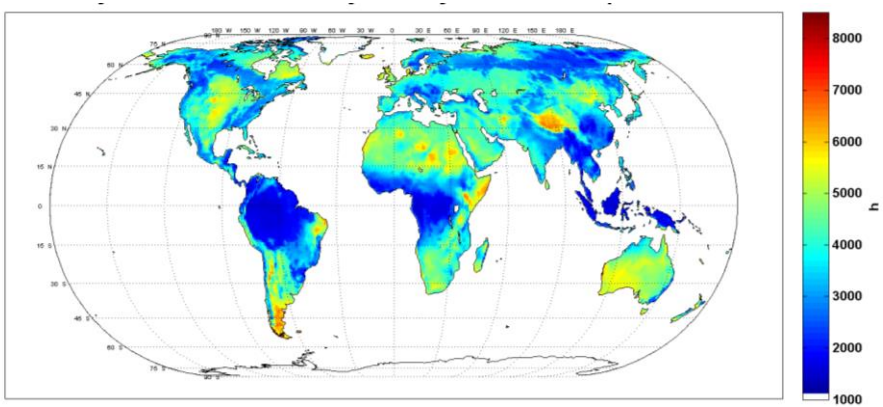
The emergence of low-cost renewable power is a game-changer

Average auction prices by commission dates



Source: IEA, Renewables 2017

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

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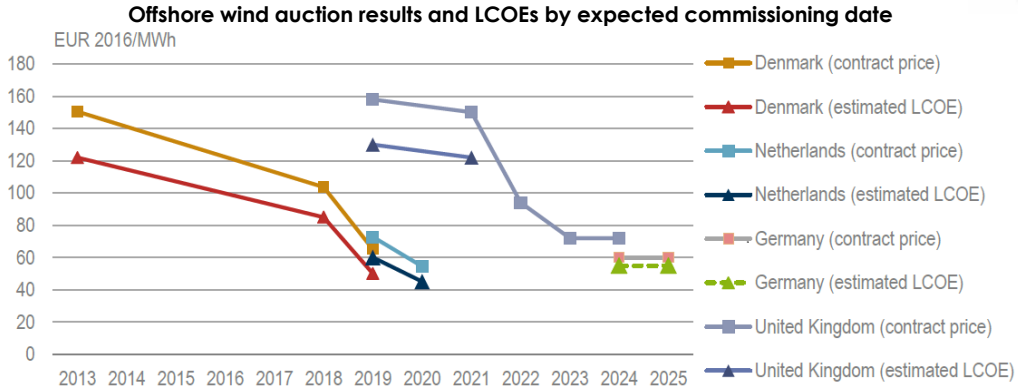
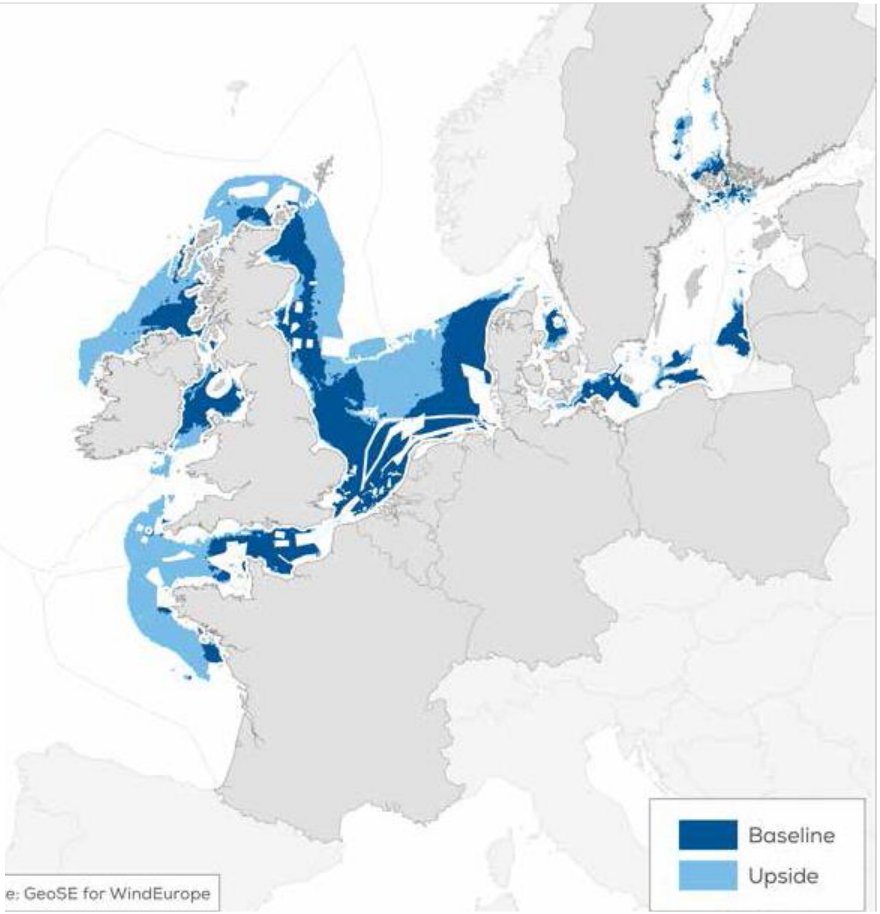
Offshore wind in Northern Europe: a large affordable potential

