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ROBERT SCHUMAN CENTRE FOR ADVANCED STUDIES

How to build a “wise” support for deployment of renewable and low-carbon hydrogen

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4/03/2021

Hydrogen Strategy for a Climate-Neutral Europe

- Driving down the costs for renewable hydrogen (1,1-2,4 EUR/kg)

- Increasing electrolyser capacity (60MW(2020); 6GW(2024); 40GW(2030); 500GW(2050))

- Mobilising $550 billion (RES; Electrolysers; CCUS; Transport, Distribution, Storage, Refueling)

Hydrogen Strategy for a Climate-Neutral Europe

SUPPLY

- Use of life cycle CO_2 thresholds
- Threshold for low carbon
- Use of certification schemes
- Adoption of tenders

INFRASTRUCTURE

- Reform of gas market legislation
- Repurposing gas infrastructure
- Provide equal access to all stakeholders

DEMAND

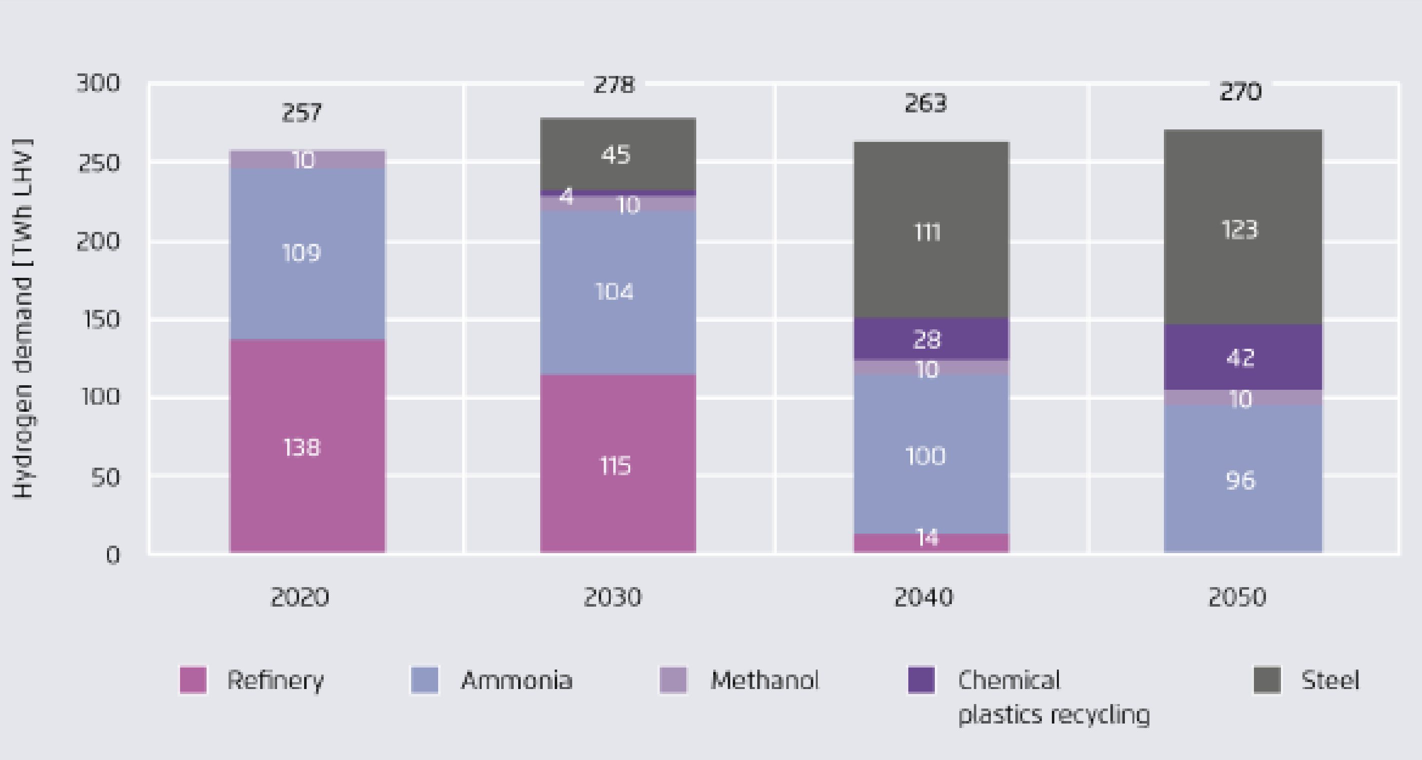
- Revision of ETS
- Introduction of ”Carbon Contract for Difference“
- Market-based support schemes
- Quotas of green hydrogen in end uses

European Clean Hydrogen Alliance

- Key deliverable - pipeline of viable investment projects (coordinated investments along the whole value chain; public support & crowding in private investments)
- Industry expectations (Project engineering; PPP; Clarified access to support schemes; Clarified regulatory framework)

“No regret” industrial demand

Industrial hydrogen demand from 2020 to 2050 in TWh per year

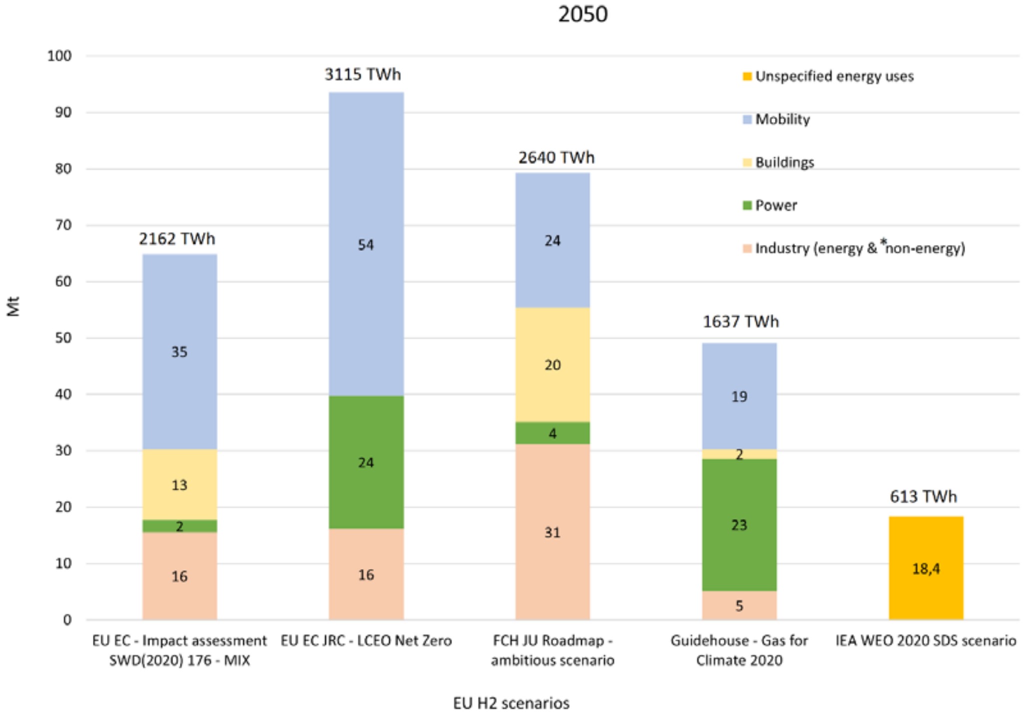


AFRY (2021)

Hydrogen demand will greatly increase until 2050 – however great uncertainty on specific sectors for uses

