L'idrogeno sostenibile
per accelerare la transizione energetica

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Strategia Italiana sull'Idrogeno: quale impatto sul sistema elettrico

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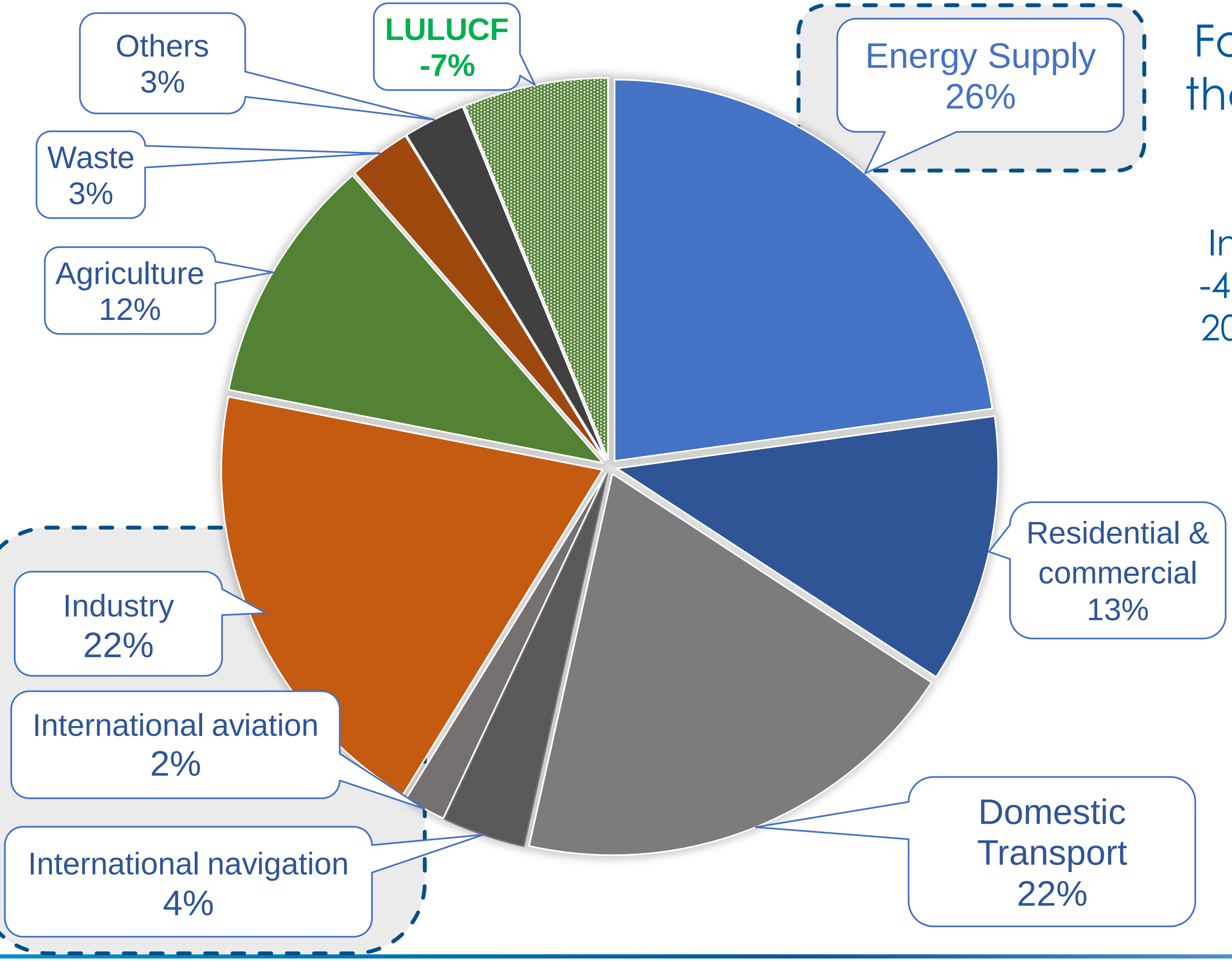
GHG Emissions in the EU by sector

Total emissions ≈ 3.247 Mton CO_2eq in 2020



Forerunner sector in the decarbonization through RES-e

In the EU power sector: -47% of CO_2 emissions in 2020 compared to 1990

Sectors hard to decarbonize only through electrification

Role of **"green" or "low carbon" gases**

Hydrogen final uses and production

Some sectors can hardly be decarbonized through electrification

Chemicals
- Fertilizers, ammonia
- Polymers
- Resins

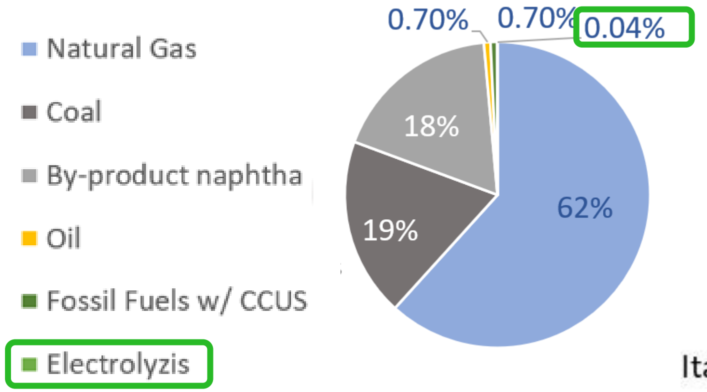
Refining
- Hydrocracking
- Plastics

Iron & Steel
- Thermal treatments
- Process gases

Other industrial uses
- Semiconductors
- Propellant fuel
- Glass production
- Hydrogenation of fats
- Cooling of generators

Heavy transports
- Trucks
- Ships
- Trains
- Aviation

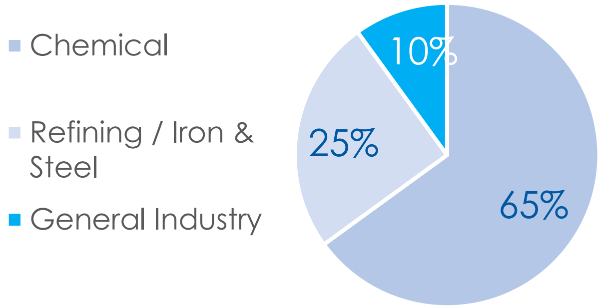
Current hydrogen sources (*)



