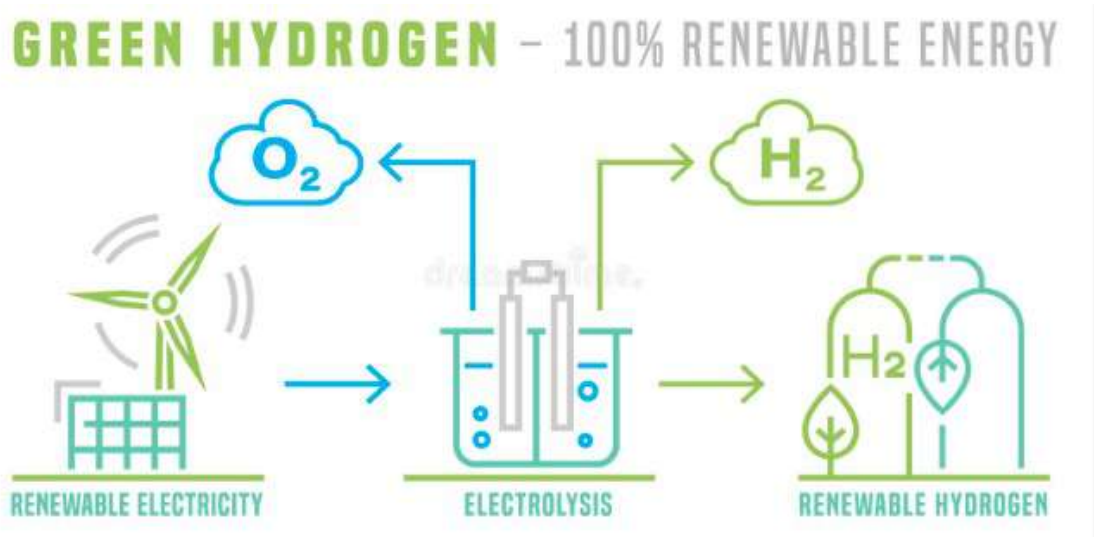
Challenges for large scale green H_2 and CCU projects

Brussels, August 2022



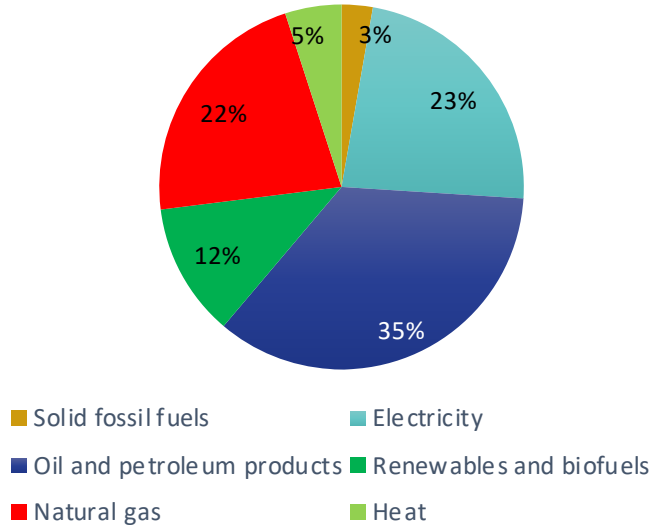
Challenges to implement large scale green H_2 projects

Green H_2 is key to achieve Carbon neutrality

But it is the most expensive way.

Final energy consumption EU

Source Eurostat 2020



40% of the final energy consumption has no direct CO_2 emissions

1. **Electricity** represents only 23% of the final energy consumption.

Green H_2 is key to achieve Carbon neutrality

But it is the most expensive way.