- Wind offshore potential in European waters is 2600 – 6000 TWh
- @ € 55 to 70/MWh (*WindEurope*)
- Possible additional uses:
  - Partial electrification of industries
  - Balancing power plants
  - Heating and transport fuels





Source: Hundleby and Freeman (2017)

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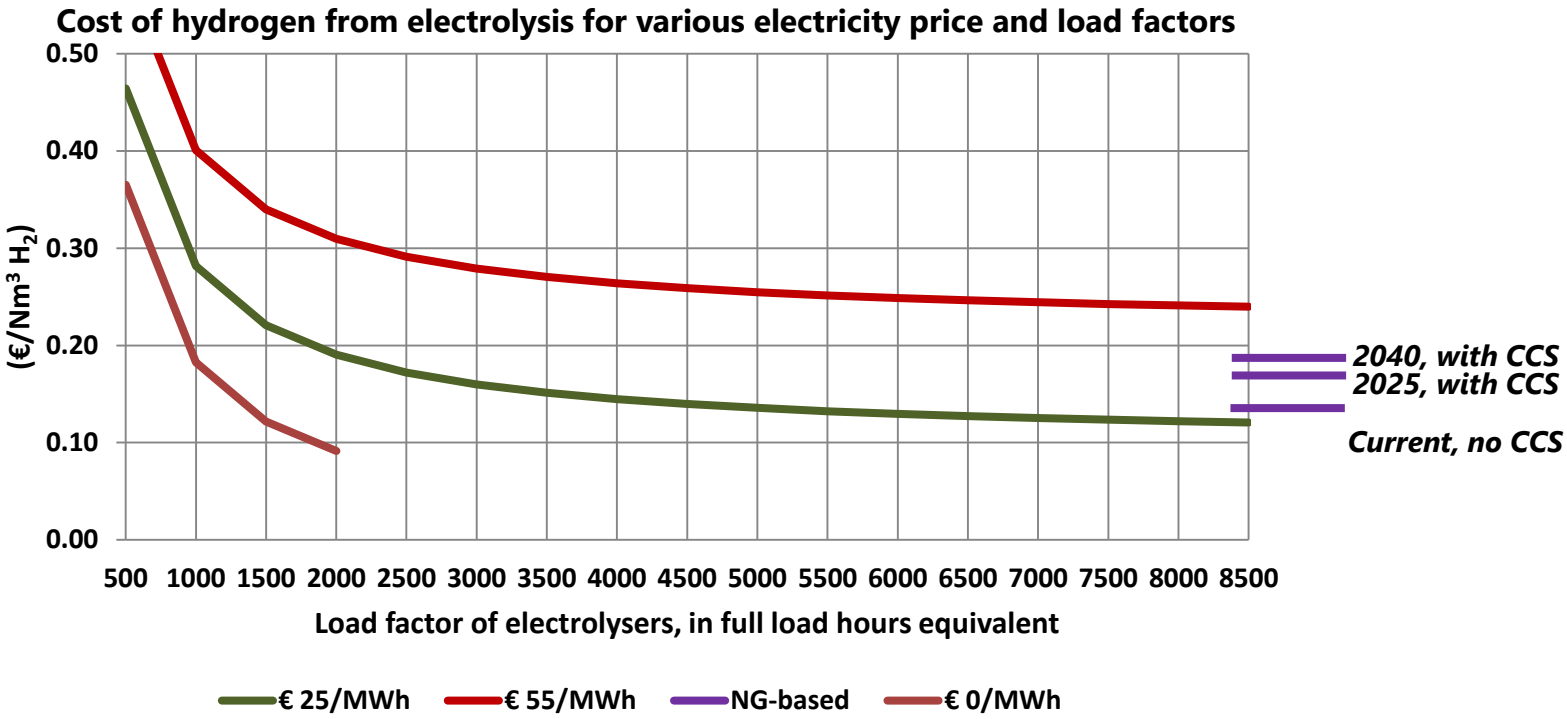
Green hydrogen from water electrolysis can compete…