Electrolyzers installed capacity

2020 210 MW
2021 510 MW
2022 1+ GW
…
2030 134 GW

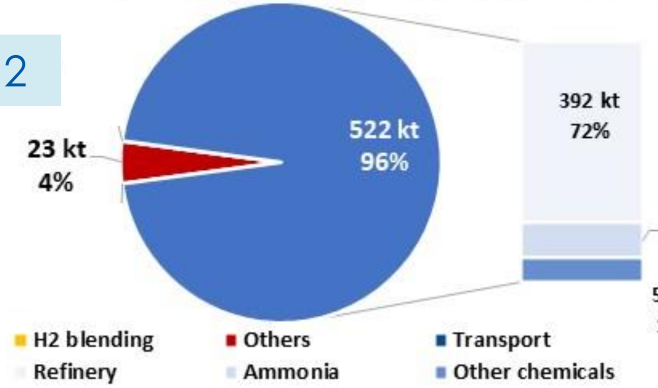
Current uses of hydrogen



Total H2 consumption worldwide: 94 Mton(*)

Italy - historical H2 demand by sector - 2020

545 kton H2



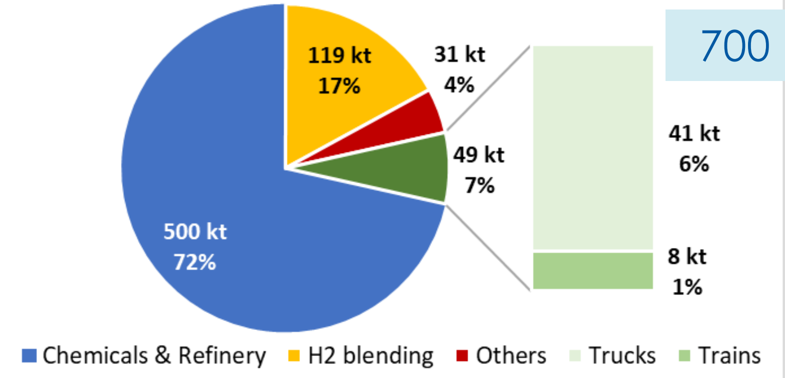
Source: Fuel Cells and Hydrogen Observatory (FCHO)

CAGR= 2.5%

evolving hydrogen final uses

Italy - Expected H2 demand by sector - 2030

700 kton H2



Source: Preliminary National Hydrogen Statategy

(*) Source IEA Global Hydrogen Review 2022 – data referred to 2021

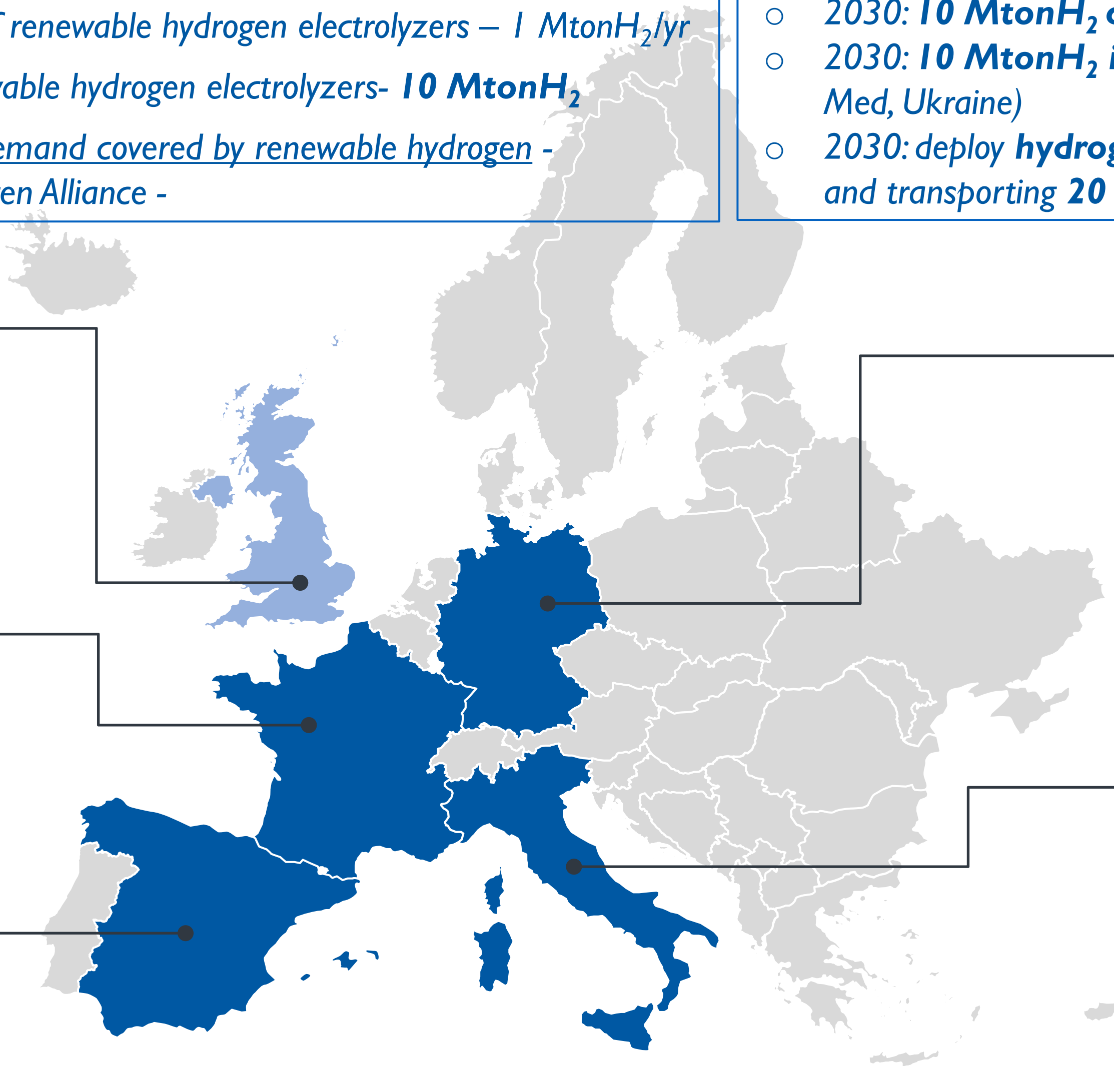
Hydrogen Strategies in Europe

The EU Hydrogen Strategy[1] – **July 2020**

- *2024: at least* ***6 GW*** *of renewable hydrogen electrolyzers – 1 MtonH_2/yr*
- *2030:* ***40 GW*** *of renewable hydrogen electrolyzers-* ***10 MtonH_2***
- *2050:* ***14%*** *of energy demand covered by renewable hydrogen - European Clean Hydrogen Alliance -*