Overall demand today in EU: almost 10,7 Mt of hydrogen; 357 TWh

demand for industrial processes: 10 Mt; 303 TWh



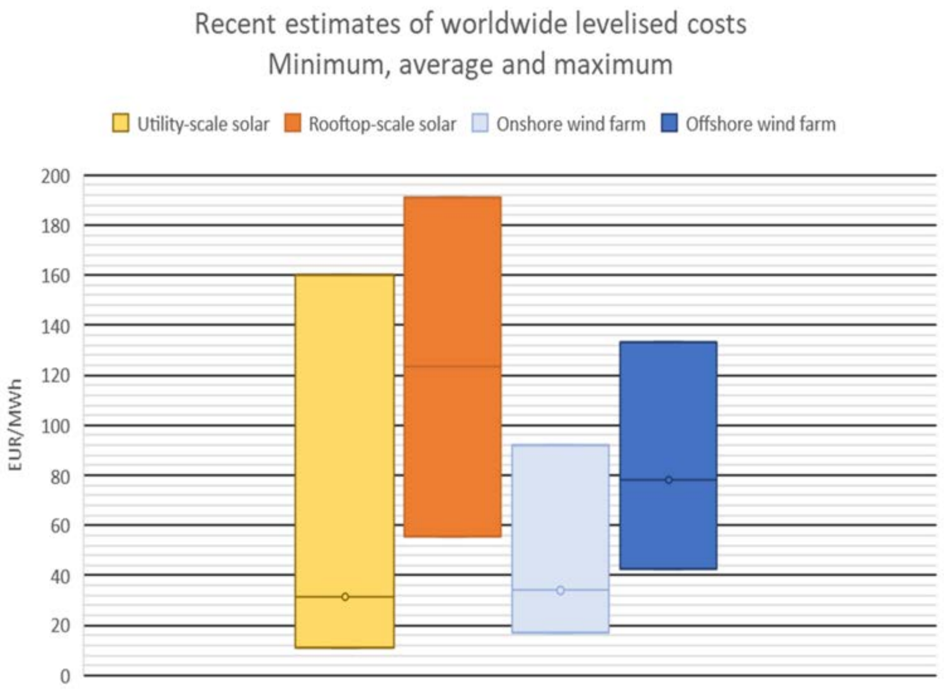
Note 1: hydrogen uses as a feedstock to produce synthetic fuels are allocated to each main type of uses identified, except for IEA WEO 2020 SDS scenario, which does not specify those.
Note 2: * if available

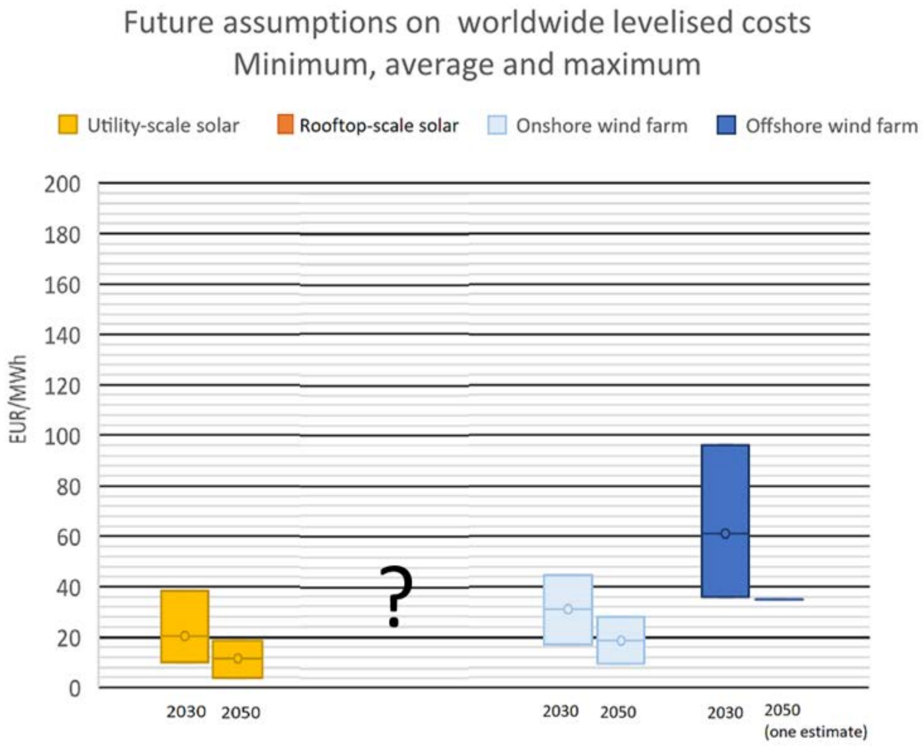
Producing Hydrogen

2050: 4 key costs drivers

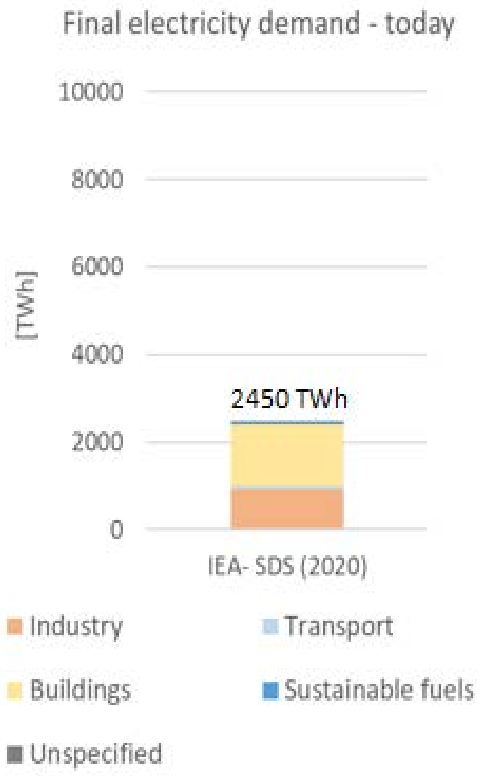
Technologies	**Electrolyser – solar PV**	**Electrolyser – offshore wind**	**Electrolyser – electricity from regional decarbonised power mix**	**SMR + CCS – 'sustainable' biomethane**	**Methane pyrolysis with CCU – 'sustainable' biomethane (based on less available information)**
Cost driver 1	Electricity costs 4-20 EUR/MWh	Electricity costs 30-40 EUR/MWh	Electricity costs 28-62 EUR/MWh	Biomethane costs 30-60 EUR/MWh	
Cost driver 2	Efficiency- LHV (Lower Heating Value) 74-85%			Efficiency-LHV 69-70%	Efficiency – LHV 55%
Cost driver 3	Full load hour factor 16%-40%	Full load hour factor 45%-60%	Full load hour factor 90%-99%	Overnight CAPEX 1088 EUR/kW-H2	Costs reduction (selling by-product solid carbon) 0-0.25 EUR/kg solid carbon
Cost driver 4	Electrolyser CAPEX 68-110 EUR/kW-el			CO2 transport & storage cost 17-55 EUR/tCO2	CAPEX 1261 EUR/kW-H2

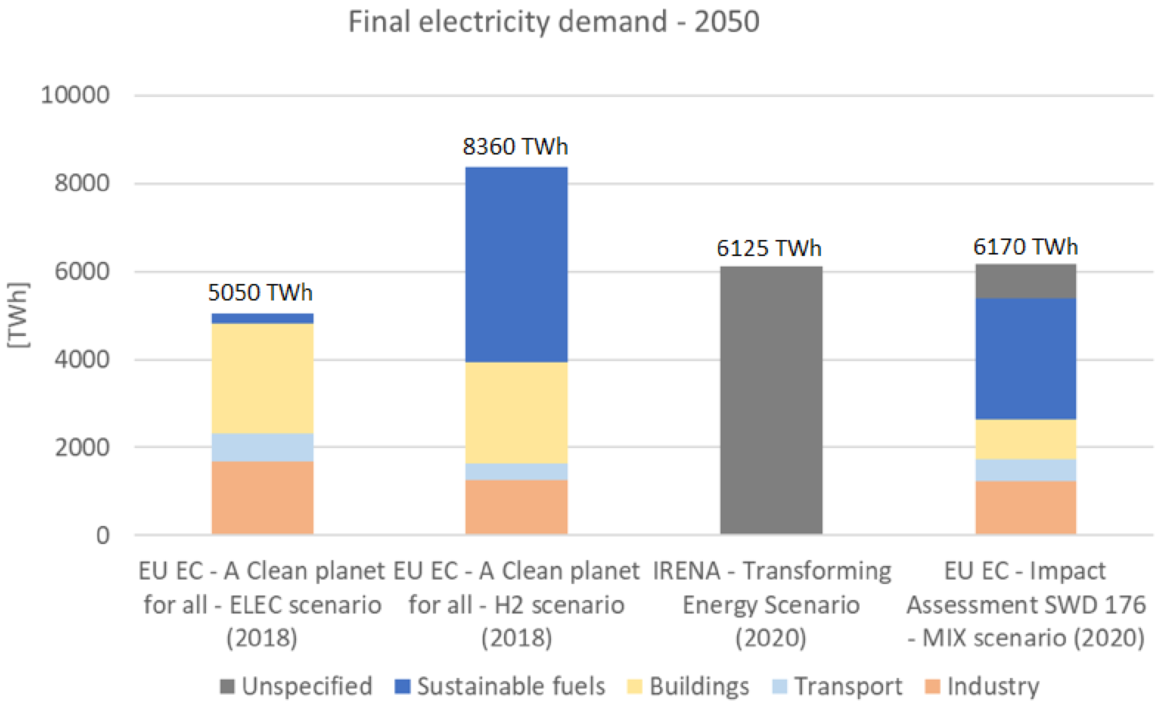
Renewable electricity costs will continue to decrease