Assumptions: Capex electrolysers € 366/kW$_{in}$ + 30% install. +20% Opex; lifetime 30 y; WACC 7%; efficiency 70%; H_2 from NG reforming based on gas prices in Europe (SDS - WEO 2017)



Beyond 50% 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

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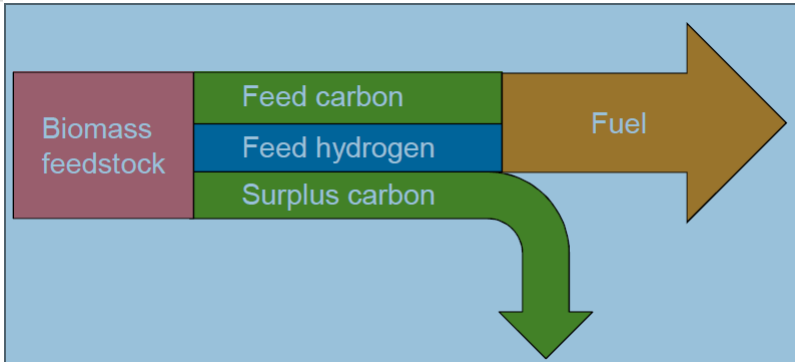
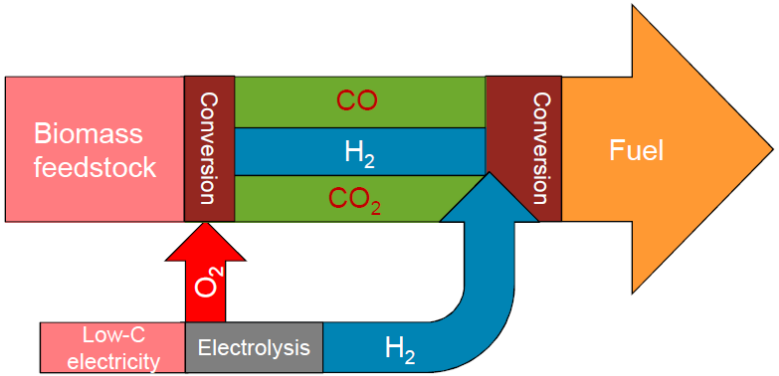
Sustainability issue: only carbon from air for electro hydrocarbons?