REPowerEU plan – **May 2022**

- *2030:* ***10 MtonH_2 domestic*** *production*
- *2030:* ***10 MtonH_2 imported*** *renewable hydrogen (North Sea, Med, Ukraine)*
- *2030: deploy* ***hydrogen infrastructure*** *for producing, importing and transporting* ***20 MtonH_2***



United Kingdom

5 GW electrolyzers in 2030
(National Strategy 2021)

France

6.5 GW electrolyzers in 2030
(National Strategy 2020)

Spain

4 GW electrolyzers in 2030
(National Strategy 2020)

Germany

5 GW electrolyzers in 2030
(National Strategy 2020)

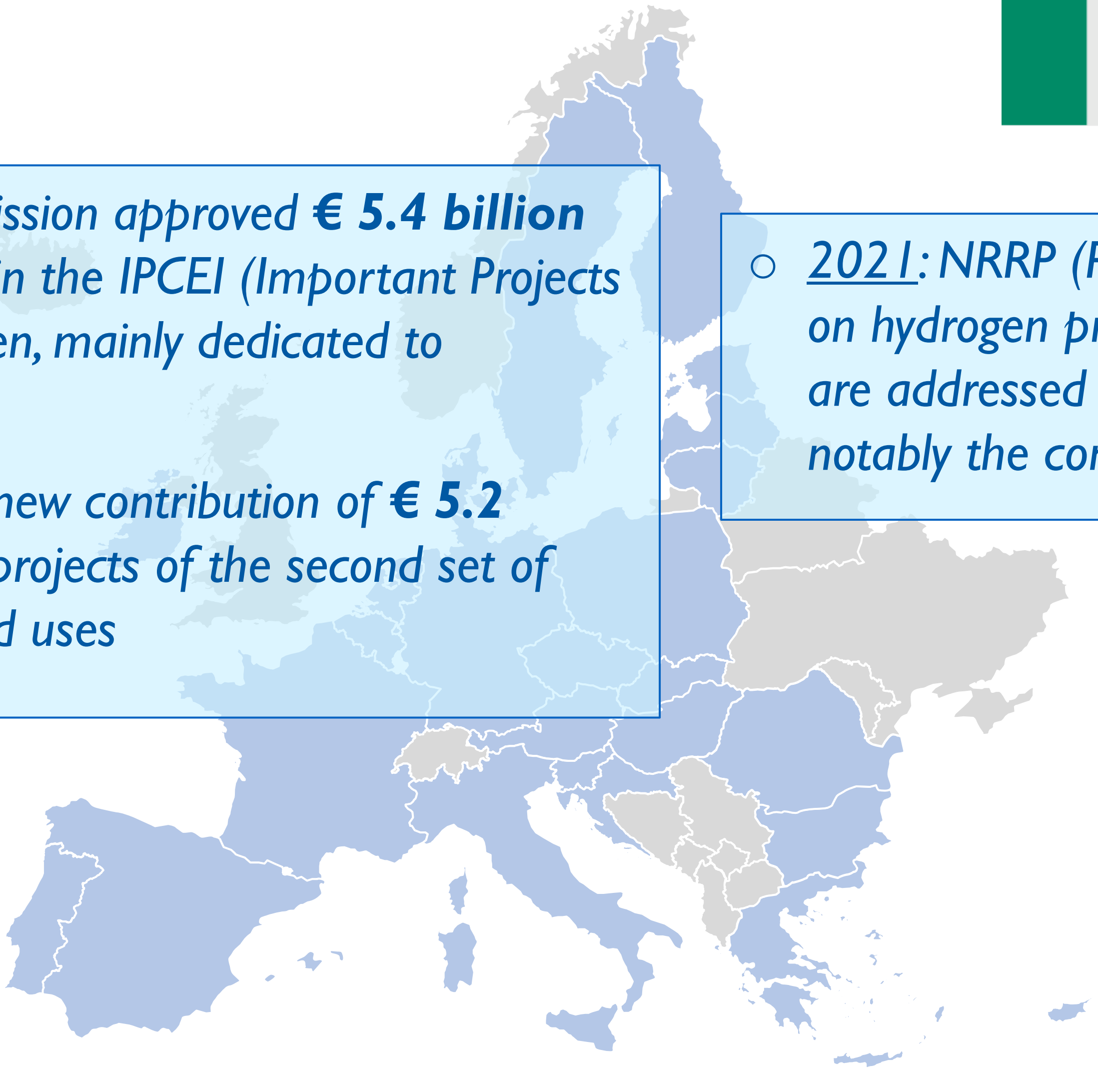
Italy

5 GW electrolyzers in 2030
(MiSe Preliminary Guidelines 2020)

Current hydrogen demand in the EU 27: 7.9 Mton/yr

[1] Already excluding UK

Hydrogen Strategies in Europe – Concrete steps



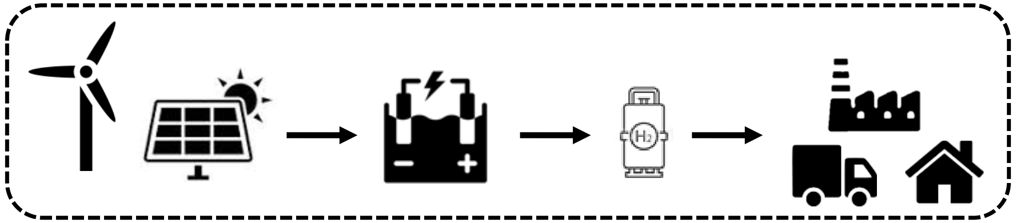
- *July 2022: the European Commission approved* ***€ 5.4 billion*** *in funding for projects included in the IPCEI (Important Projects of Common Interest) on hydrogen, mainly dedicated to technology*
- *Sept. 2022: the EC approved a new contribution of* ***€ 5.2 billion*** *to support the winning projects of the second set of IPCEI hydrogen, dedicated to end uses*

- *2021: NRRP (PNRR) allocated* ***€ 3.64 billion*** *on hydrogen projects, out of which € 2 billion are addressed to the hard-to-abate sectors, notably the conversion of steel plants*