Electrification & demand for sustainable fuels will increase final electricity demand by 2 – 3.5 times

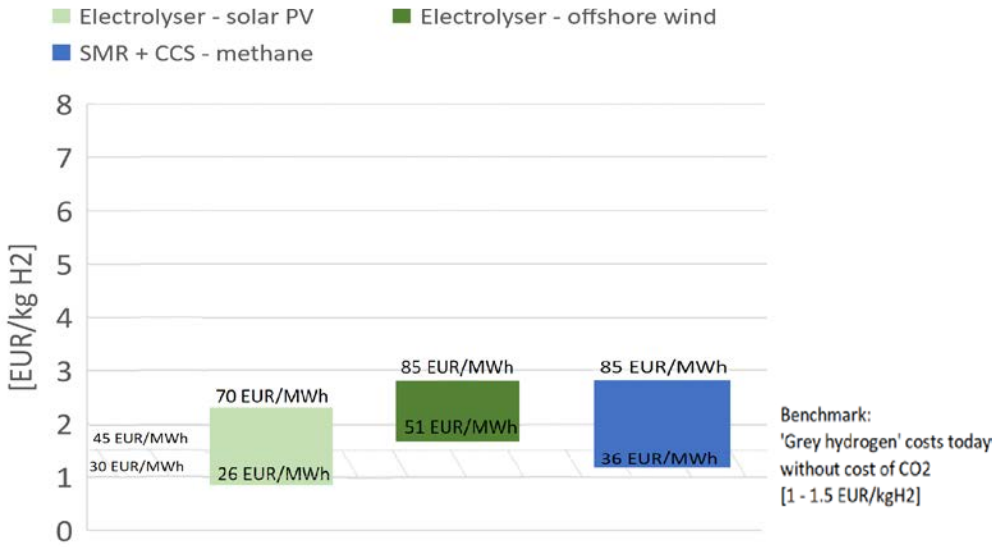




Production of hydrogen towards decarbonisation :

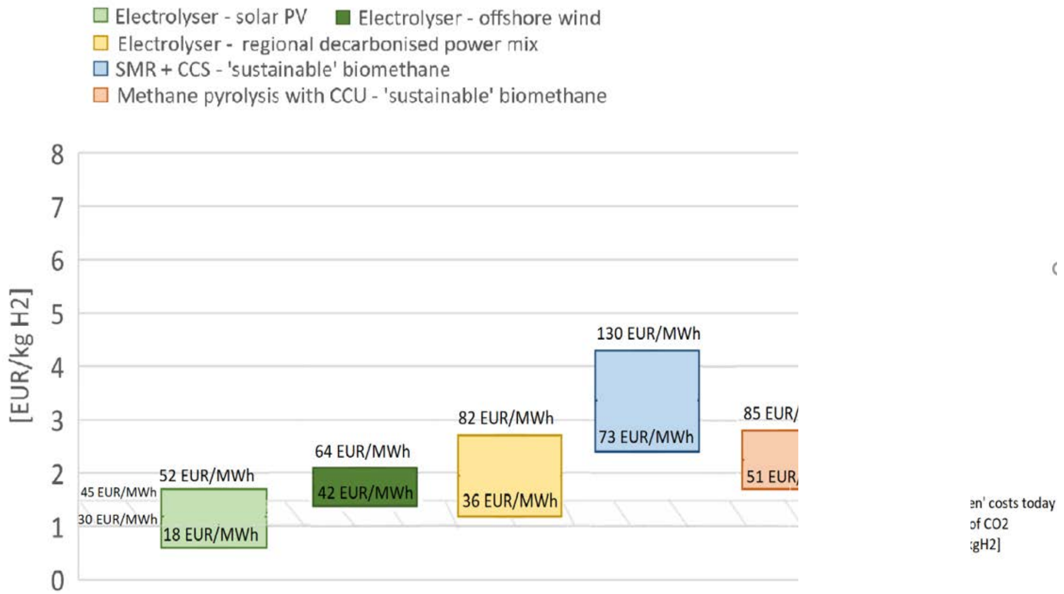
Technologies & costs without cost of CO2

2030:



- Supposing CO2 transport & storage infrastructure is available
- Supposing enough primary resources, financing and human skills are available
- Free of «regulatory costs», taxes and subsidies
- …

2050:



- Supposing CO2 transport & storage infrastructure is available
- Supposing enough primary resources, financing and human skills are available
- Free of «regulatory costs», taxes and subsidies
- …

Consensus findings of expected costs of different technologies

Scenario	Current technological Maturity	Average levelised cost assumption across all sources Today	Average levelised cost assumption across all sources 2030	Average levelised cost assumption across all sources 2050	Direct GHG emissions [kgCO2e/kgH2]
Domestic green Hydrogen based on utility scale PV	***Commercial***	€ 3.45/kg H2	***€ 2.1/kg H2****	€ 1.4/kg H2*	***0***
Domestic green Hydrogen based on Offshore Wind	***Commercial***	€ 4.9/kg H2	***€ 2.6/kg H2***	***€ 1.65/kg H2***	***0***
Domestic Blue Hydrogen	***Demonstration (e.g. Port Jerome refinery, Repsol SMR plant)***	***€ 1.7/kg H2***	***€1.95/kg H2***		0.8 - 1.5
Domestic Turquoise Hydrogen	***Demonstration (e.g. BASF, Carbotopia, Bosch)***	–	***€1.4/kg H2***	***€ 1.2/kg H2***	***0 - 2.5***

* Can be expected to reduce very significantly if lowest cost PV from a sunny area is used; € 0.9/kg H2 2030, € 0.5/kg H2 2030