- Combine green hydrogen with carbon…
- Sustainable options:
  - Capture from a plant run on plants
  - Direct air capture
  - Hydrogen-enhanced biofuel production
- Transition options:
  - Capture from plants run on fossils
  - *Fine if unavoidable emissions*
  - *Real effectiveness must be analysed in comparing all other pathways*
  - *Risk of creating absurd situations*





Economic, environmental and social aspects of electro fuels must be taken in account

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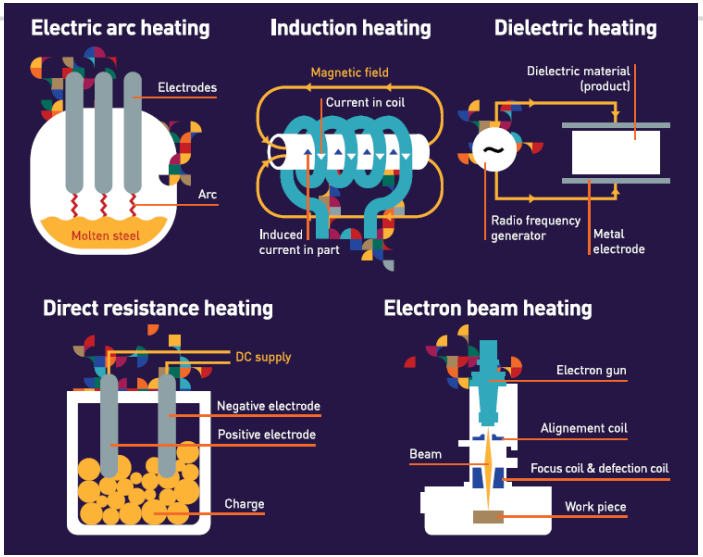
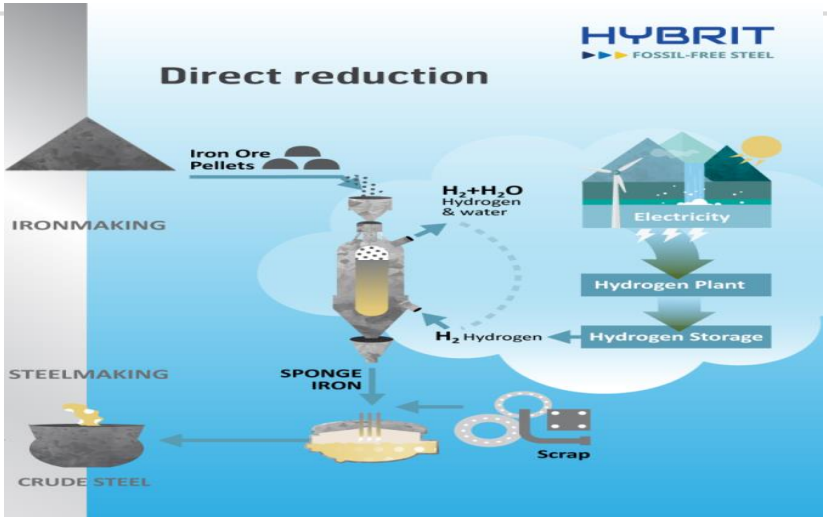
Electro fuels to complement electrification in industry





- Options for electrification
  - Electro-magnetic technologies
  - Heat pumps/mechanical vapour recompression
  - Resistance bypassing fossil fuels
- Hydrogen as feedstock/reactant
  - Greening industrial ammonia
  - Refineries (contribute to cleaning fuels)
  - Direct iron reduction in steelmaking
- Hydrogen or ammonia as a fuel

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Electro fuels to complement electrification in transports

- Direct electrification more efficient
  - Real range needs should be considered carefully
- On-the-move electrification is an option for long haul trucking
  - Eggs and chicken problem
- Battery busses, trolley-busses and tramways excellent city options
- Hydrogen fuel cell vehicles vs. synthetic gasoline/diesel fuel
- Ammonia & biofuels best options for maritime transportation
  - Can be used in existing vessels
- Hydrocarbons likely to remain needed for aviation
  - Best in volumetric and gravimetric densities
  - Hydrogen-enhanced biofuels the preferred option?