Final energy consumption EU

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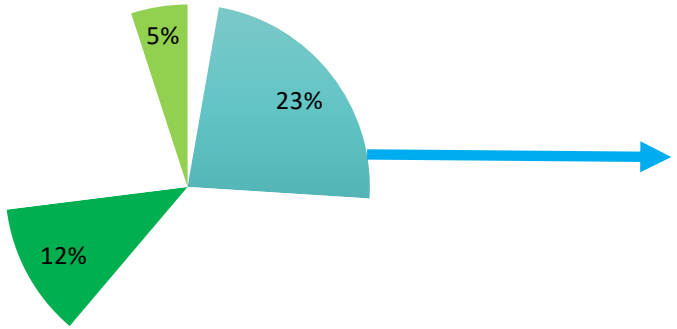
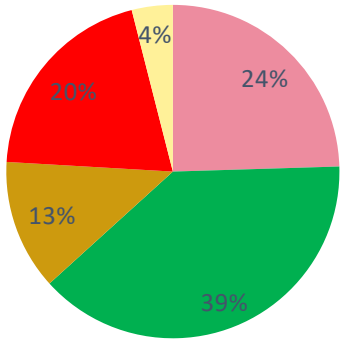


Solid fossil fuels
Electricity
Oil and petroleum products
Renewables and biofuels
Natural gas
Heat

Electricity mix



Nuclear
Renewable
Coal lignite peat
Gas
other

Fossil electricity production represents
~1000 TWh/y

1. **Electricity** represents only 23% of the final energy consumption, it will increase but it will remain limited as electricity **cannot be stored economically for longer duration** .
2. **Biomass & Renewable** heat will not be sufficient compared to future demand**.**

Green H_2 is key to achieve Carbon neutrality

But it is the most expensive way.

Final energy consumption EU

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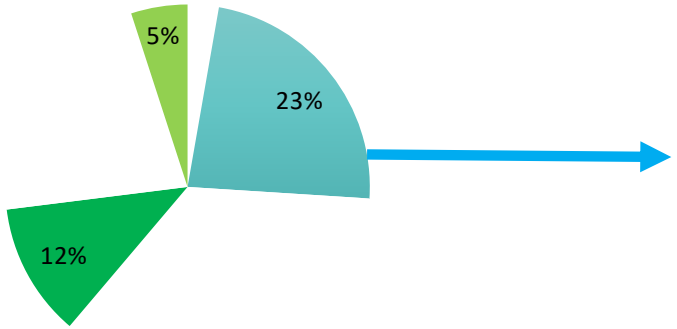

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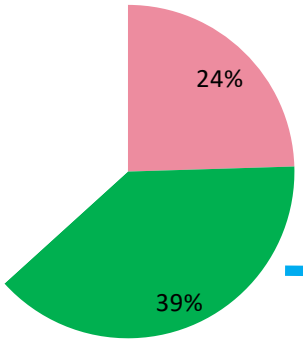

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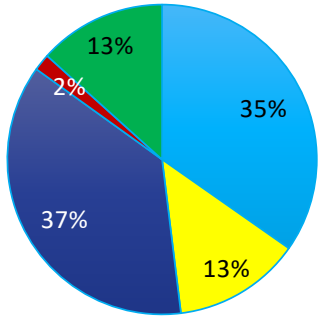
Renewable electricity

Growth in renewable electricity will be driven by wind and solar



Hydro
Solar
Wind
WTE renewable
Biomass

1. **Electricity** represents only 23% of the final energy consumption, it will increase but it will remain limited as electricity **cannot be stored**.
2. **Biomass & Renewable** heat will not be sufficient compared to future demand**.**
3. **Hydrogen and E molecules** are needed to achieve carbon neutrality, but are **the most expensive solution** (due to efficiency). So it must be used mainly **in hard to abate sector** or to **import green energy**.