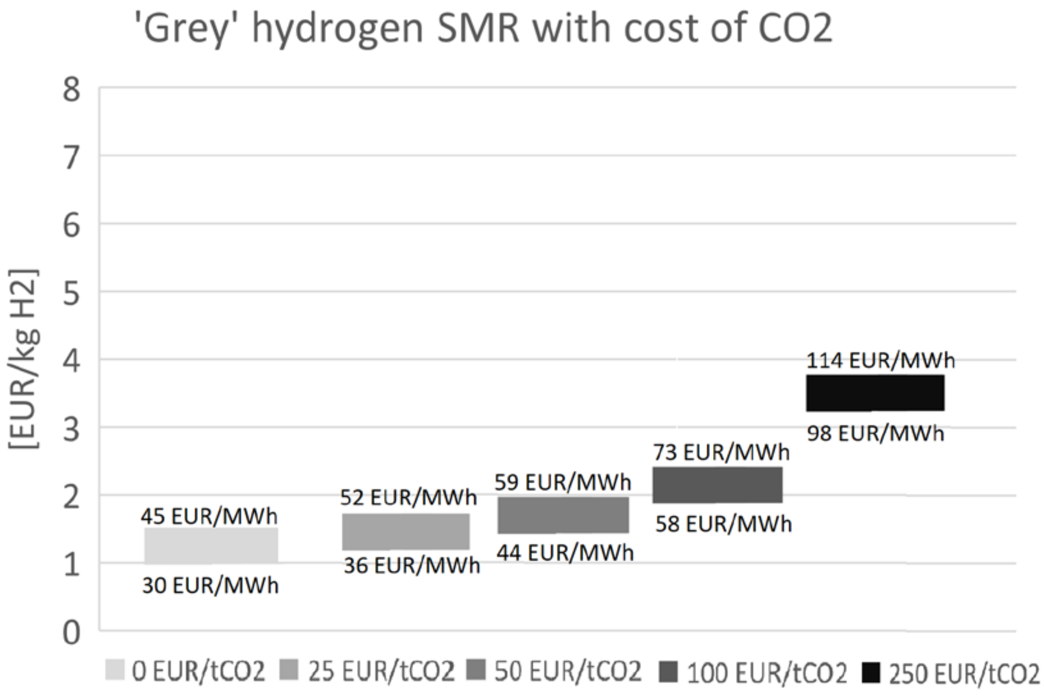
Production of hydrogen towards decarbonisation :

Technologies & costs with cost of CO2

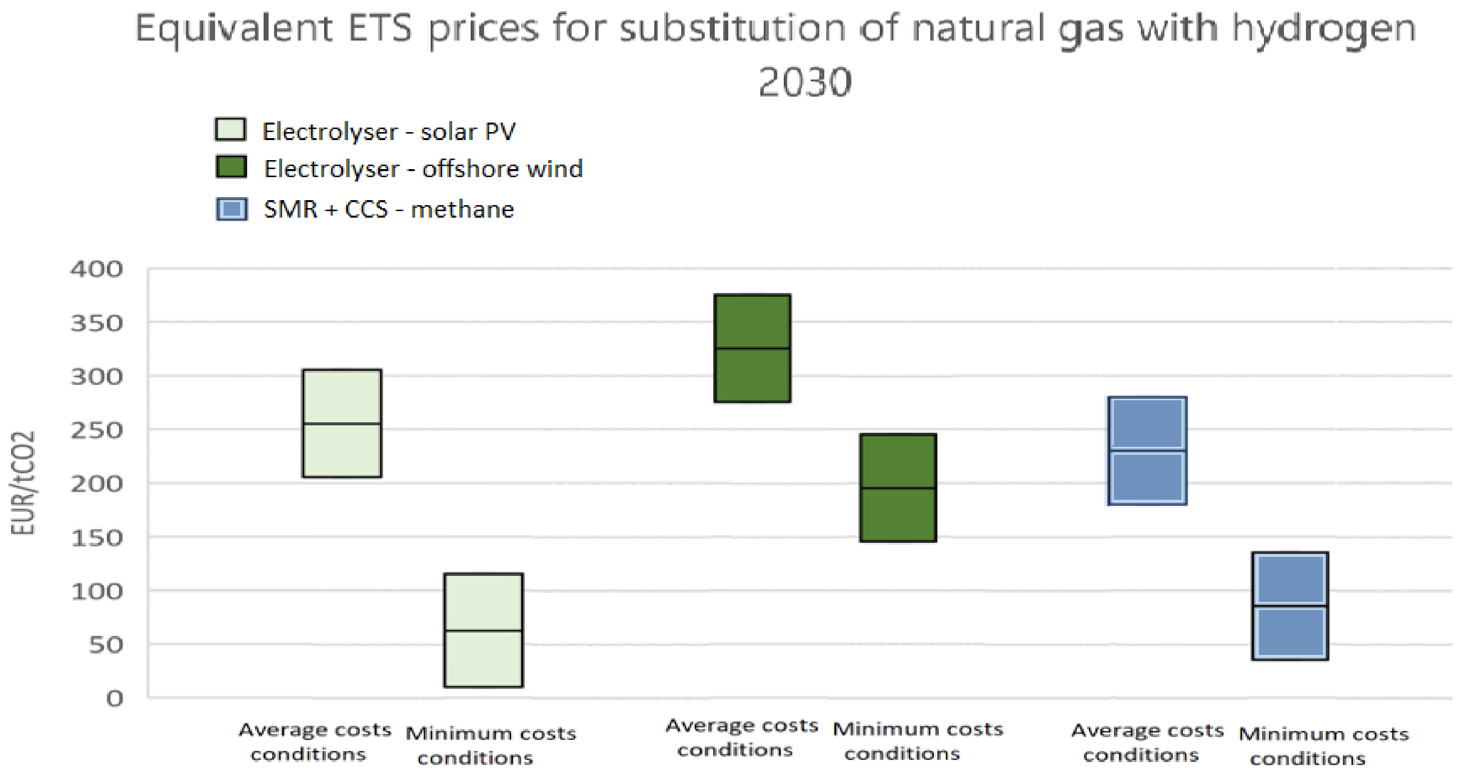
Costs of ‘grey’ hydrogen SMR changes significantly, whereas those of blue and turquoise hydrogen do not:

At cost of CO2 > 25-145 EUR/tCO2
New blue H2 in 2030 becomes
competitive with ‘grey’ H2

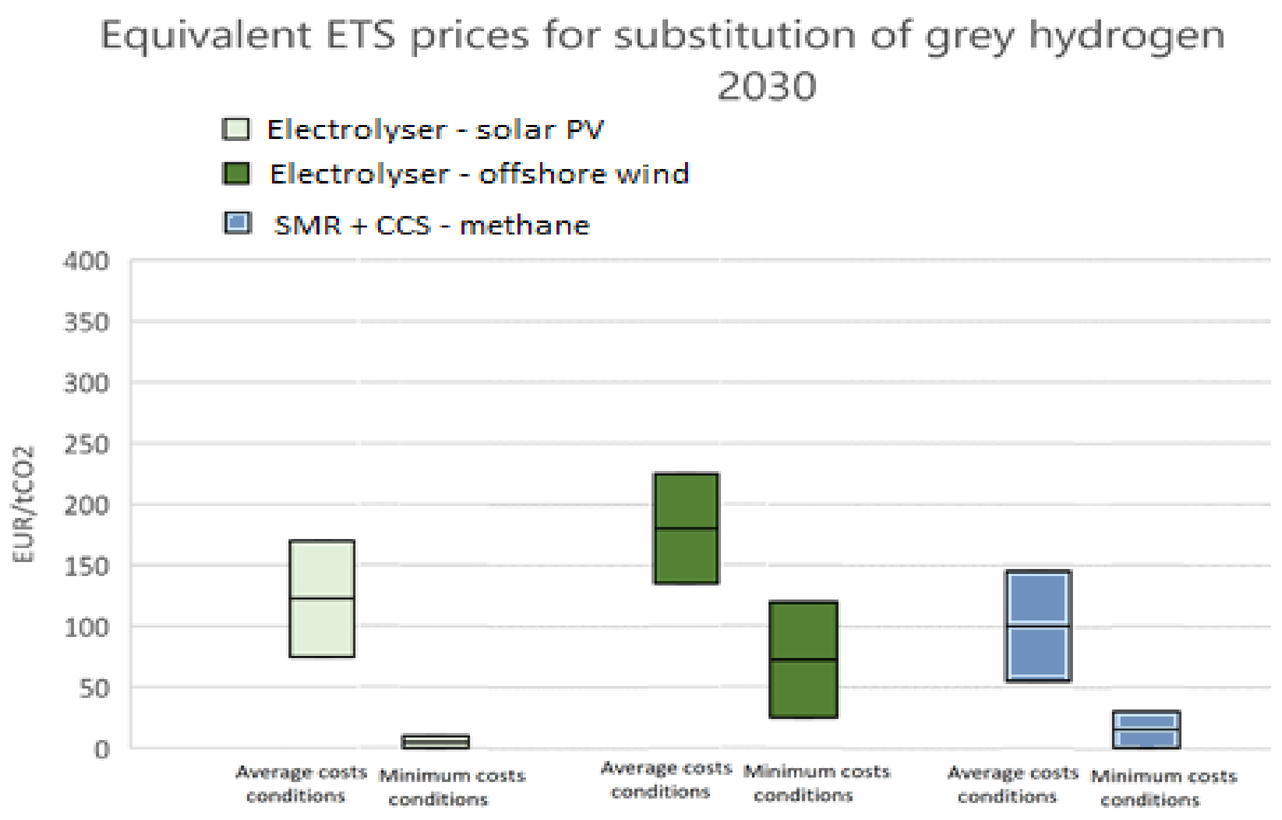
At cost of CO2 > 33-82 EUR/tCO2
It becomes competitive today
for existing ‘Grey’ H2 to be
upgraded to ‘blue’, supposing
CO2 storage & transport is available



Substituting natural gas with 'cleaner' hydrogen will involve extremely high costs of CO2 – except for very favourable solar PV conditions. Electrify? Or subsidise?