Direct electrification efficiently drives the change in transport
Electro fuels will find effective uses in transport

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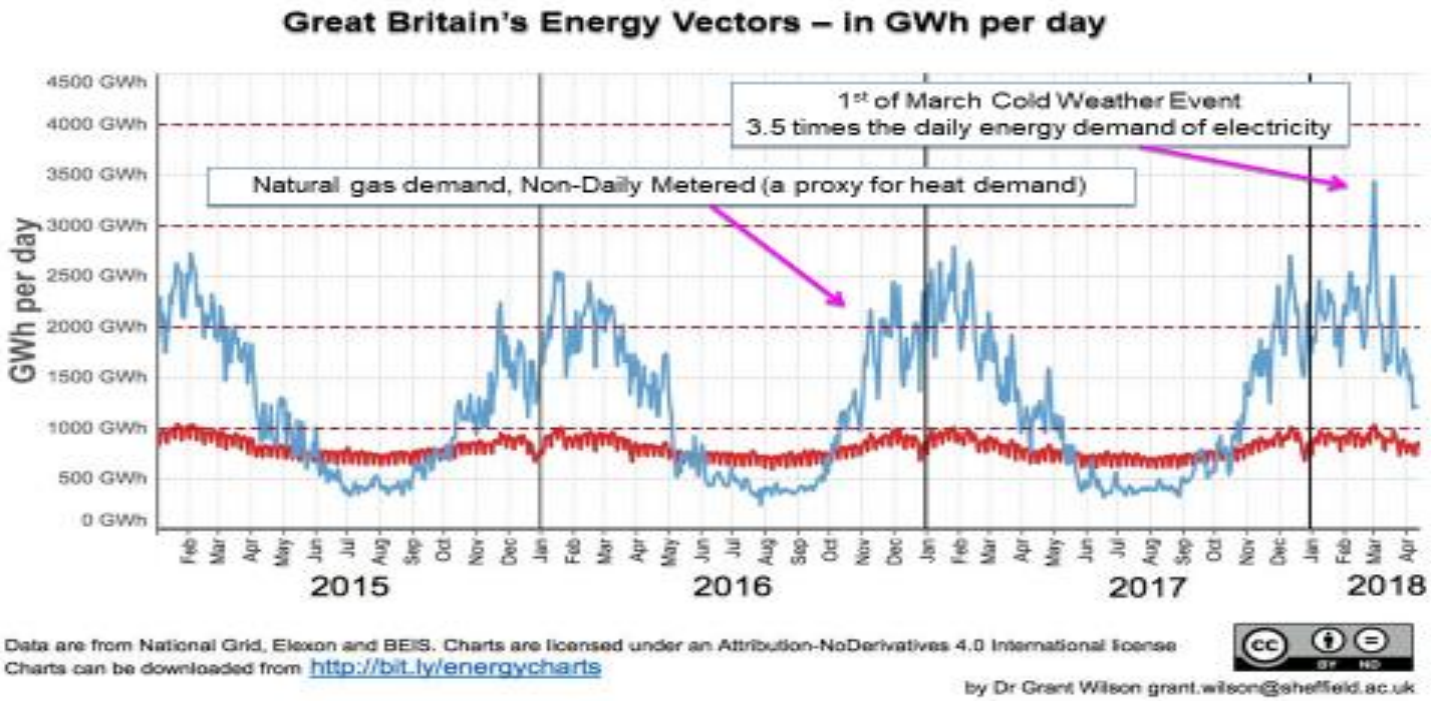
Electro fuels to complement electrification in buildings

Electricity and natural gas demand for heat in the U.K.