Possible schemes for integration of Green Hydrogen

Three possible implementation scenarios for H2 production, transport and consumption:

✓ **Decentralized:** electrolyzers and V-RES at consumption centres

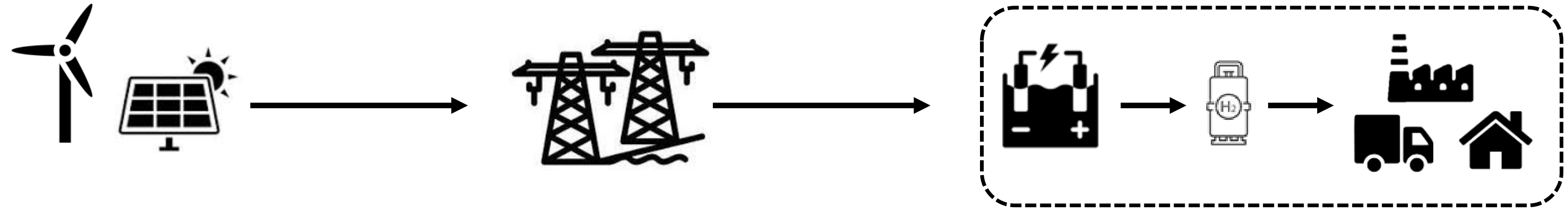


Off-grid

Grid connection

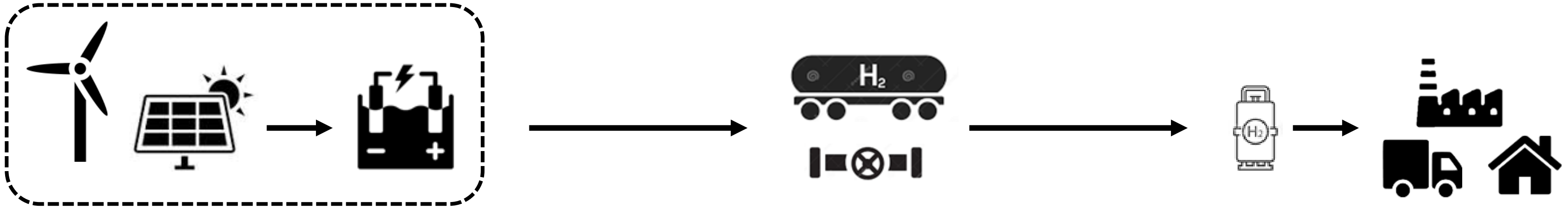
Co-location

✓ **Transport of electricity:** V-RES PP in most favourable areas with electricity transmission, electrolyzers at consumptions centres



Grid connection

✓ **Transport of H2:** electrolyzers and V-RES PP in the same locations with transport of H2



Grid connection

Key factors and questions to be addressed

Key Factors considered

- Network reinforcements
- V-RES intermittency and variability
- Power markets simulation
- Location of H2 demand
- Batteries
- H2 Pipeline infrastructure

Key Questions addressed

What are the implications of each implementation scenario on the power system?

Which is the impact of electrolyzers on the power markets?

Would the electrolyzers be able to support the integration of renewables?

https://www.cesi.it/views/

How much will 1 kg of H_2 cost in the different implementation scenarios?

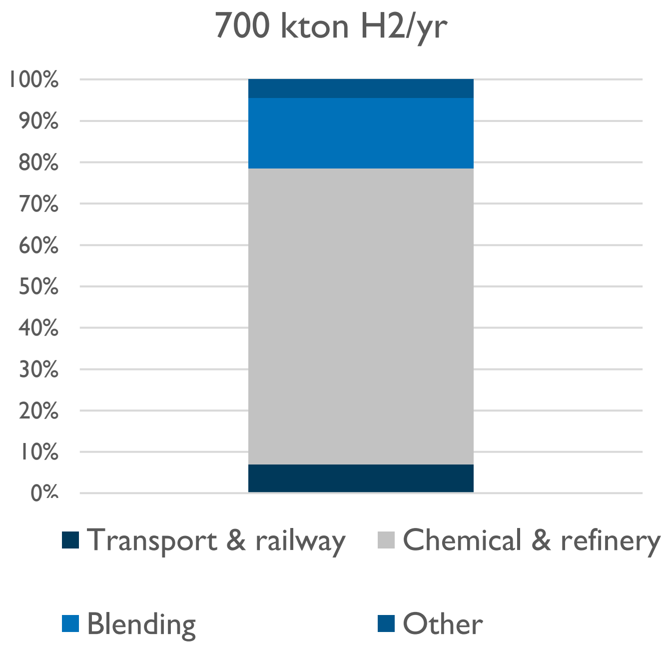
How to assess the Levelized Cost of Green Hydrogen - A practical study case applied to Italy

National Hydrogen Strategy: preliminary guidelines

✓ issued by Ministry of Economic Development – Oct. 2020

Targets and key figures:

- about **5 GW** of electrolyzers by 2030
- **2%** energy demand: 700 kton/yr by 2030 [(1)]
- *2050 objective: up to **20%** of energy demand covered by green hydrogen*



Preliminary **estimated benefits**:

- Up to **8 Mton** of avoided CO_2 eq emissions
- about **200 k** temporary and **10 k** permanent jobs
- Up to **€ 27 billion** of accrued additional PIL

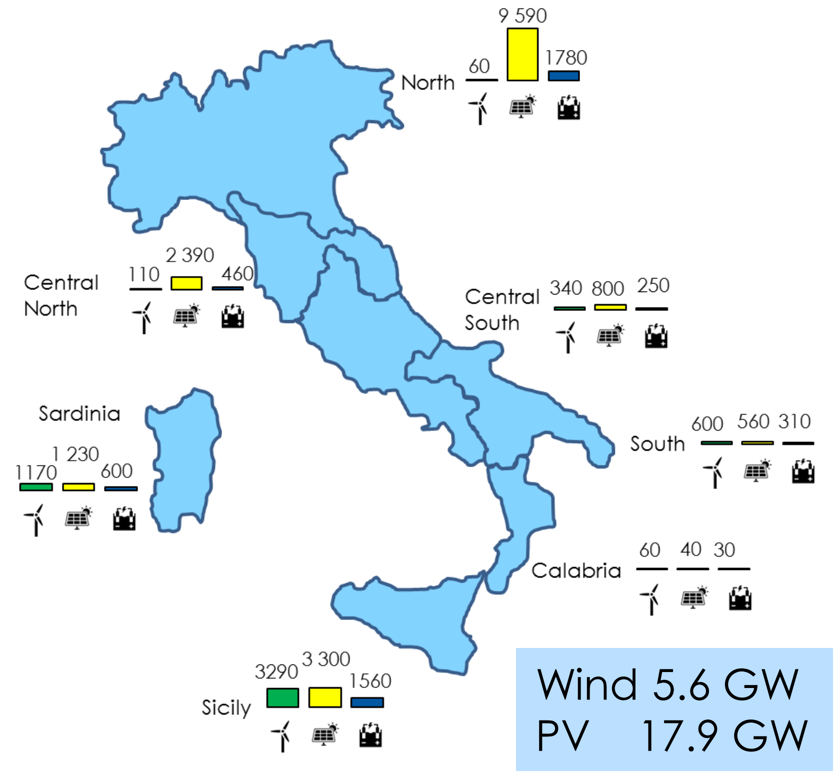
[(1)] Current hydrogen demand: ≈550 kton/yr