Substituting 'grey' hydrogen with 'cleaner' hydrogen may only need low costs of CO2 in average conditions, all the less in favourable conditions



From demand to production (EU)

- **2559 TWh** (industry, maritime, aviation) **= 84 MtH2**

- At least **doubling** electricity production (from 2450 TWh to 4500-6000TWh)

- Renewable capacity increase **5 times** (from 285GW to 1400GW)

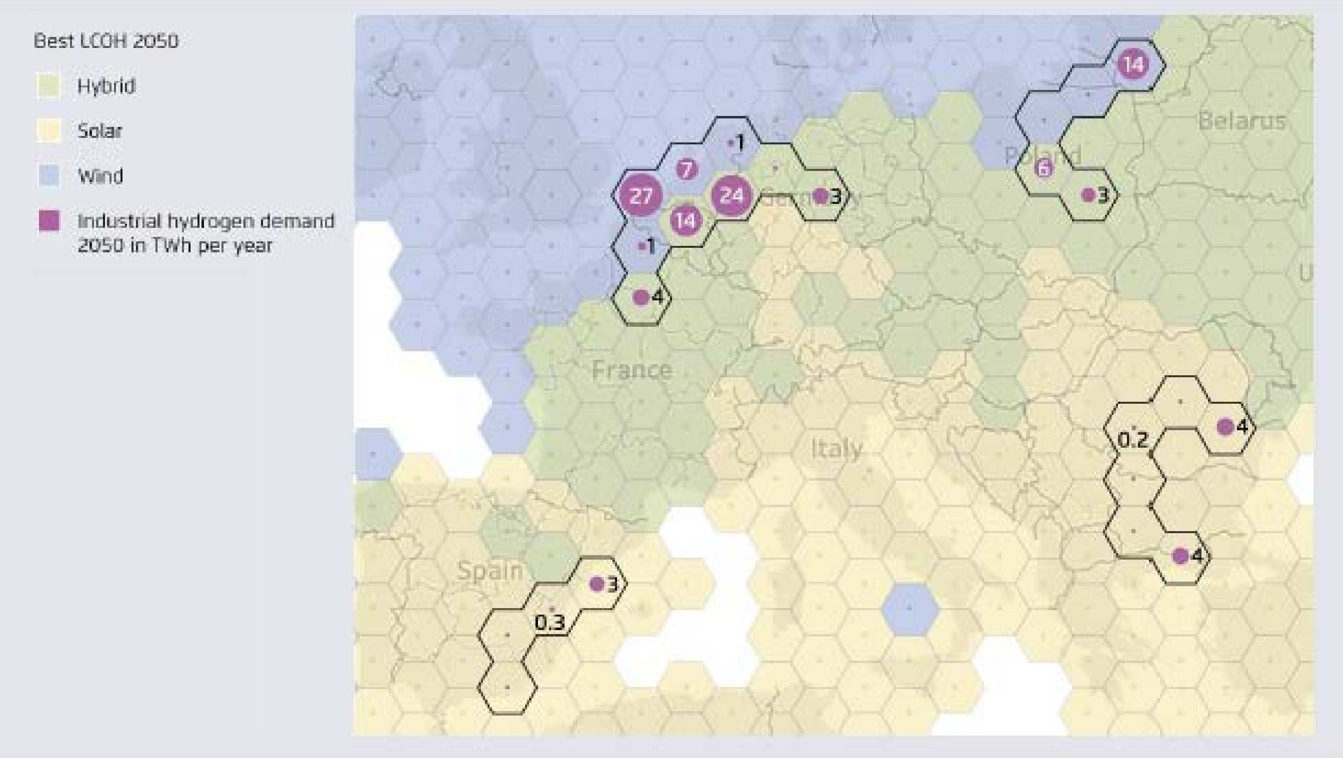
Hydrogen transport

- Transport modes - Transmission & distribution pipelines; Shipping; Storage & Maritime terminals; Truck loading

- Transport technologies - Pressurised hydrogen; Liquefied hydrogen; Liquid organic hydrogen carriers (LOHC); Methanol; Ammonia

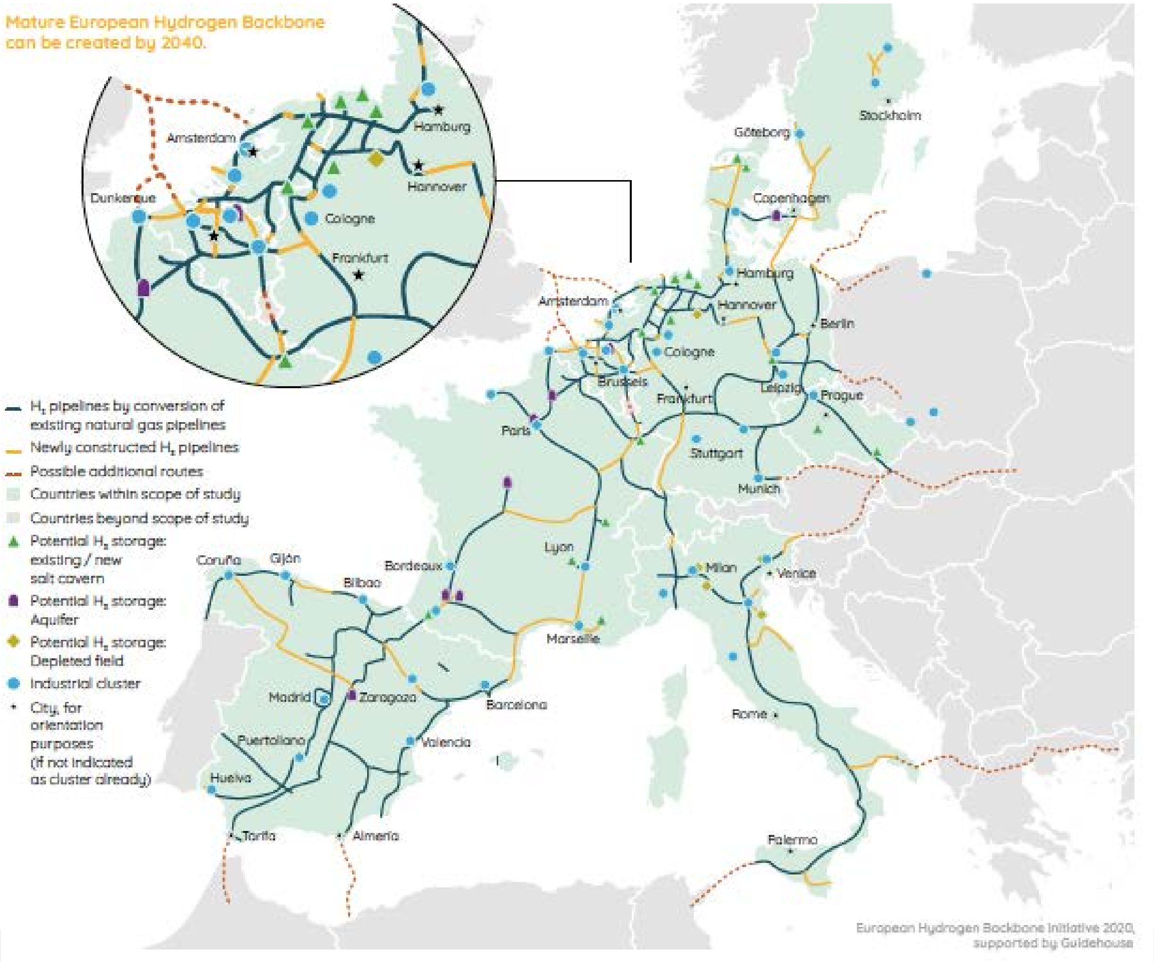
Will this be enough?