Fossil H_2 cheaper than Green H_2

Green H_2 only feasible if final customer is ready to pay a premium

Physical reaction: $2H_2O + 39{,}6\ MWh/\ t\ H_2 = 2H_2 + O_2$

	Steam Methane Reformer (SMR)	Blue Hydrogen	Water Electrolysis (wind offshore)
Formula	$2H_2O + CH_4 => 4H_2 + CO_2$	$2H_2O + CH_4 => 4H_2 + CCS$	$2H_2O$ + electricity => $2H_2 + O_2$
Industrial efficiency	85% (high temperature reaction)		77% (Low temperature reaction).
CO_2 emissions	9,4 tCO_2/tH_2		0 if green electricity.
Energy consumption	47 MWh/tH_2		51,3 MWh/tH_2
Capex	~500€/kW		~1000€/kW
Production cost *	113,7 €/MWh or 3.4€/kg	113,7 €/MWh or 3.4 €/kg	138,7 €/MWh or 4,16 €/kg without storage costs

Grey & Blue H_2 are easier to use (baseload) and cheaper to produce, marginal cost of natural gas is low.

→ Green green H_2 needs regulatory & economic support to be competitive.

*(CH_4 @ 50€/MWh, Green offshore electricity 45€/MWh, ETS 80€/tCO_2, CCS cost 80€/t CO_2 Wacc 7% depreciation 20y)

Physical constraints of green H_2 development

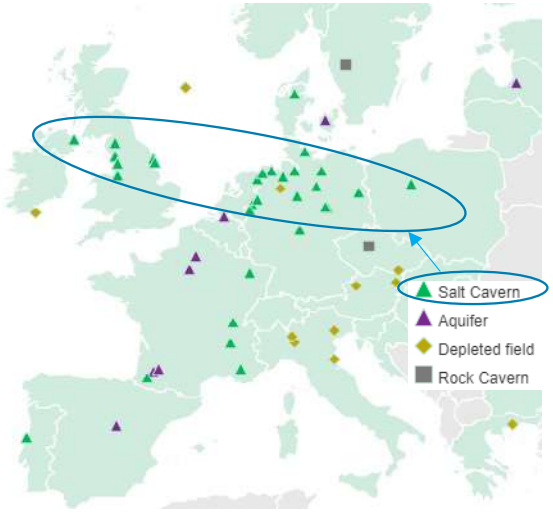
Hydrogen is difficult and expensive to store and to transport

1. Very limited and 100% private transport infrastructure for H_2 and O_2 (sized for current needs). For large scale H_2 project, necessity to be close to the customer or to be owner of the H_2/O_2 infrastructure. No tanker/terminal existing yet to import green H_2.

2. No current storage and storage potential technically limited to salt caverns **50 TWh** at European level, compared to **1200 TWh** for natural gas at present. Hydrogen is **physically** not made to be stored in big quantity.

3. Very low volumetric energy density, difficult to import massively.

4. Non-radiating flame => difficult to use in high temperature processes due to NOx creation.



Source: The European Hydrogen Backbone (EHB) initiative

	Energy density (LHV)			
	kWh/kg	kWh/m³	kWh/l	°t
		Gas	Liquid	
Hydrogen	33.33	2.7	2.36	-252°C
Methane	13.9	10.5	6.2	-161°C
Methanol	5.5		4.3	Ambient
Ammonia	5.2	3.8	3.2	-32°C
Diesel	12		10	Ambient

EU Hydrogen ambition vs Green electricity needed

The REPowerEU plan's ambition is to produce in the EU by 2030

- **10 million tons** of renewable hydrogen (**333 TWh/y** of H_2)
- Additional green electricity needed = **510 TWh** (65% electrolyser efficiency)
- **In 2019 the total production of wind and solar was**
  - ✓ 155 GW wind onshore with in average 24% capacity factor*: 325 TWh
  - ✓ 12 GW wind offshore with in average 38% capacity factor*: 40 TWh
  - ✓ 118 GW solar with in average 11% capacity factor* : 118 TWh
  - ✓ Total Wind and solar with average capacity factor 19,5%* : **483 TWh.**