Scenarios: geographical location of electrolyzers and additional RES for green hydrogen

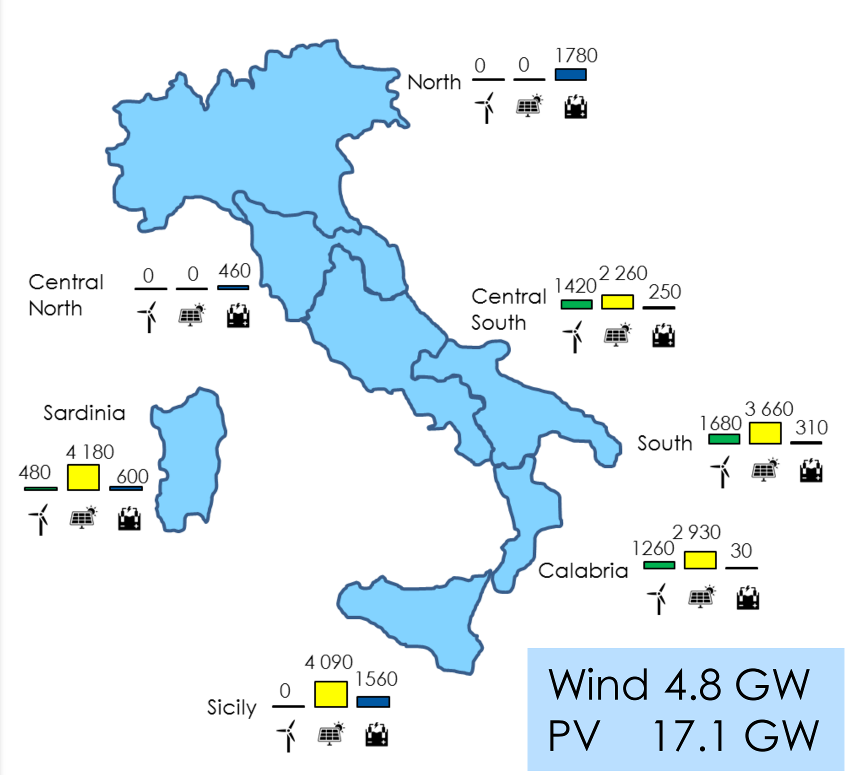
- Wind installed capacity [MW]
- PV installed capacity [MW]
- Electrolyzers installed capacity [MW]

700 kton/year → 35 TWh_{el} assuming that the whole hydrogen demand is produced through electrolyzers

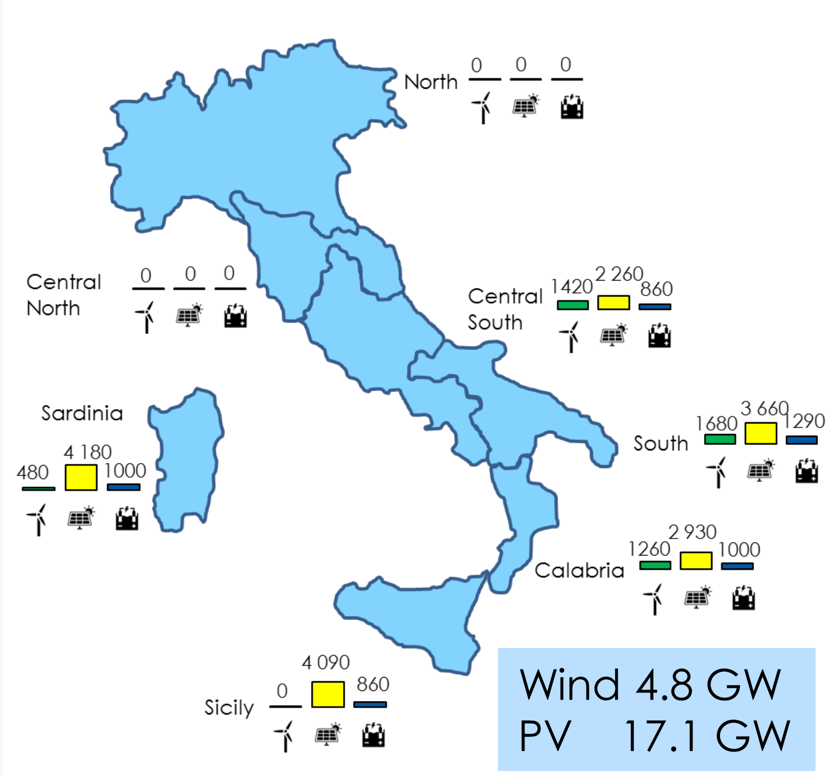
2 - Decentralized



3 – Transport of Electricity



4 – Transport of H2



Note: figures are based on the assumption that additional V-RES power plants shall generate the energy needed to produce 700 kton of green hydrogen by means of 5 GW electrolyzers

Power market simulations and computational tools (outline)

Power markets

Day-Ahead Market	Intraday Market	Scheduling Ancillary Services Market	Balancing Market
Mercato del Giorno Prima (MGP)	Mercati Infragiornalieri (MI)	Mercati Servizi Dispacciamento Ex-Ante (MSD Ex-Ante)	Mercato di Bilanciamento (MB)
Definition of withdrawals and injections schedules for the next day (24 hours)	Correction of schedules by market operators considering updated forecasts, unplanned unavailability, or because of technical unfeasibility.	Procurement of reserves margins and redispatching for network constraints which can be foreseen some hours in advance (Voltage control, lines congestion, …)	Activation of reserves margins in order to keep real-time balance between withdrawals and injections. Real-time redispatching for network constraints.