No-regret corridors with industrial hydrogen demand in TWh per year in 2050

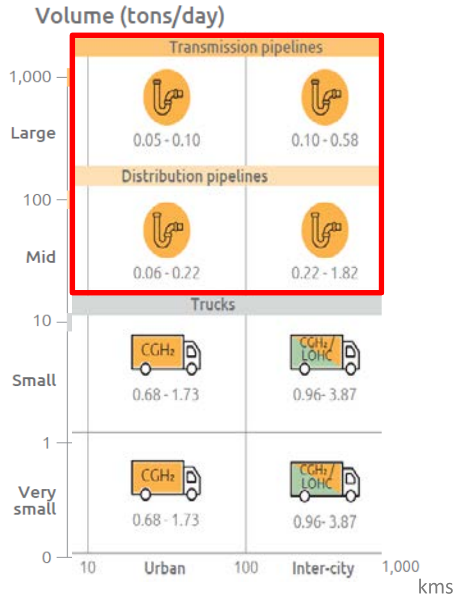


AFRY (2021) Only those hydrogen pipelines that are resilient to the future levels of hydrogen demand and the technology assumptions used here have been considered to be “no-regret”.

Will the hydrogen network be as current NG network?



Hydrogen transport – new or repurposed H2 pipelines are most cost-competitive option over short distances (≤ 100s kms)



BNEF

2019

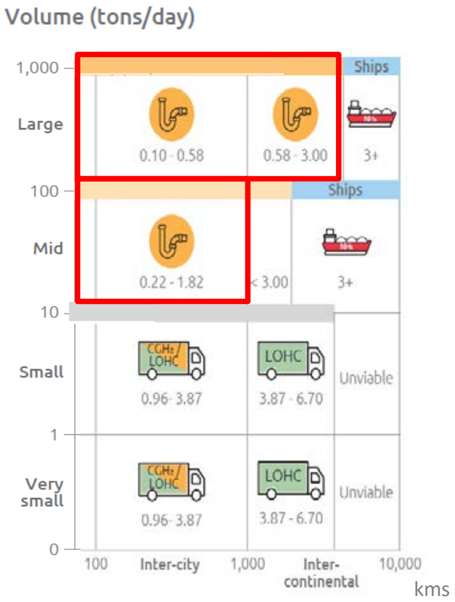
Transport means	State of hydrogen transported	Volume	Costs (50 – 500 km)
Pipe	Gas H2	500 tons/day	0,03 – 0,30 USD/kgH2
		100 tons/day	0,11 – 0,88 USD/kgH2
Truck	Gas H2	Not specified	0,47 – 1,81 USD/kgH2
	LOHC		1,57 – 3,92 USD/kgH2
	Liquid H2		1,14 – 1,40 USD/kgH2
	Ammonia		1,85 – 2,23 USD/kgH2

IEA

Undefined time horizon

Data includes costs for compression, any required storage, conversion and reconversion
Sources: «Global Gas Report 2020» BNEF (2020), «The future of hydrogen» IEA (2019), own analysis

Hydrogen transport – new or repurposed H2 pipelines are most cost-competitive option also over long distances (100s- 1000s kms)



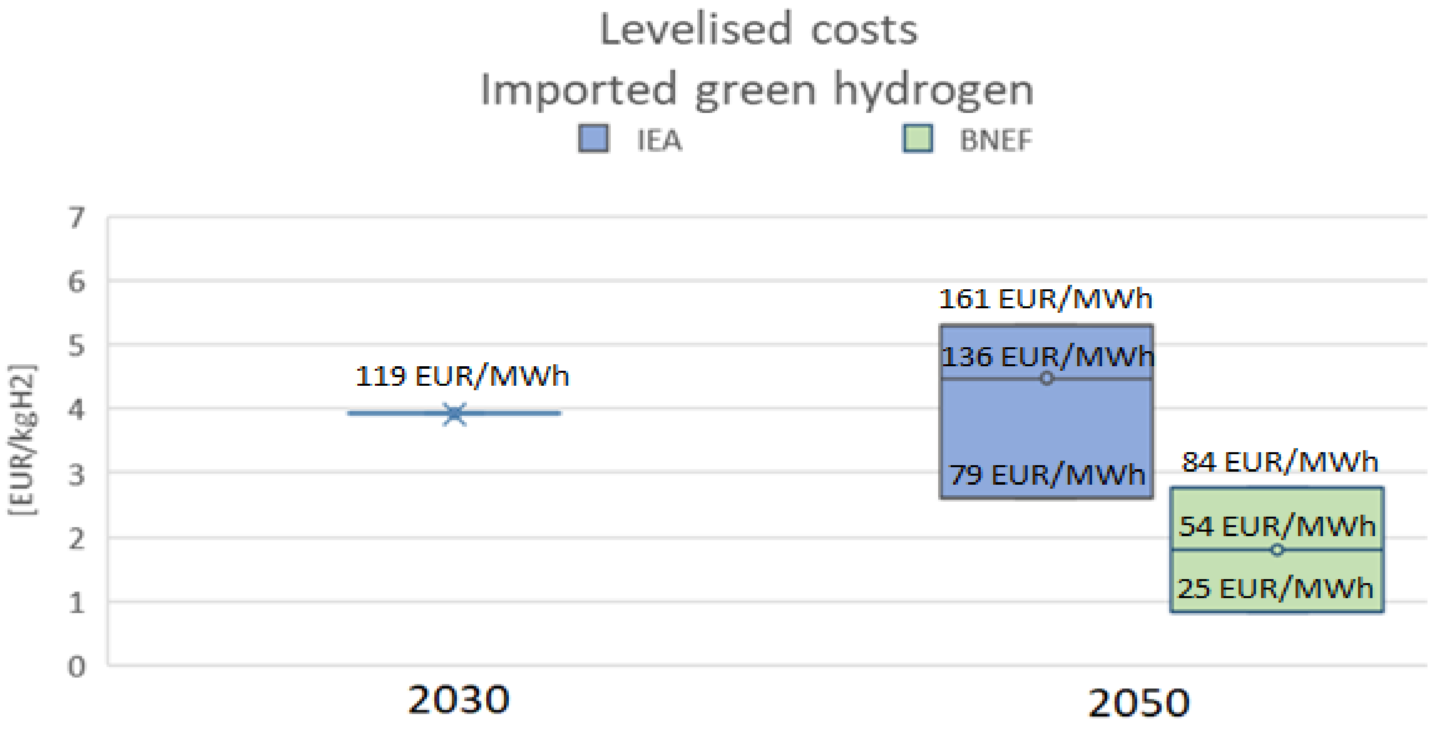
BNEF
2019

Transport means	State of hydrogen transported	Volume	Costs (500 – 3000 km)
Pipeline	Gas H2	Not specified	0,32 – 2,00 USD/kgH2
	Ammonia		2,00 – 3,22 USD/kgH2
Ship	Ammonia		1,92 – 2,23 USD/kgH2
	Liquid H2		2,04 – 2,35 USD/kgH2
	LOHC		1,56 – 2,77 USD/kgH2

IEA
Undefined time horizon

Data includes costs for compression, any required storage, conversion and reconversion
Sources: «Global Gas Report 2020» BNEF (2020), «The future of hydrogen» IEA (2019), own analysis

Few estimates on costs of imported hydrogen point to it being on average more expensive –transport costs for shipping matter. Importing through pipelines (North Africa) makes imported hydrogen cheaper