Electrification of heat can short term integration of renewables, but may aggravate the seasonal imbalance of the power demand. Green gases may be called to help

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Electro fuels to provide additional flexibility in power systems

- Interconnections and demand side response major flexibility options
- Pumped-storage hydropower and batteries excellent for short term storage
- Seasonnal storage needs chemical conversion
  To store 250 GWh over half a year:
  - Batteries cost 100 **bn $** (cost 400$/kWh)
  - Ammonia tanks cost 100 **M $** + combustion
  - Storing hydrogen gas cost-effectively requires availability of salt caverns

Power to power efficiencies

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%*	

Hydrogen-based storage is less efficient than than battery and PSH
It remains the most realistic option for long duration storage

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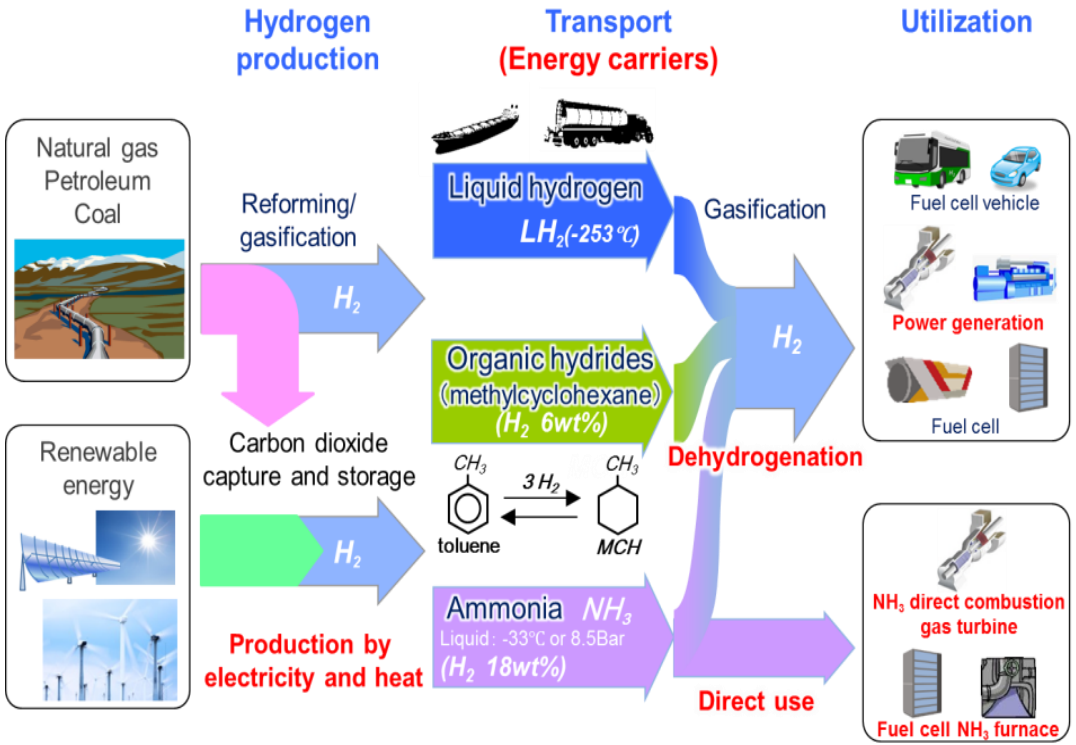
Exploiting cheap RE will require massive trade



Source: Japan's Energy Carriers Program, 2017

Japan is considering liquefied hydrogen, organic hydrides and ammonia as possible energy carriers from Australia and Middle East to Japan – with a growing preference for ammonia

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Where to start from?

- Multiple drivers
  - In industry, greening H_2 uses and develop new ones, such as green steel
  - In transports, to fill the niches where direct electrification appears impossible
  - In buildings, to benefit from existing gas networks
  - In power systems, to provide additional flexibility options
  - As a way to harness cheap but stranded (remote) renewable resources
- Public support/decision needed for R, D&D, and infrastructure
  - Network effects and learning through mass deployment needed
  - Benefits of scale production vs. better adaptation to each sector needs
  - Thorough analyses can reduce the risks associated with “picking the winners”

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

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