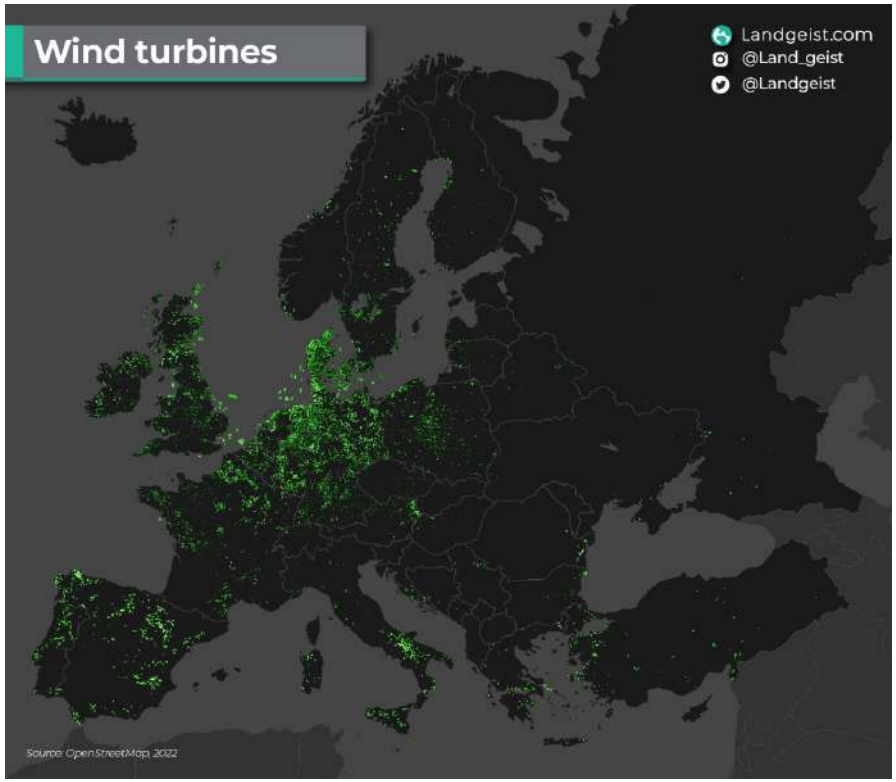
* Source Eurostat 2019

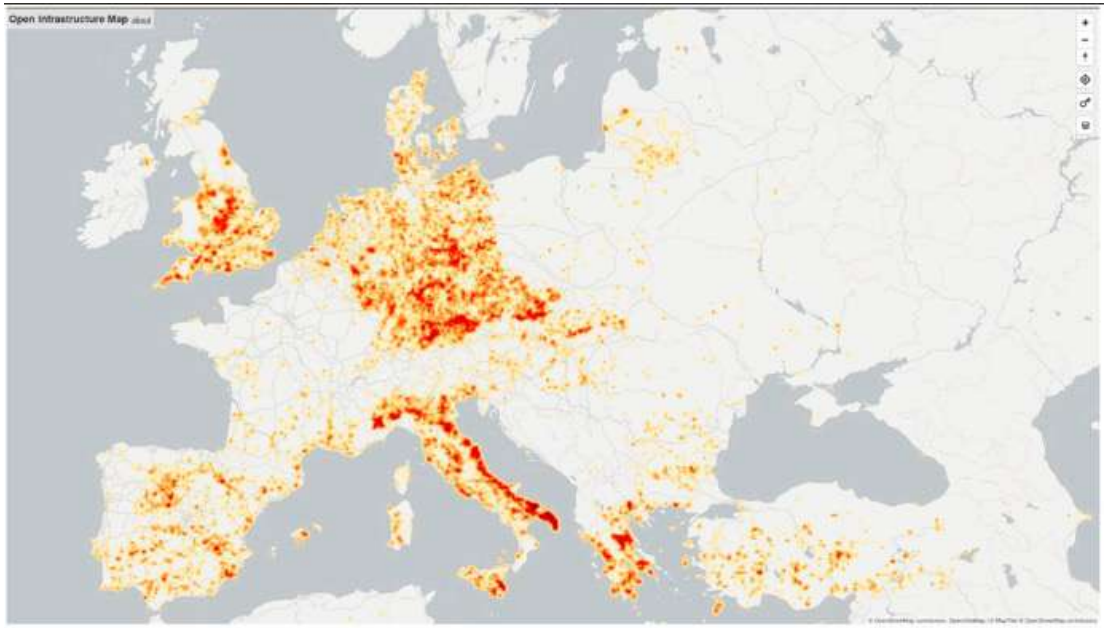
- Installed Electrolyser capacity needed with 19,5% capacity factor: 300 GW (**40 GW** to be installed each year)
- Installed Electrolyser capacity needed with 38% capacity factor: 150 GW (**20 GW** to be installed each year)