Sustainability guarantees

- **Additionality** - electrolysers use “new” renewable electricity accordingly to a robust methodology
- **Geographical correlation** - same country/same bidding zone
- **Temporary correlation** - correlation at daily/1h/15minutes granularity
- **Lifecycle analysis**
- **Value of GoO** - GHG savings depend from use (92gCO2eq/MJ to replace “grey H2”; 56gCO2eq/MJ to replace NG)

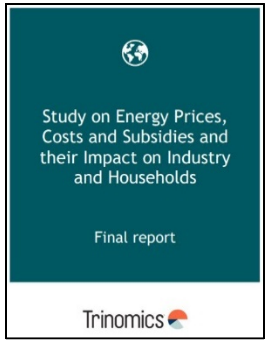
P2G - market based activity

- **TSOs/DSOs-** precluded from investing/running P2G
- **Derogation-** to guarantee reliable network operation & no market interest in investing
- **Virtual P2G Plant-** TSOs/DSOs develop and operate/capacity tendered off to market actors
- **P2G part of network planing-** locational information provided to investors
- **Definition of P2G-** alignment of definitions in electricity/gas sectors

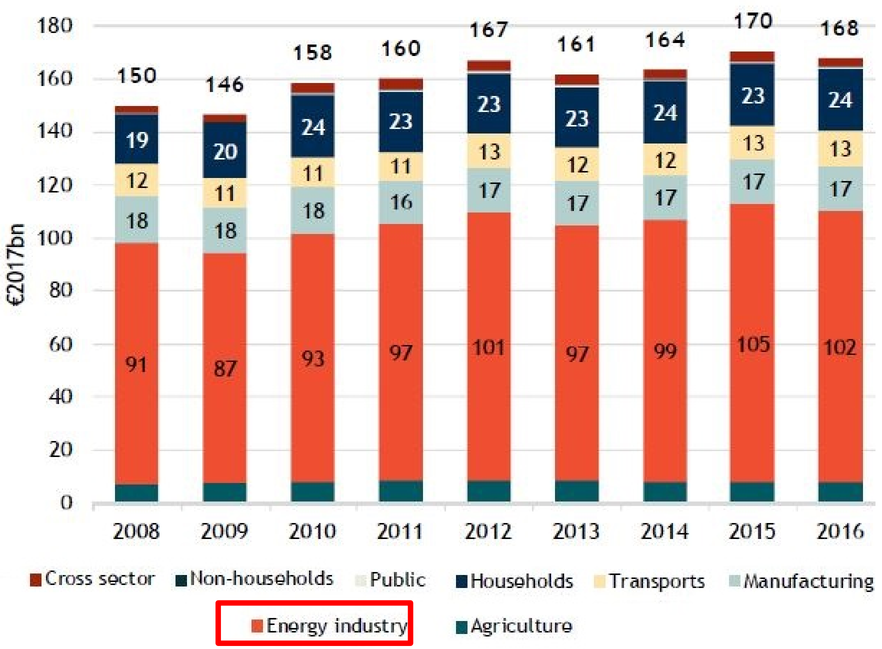
What do we support?

Financial support for energy-related purpose

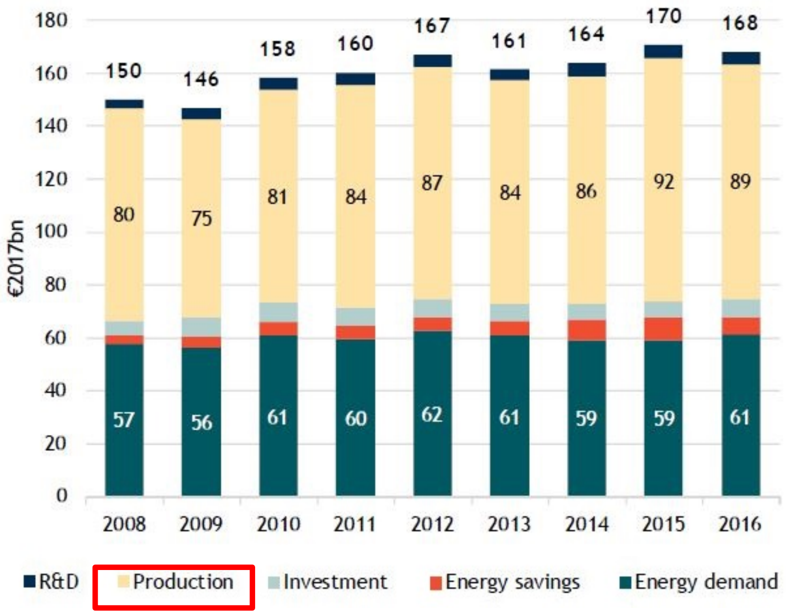
The bigger picture in the EU – 3 divisions



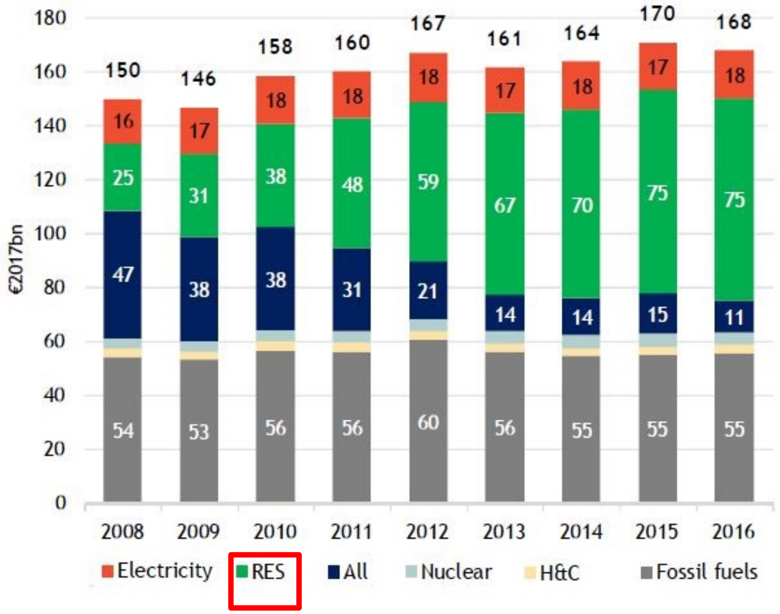
SECTOR



ACTIVITY



ENERGY SOURCE



What do we support?

Focus on 4 technologies: Solar (utility/roof top) & Wind (onshore/offshore)

Figure 6-21: Financial support to RES by energy source (2008-2016, €2017bn)