Market simulators

Promedgrid

CIGRE 2012 C5 - 101 ‘**Market integration in Europe**: a market simulator taking into account different market zones and the increasing penetration of RES generation”

CIGRE 2016 C1 – 317 “An innovative **cost-benefit analysis** to assess transmission projects: The Italian case”

MODI$

CIGRE 2018 C1–103 “Assessing the impact of transmission investments on the Italian **Ancillary Services Market** using MODIS simulator”

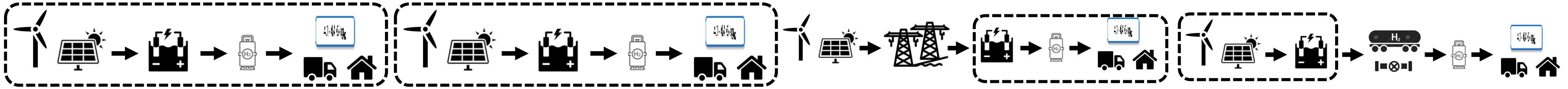
Results – Low Flexibility Electrolyzers

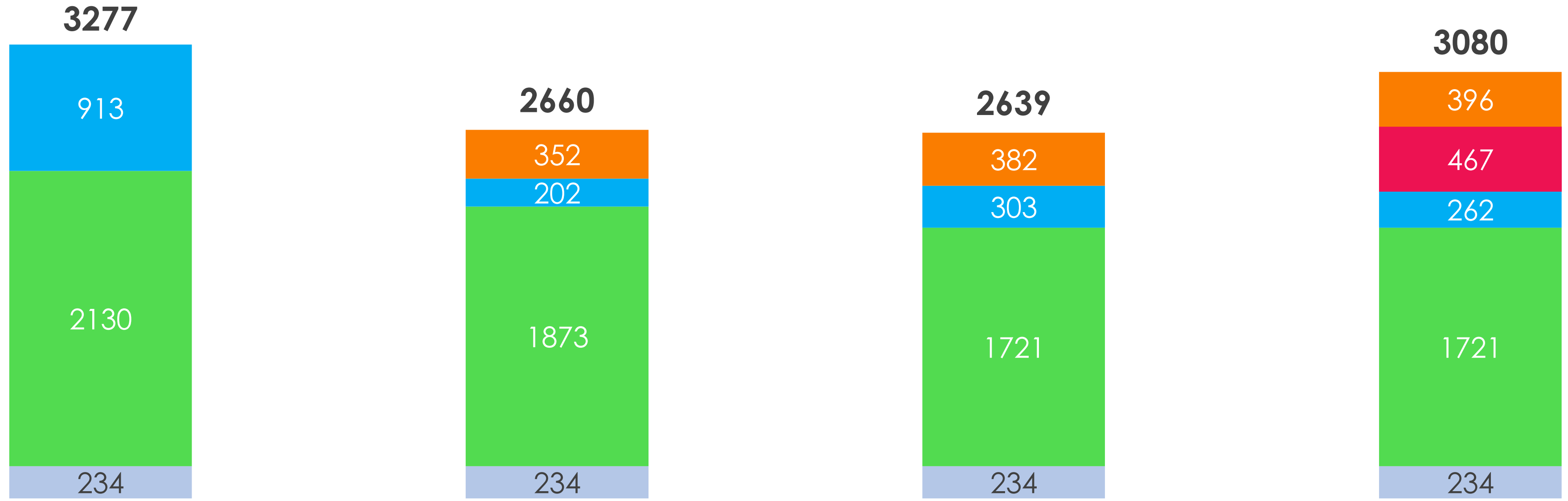
Estimations at horizon year 2030

Low Flexibility*

Figures in M€/year

	Off-grid	Connection with power grid		
	1 - Decentralized	2 - Decentralized	3 – Transport of Electricity	4 – Transport of H2





	1 - Decentralized	2 - Decentralized	3 – Transport of Electricity	4 – Transport of H2
System LCOH	4.7 €/kg_{H2}	3.8 €/kg_{H2}	3.8 €/kg_{H2}	4.1÷4.4 €/kg_{H2}
Avoided V-RES curtailment (<0 means increase of curtailment)	-6300 GWh	- 853 GWh	- 775 GWh	- 429 GWh

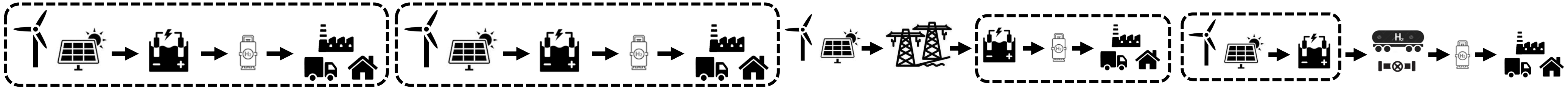
** Need of system reserves to compensate variability of RES dedicated to green hydrogen production*

Results – High Flexibility Electrolyzers

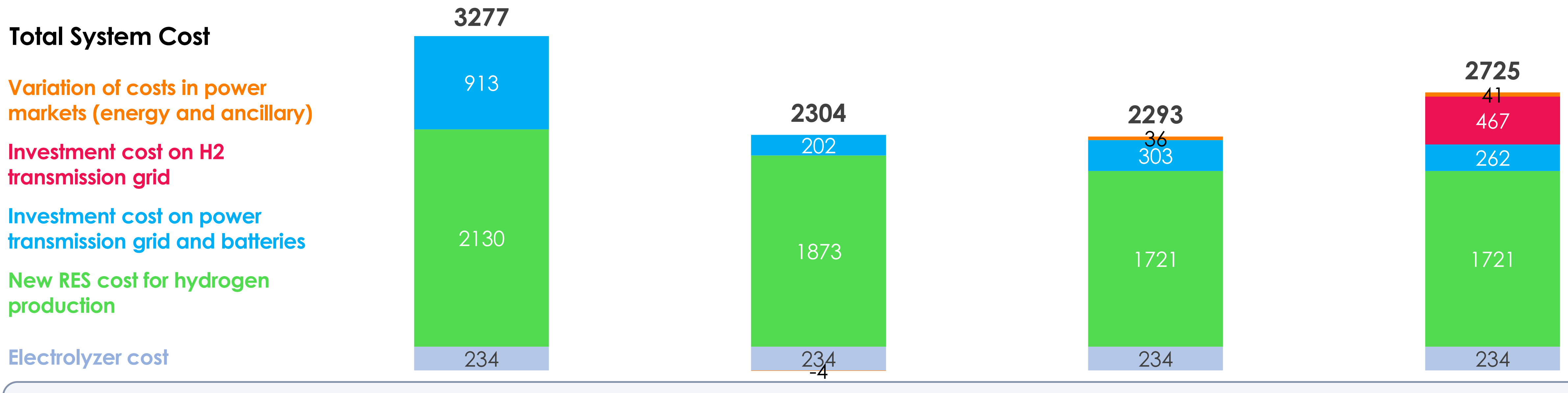
Estimations at horizon year 2030

High Flexibility *

	Off-grid	Connection with power grid		
	1 - Decentralized	2 - Decentralized	3 – Transport of Electricity	4 – Transport of H2