The new demand of green electricity is not limited to the production of green H_2, all the European industry is looking to move to green electricity, and some sectors like the data centers (GAFAM) are ready to pay much more as the cost of electricity is marginal for them.

The sourcing of affordable electricity is very challenging for all green H_2 projects.

Installed capacity of solar and wind in Europe





Solar PV explicitly tagged in OpenStreetMap, as of May 2020, shown as a heatmap of power capacity subtotals. Note the substantial variation between countries, often due to specific mapping initiatives in country communities: for example the relatively low density in France is unreflective of that country's installed capacity. Image credit: Russ Garrett, openinframap.org.

New RES development are currently difficult for 2 reasons:

1. Limited grid capacity for large scale RES projects, time to construct new line > 10 years.
2. Difficulty to obtain permitting for onshore wind.

Hurdles for a large scale Hydrogen project

- **Green Electricity availability:** all industry and mobility is looking to use directly green electricity, and currently there are not enough of new green electricity production projects.

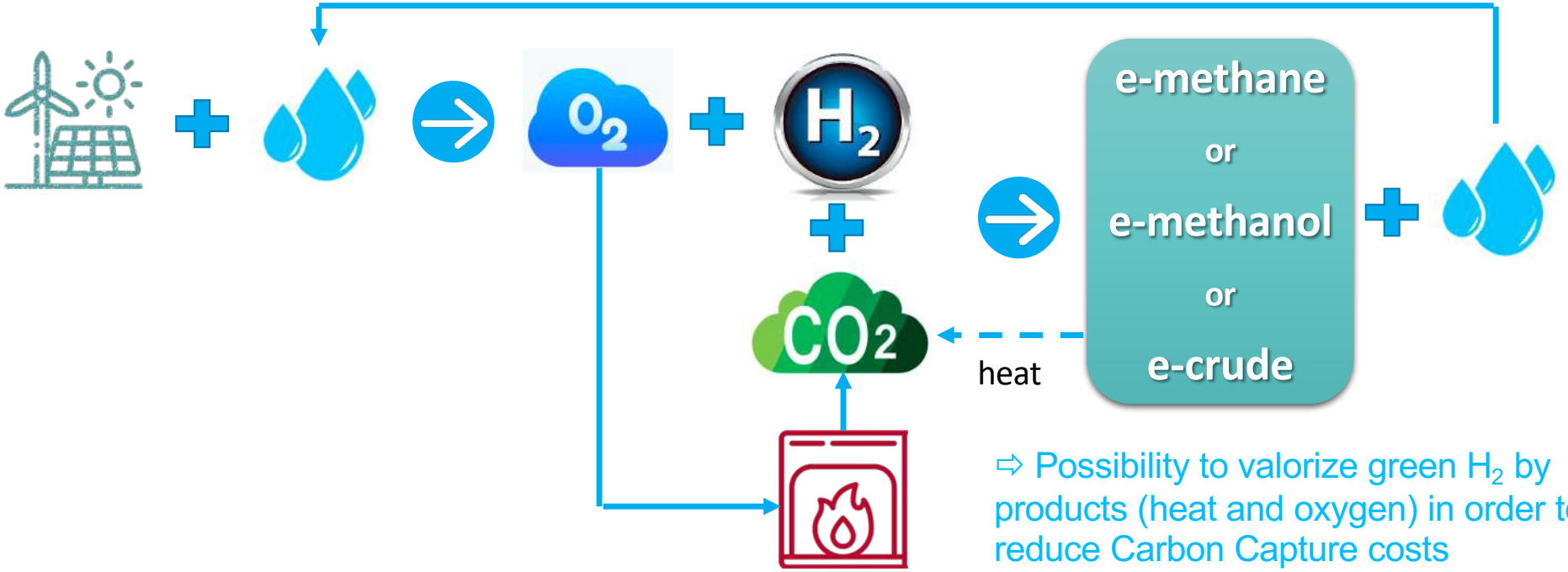
- **Electrical grid connection:** a large scale green H_2 project requires high voltage grid connection, for project over 200MW a 400 KV is mandatory. The construction of a new HV line takes a minimum of 10 years mainly due to permitting issues.