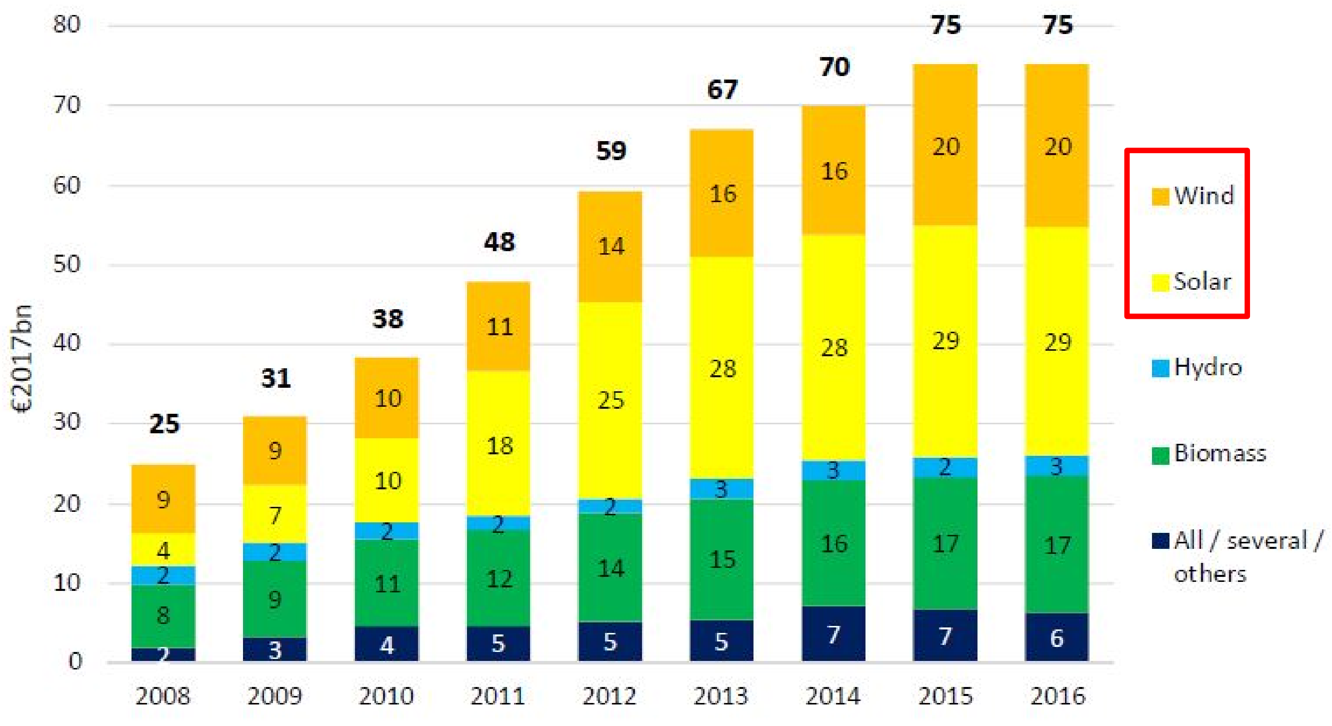
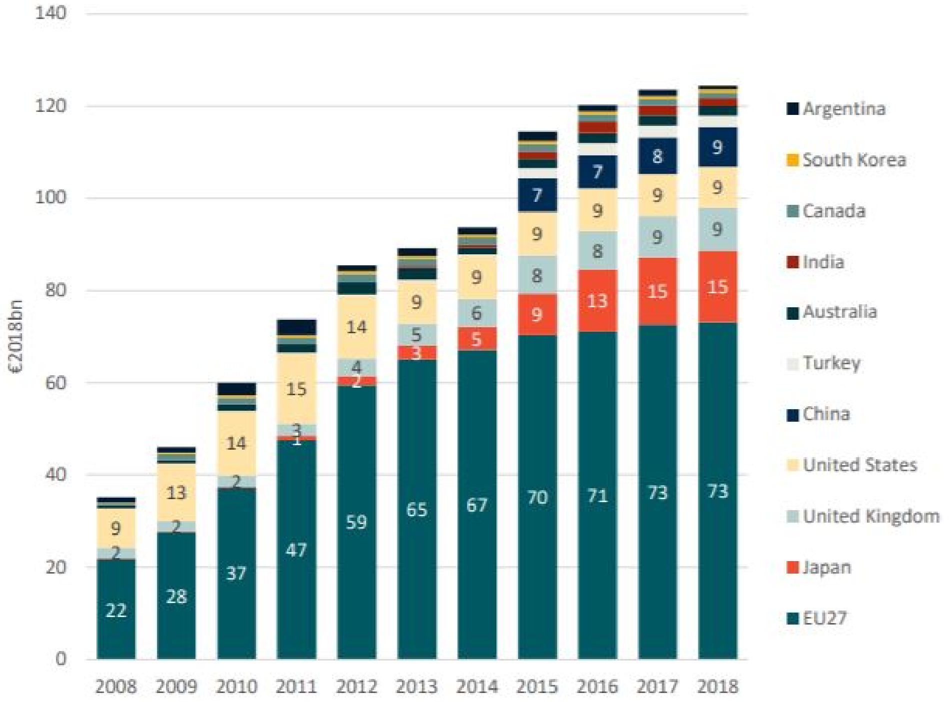


Figure 2-12 Subsidies to renewable technologies by zone and country (€2018bn, 2008-2018)*



*: data provided above are partial since the cost of some programmes couldn't be identified such as the renewable obligation schemes implemented in Japan until it ended in 2012, FiT and FiP in China before 2015 and most policies implemented at state level in Federal countries such as China, India or the United States of America.

How do we support?

Interventions to support energy-related activities in the EU

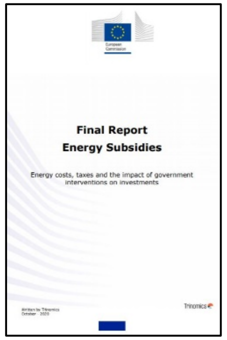
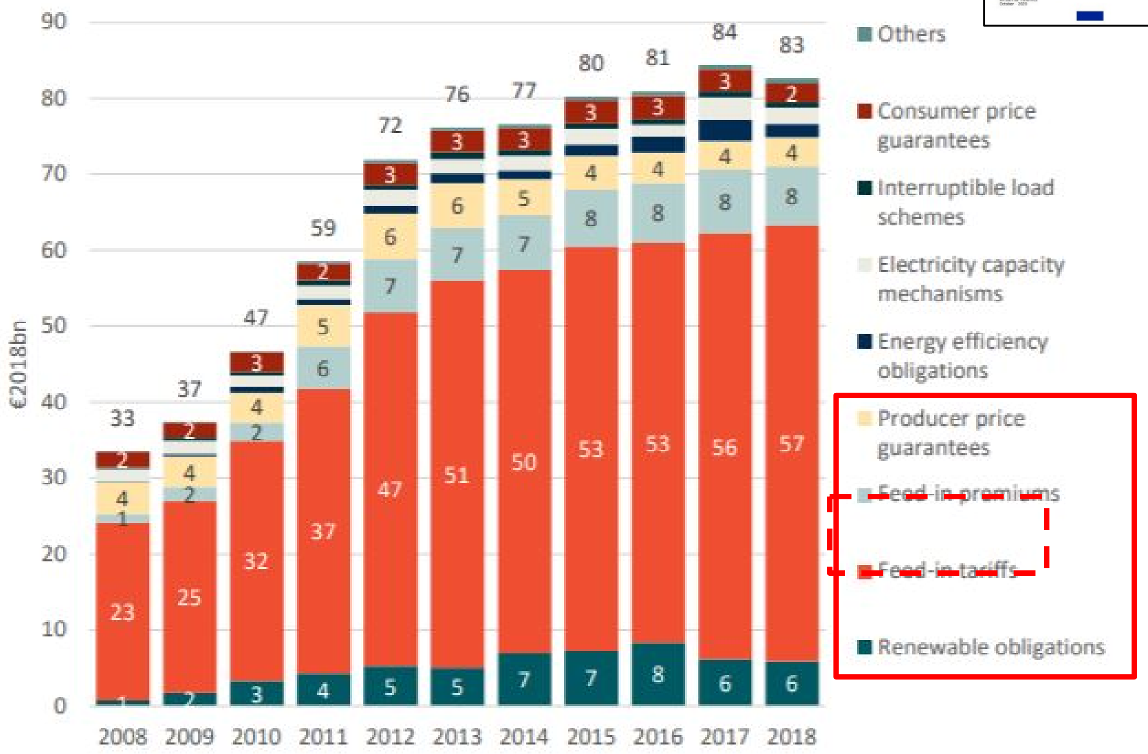


Figure 2-16 Income and price supports in the EU27 by type (€2018bn, 2008-2018)[11]



- A. Financial support (decision: governments // recuperation: surcharges in the electricity bill or public budget)
  - A.1: "Indirect transfers'', also called income or price support, e.g. feed-in tariff and premium, tradeable green certificates, CfDs (via auctions or not), CRMs,…
  - A.2: "Tax benefits" e.g. tax credits, exemption or reduction of taxes and levies,…
  - A.3.: "Direct transfers" e.g. grants, soft loans
- B. Non-financial support (decision: regulators // recuperation: often via network charges
  - Examples: net-metering, shallow connection charges, balance responsibility, priority dispatch, permitting, grid connection codes,…
  - Such regulatory actions can also be done for reasons of proportionality or difficulty of implementation

Thank you!