Figures in M€/year

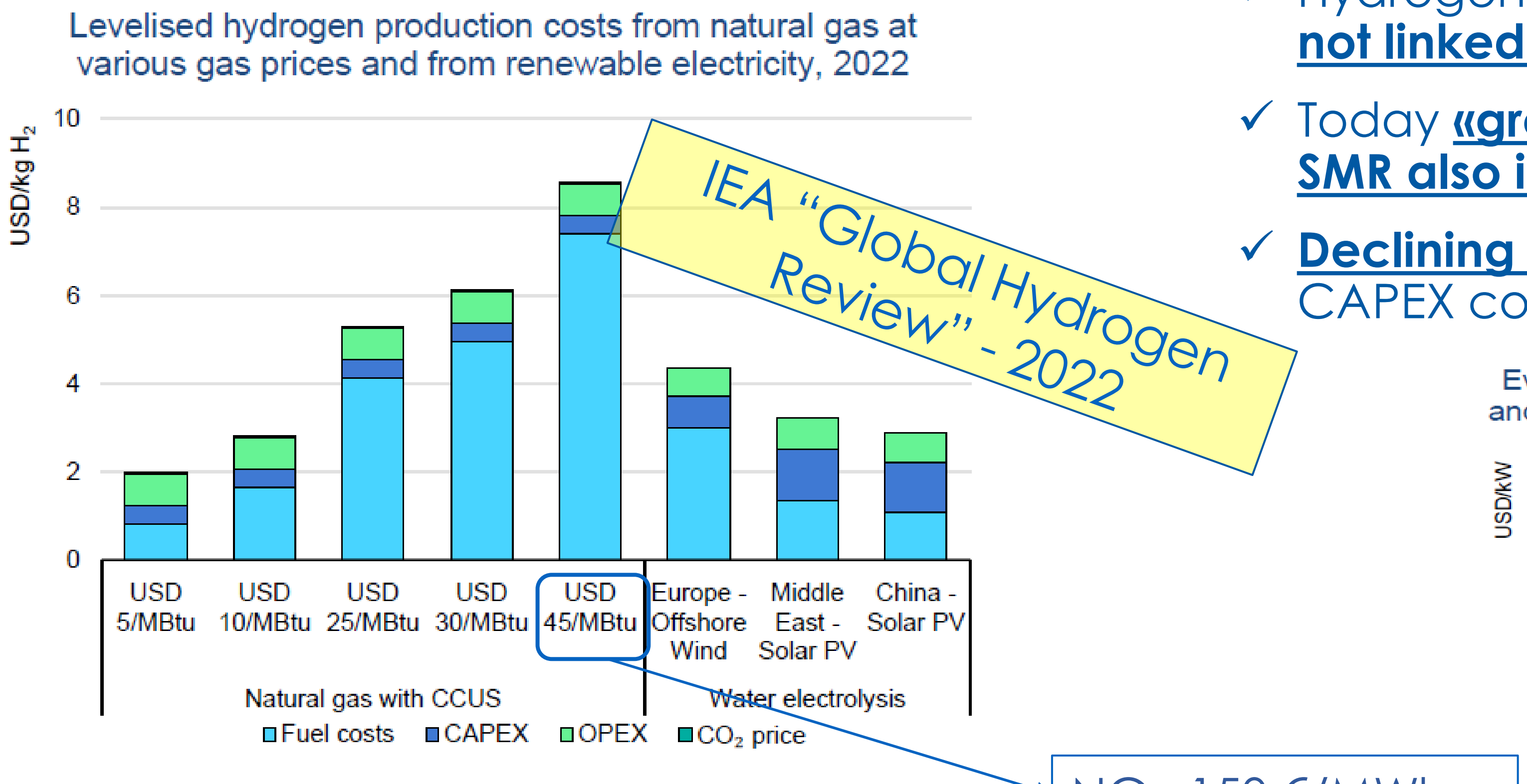


	1 - Decentralized	2 - Decentralized	3 – Transport of Electricity	4 – Transport of H2
System LCOH	4.7 €/kg_{H2}	3.3 €/kg_{H2}	3.3 €/kg_{H2}	3.6÷3.9 €/kg_{H2}
Avoided V-RES curtailment (<0 means increase of curtailment)	-6300 GWh	447 GWh	425 GWh	671 GWh

** No need of system reserves to compensate variability of RES dedicated to green hydrogen production.*

Competitivity “green” hydrogen against soaring commodity prices

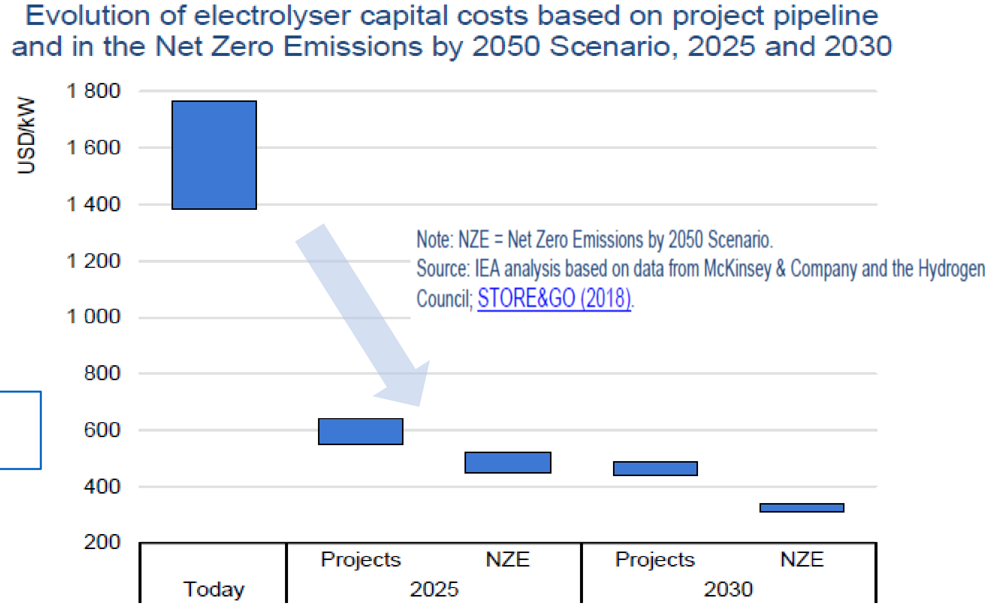
Hydrogen cost from SMR (Steam Methane Reforming) with and w/o CCUS