- **Storage possibility:** the current market of H_2 (ammonia, refineries, methanol) and the future market (steel) require baseload delivery of green H_2, without existing infrastructure and back-up, it is nearly not possible for a challenger to compete against existing hydrogen producers.

  To give an order of magnitude: **200 MW** green H_2 project directly connected to a wind offshore would require a storage capacity of 2 630 t H_2 or **75,5 GWh of H_2** (average size/salt cavern in EU 870 GWh of H_2)

Acceleration of green H_2 market: only feasible if H_2 infrastructure is not needed (ie E molecules) and if access to abundant cheap electricity.

Carbon Capture & Usage (CCU): What and Why



⇨ Possibility to valorize green H_2 by products (heat and oxygen) in order to reduce Carbon Capture costs

Why e-fuels:

- **Use of existing infrastructure** to store, transport & distribute
- **No capex needed for offtakers**: drop-in fuels
- **High energy density** ⇨ easy to manipulate and can be used in aviation and shipping
- **Captive markets** created by regulations and by 'green' products market demand

E-fuels & biofuels markets
Customer willingness to pay green premium

Regulation driven

Aviation: E Kerosene
- Total EU market size 800 TWh/y
- Carbon-neutrality target 2030: 5% ⇨ **40 TWh/y**

Shipping: E LNG, E Methanol, E Diesel
- Total EU fossil market: 640 TWh/y
  - 475 TWh/y Fuel oil, 165 TWh/y Diesel ~20 TWh LNG.
- Carbon-neutrality target 2030: 6% ⇨ **40 TWh/y**

Customer driven

Petro chemistry*: E Naphta & E Methanol
- Total EU market size 35 Mt/y
- Market growing could reach 30% recycled plastic in 2030.

Steel before 2030: E methane
- Customers demand: Car, Wind turbine, …
- Recycling steel production EU: 60 Mt/y

Steel after 2030: Hydrogen & E methane
- DRI (H_2 or CH_4) kilns up to 80Mt/y steel
  - H_2 (or CH_4) : up to 180 TWh/y baseload!

* Today EU petrochemical industry rely on naphta

Hurdles for a large scale CCU project

- **Identical hurdles for large scale H_2 production:**
  - **Green Electricity availability**
  - **Electrical grid connection**
  - **H_2 storage and transportation**

- **Sourcing of CO_2 :** with current RED 2 delegated act, after 2035 only **biogenic** but feedstock **very limited**, or with DAC but this require a lot of energy to be captured (> 2x more than CO_2 from industry). Unavoidable process CO_2 (from $CaCO_3$ decarbonisation in lime cement and glass industry, and from electrodes used in aluminum and steel industry) is not taken into account even if in majority of the case the CCS is not feasible because these industries are not close to CO_2 storage infrastructures.

- **Double Counting of CO_2 (producer and user):** today there is no clear vision on who has to declare the CO_2. With current rules the CO_2 is counted 2x.

With current Delegated Acts draft many green hydrogen projects with EU production will not be viable anymore.