Notes: CCUS = carbon capture, utilisation and storage; CAPEX = capital expenditure; OPEX = operational expenditure. Stack replacement cost included in OPEX for electrolysis. CO_2 price assumed at USD 80/tonne CO_2.

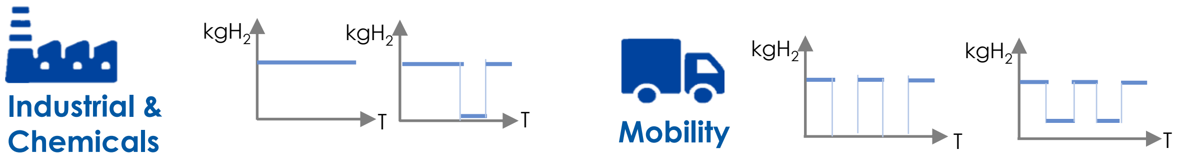
Sources: Based on data from McKinsey & Company and the Hydrogen Council; Council; IRENA (2020); IEA GHG (2014); IEA GHG (2017); E4Tech (2015); Kawasaki Heavy Industries; Element Energy (2018).

- ✓ Hydrogen costs produced through electrolyzers **not linked to commodity price volatility**
- ✓ Today **«green» hydrogen competitive against SMR also including costs for CCUS**
- ✓ **Declining cost of «green» hydrogen** thanks to CAPEX costs cut of electrolyzers and RES



From systemwide to project-based analyses and design

H_2 demand: volume and profile



RES energy supply & e-storage

Decentralised RES vs supply from the grid through PPA (out-sourcing)

Power to H_2

Compression & Storage

Importance of the optimal design of "green hydrogen" projects, minimizing LCOH

OPTIMISATION PROBLEM to minimize LCOH

$\min LCOH\ ([u])$

[u] = [RES en.supply mix, Electrolyzer size, Compressor&StorageH_2 size,…]

s.t.:
- *demand volume and time profile*
- *geographical location*
- *CAPEX&OPEX of power & gas components*
- *PPA prices*
- *percentage of decentralized RES production*

LCOH: Decentralised / Out-Sourcing

indicative

		Decentralised	Out-Sourcing
Transport	Nord	4.75 – 5.68 $/kg	4.46 – 4.86 $/kg
Transport	Sud	3.77 – 4.52 $/kg	4.46 – 4.86 $/kg
Hard To Abate	Nord	4.82 – 5.82 $/kg	4.32 – 4.92 $/kg
Hard To Abate	Sud	3.84 – 5.29 $/kg	4.32 – 4.92 $/kg

Regulatory issues for "green hydrogen" / RFNBO

Under what conditions H_2, in general RFNBO*, can be qualified as "renewable" / "carbon free"?

May 2022 – EC issues the **proposal of Delegated Regulation** on "*methodology setting out detailed rules for the production of renewable liquid and gaseous transport fuels of non-biological origin*"

Additionality	**Electrolyzers supplied by new RES PP other than biomasses**
Spatial correlation	**Co-location of electrolyzers and RES PP in the same bidding zone model or adjacent bidding zones vs nodal model vs levelized playing field**
Temporal correlation	**Debate still open on the width of the time window to count RES generation and electrolyzers absorption: hr, month, quarter…**
Hydrogen from overgeneration	**How to certify hydrogen produced by RES PP that would be downward redispatched to balance the system? How to monetize the value of this hydrogen? Which electrolyzers shall be used?**
Hydrogen import from outside the Union	**How to certify compliance with EU regulation of hydrogen produced in countries non applying the EU regulations and possibly not having compliant data monitoring and recording ?**

No consensus on many key principles

Transitional phase to be managed

New version of the **proposal of Delegated Regulation** still to be issued with looser constraints

* Renewable Fuels of Non-Biological Origin

Regulatory issues for "green hydrogen" / RFNBO

Actions from Member States:

Apr. 2022 – Decreto PNRR 2 (D.L. 36 G.U. 30/4/2022) prevede per l'idrogeno verde un incentivo

Esenzione dall'accisa se non direttamente utilizzato in motori termici come carburante

Sept. 2022 – Decreto MiTE 21/9/2022 su "*Condizioni per l'accesso alle agevolazioni sul consumo di energia rinnovabile in impianti di elettrolisi per la produzione di idrogeno verde*» (G.U. 23/09/2022)

Il provvedimento si rivolge a soggetti, pubblici o privati, in relazione ai consumi elettrici annui da FER utilizzati per l'elettrolisi

Esenzione dal pagamento oneri di sistema

Condizioni: l'idrogeno verde prodotto deve comportare una riduzione delle emissioni di gas serra nel ciclo di vita del 73,4% rispetto a un combustibile fossile di riferimento di 94 g CO_2eq/MJ. o più semplicemente emettere meno di 3 ton CO_2eq/ton di H2

Oct. 2022 – D.M. MASE 21/10/2022 "Hydrogen Valleys" – Settori "hard-to-abate"

Dec. 2022 – Decreto Direttoriale MASE "Hydrogen Valleys": specifiche tecniche e bandi tipo

Bando tipo per la concessione delle agevolazioni da parte delle Regioni e delle Prov. Aut.

Milan (IT) · Arnhem (NL) · Berlin (DE) · Mannheim (DE) · Prague (CZ) · Chalfont (US) · Knoxville (US) · Dubai (AE) · Dammam (SA) · Santiago de Chile (CL) · Rio De Janeiro (BR) · Shanghai (CN)