Conclusions

EU targets are challenging, but there is no alternative. To achieve them there is a need for:

1. Industrial innovation:

- Develop massively **ALL carbon neutral electricity production.**
- **Enable electrification of processes**
- **Scale-up technologies** to industrial scale
- **Circular economy** and collaboration between industries
- Support current business cases with **subsidies/grants**

2. Policy and regulation:

- Consistent review of **ETS, REDII, carbon border tax**,…
- Consider also **E-molecules** to reach carbon neutrality in a circular economy
- Ensure **stable regulatory framework** for cross-border transports of CO_2, H_2 and E-molecules
- **Open access backbones** (O_2, CO_2 and H_2)
- Adapt **grid costs and taxes on electrification of processes**

Thank you

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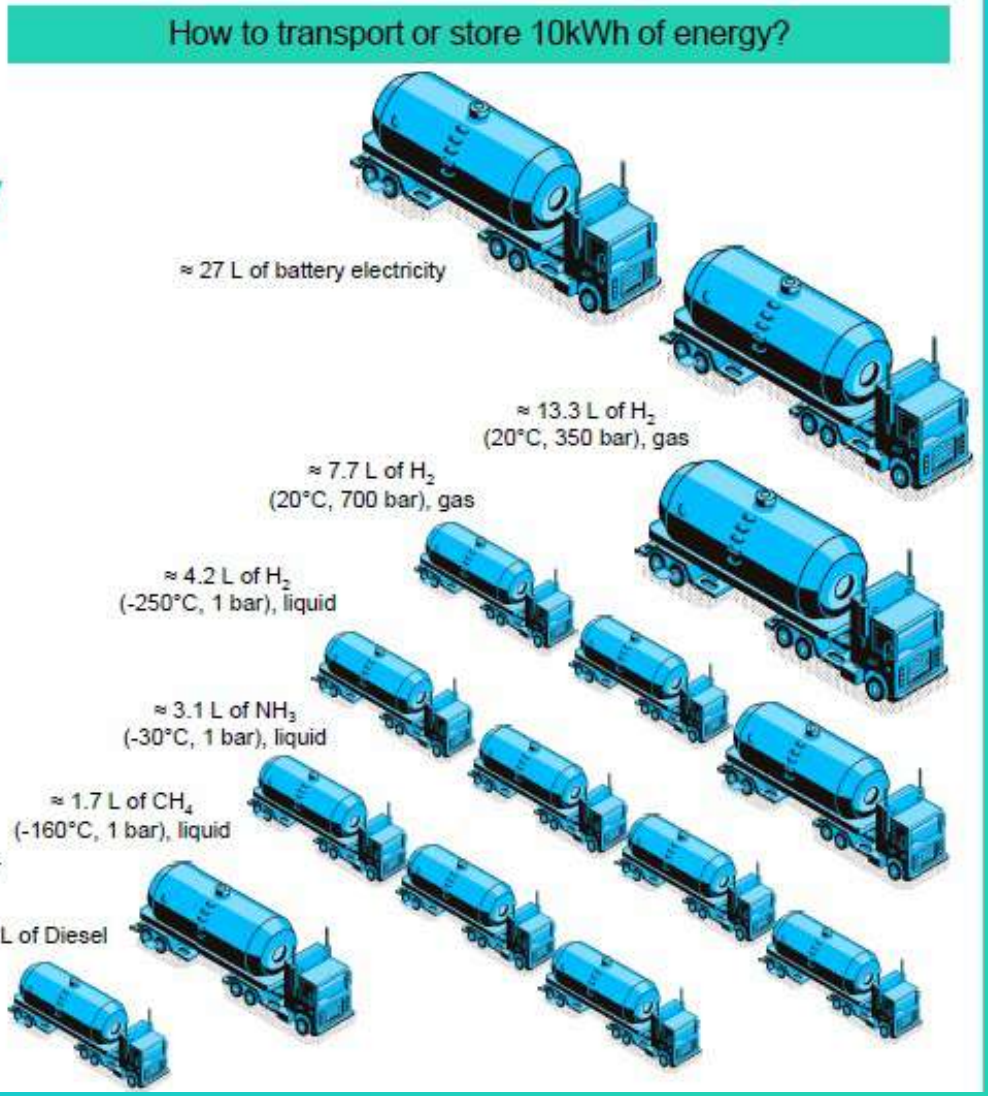
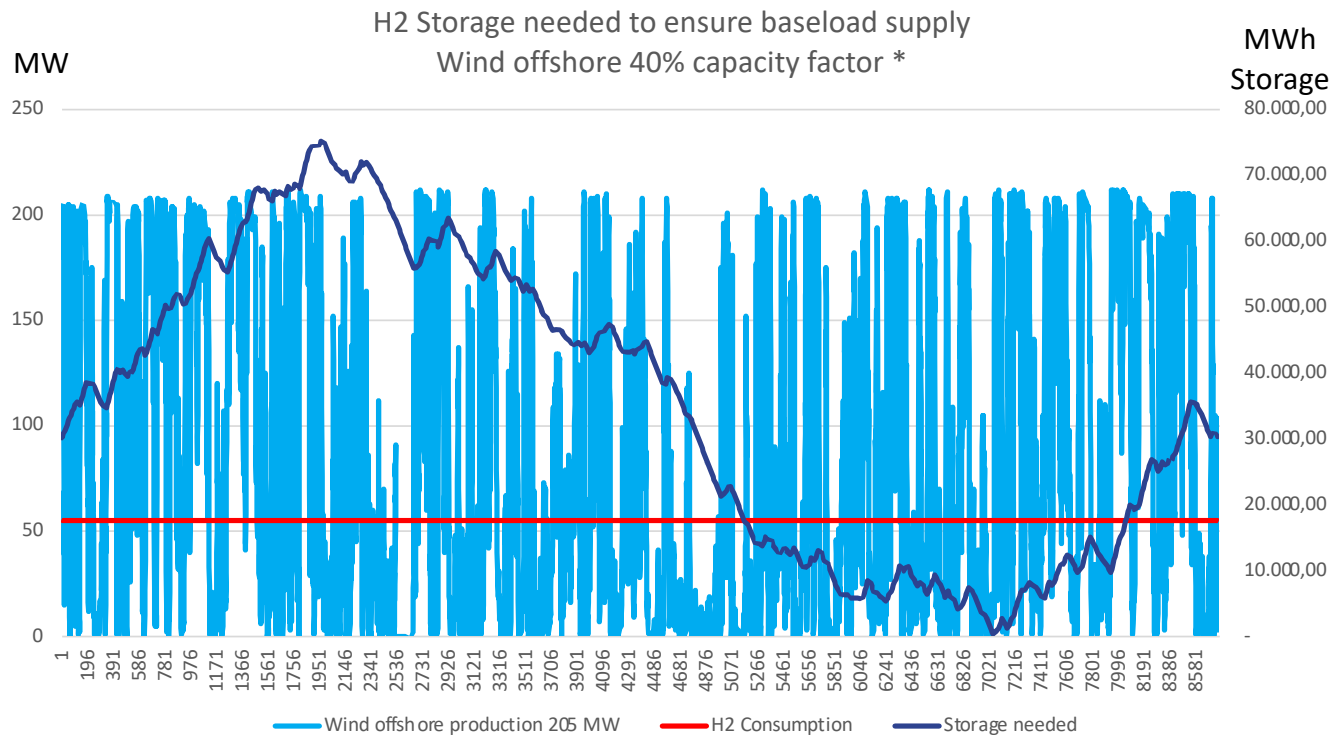
H_2 has a very low energy density and is thus extremely hard and expensive to store and move around

→ Need for synthetic other molecules!*



* Mertens, J., R. Belmans and M. Webber, 2020. Why the carbon neutral transition will imply the use of lots of carbon. *C-Journal of Carbon research*, 6 (39), 1-8

Storage needed for a 200 MW green H_2 directly connected to wind offshore.



* Real data's coming from a wind offshore Belgian park