



# Hydrogen and the energy transition

Summer School on Control and optimization of renewable  
and green hydrogen energy systems  
June 30<sup>th</sup>, 2021

Claudio Marcantonini  
ARERA

*Disclaimer: the views and opinions expressed in this presentation are those of the author and do not necessarily reflect those of ARERA*

# INDEX

---

## 1. The energy transition

- 1.1 From national sectors to an EU energy sector
- 1.2 The third energy package
- 1.3 The Clean energy package
- 1.4 The EU Green Deal

## 2. Hydrogen

- 2.1 Why hydrogen?
- 2.2 Cost of hydrogen production
- 2.3 The European Commission's hydrogen strategy

# INDEX

---

## 1. The energy transition

- 1.1 From national sectors to an EU energy sector
- 1.2 The third energy package
- 1.3 The Clean energy package
- 1.4 The EU Green Deal

## 2. Hydrogen

- 2.1 Why hydrogen?
- 2.2 Cost of hydrogen production
- 2.3 The European Commission's hydrogen strategy

# INDEX

---

## 1.1 From national sectors to an EU energy sector

# 80s and early 90s

---

## Framework

- Large national infrastructures
- Vertically integrated companies/national champions
- Technological stability: coal, gas, nuclear, hydro

## Energy policy and regulation

- Done at national level by the government (no regulator)

## Priorities:

- security of supply
- provision of energy at a low price

# 1st and 2nd Energy Package (1996-2003)

---

- From 96' the EU has gradually **liberalized the energy sector**
- *Competition where possible, regulation where necessary*
- **Separation** of the energy supply chains in:
  - **generation and retailing** open to competition
  - **transmission and distribution**: monopolies to be regulated
- Because:
  - **Technological evolution** in power plants would make easier to invest
  - Policymakers supported **competition for reducing cost**
  - High public debt

# INDEX

---

## 1.2 The 3<sup>rd</sup> energy package

# The 3<sup>rd</sup> energy package (2009): priorities

---

## 1. Consolidation of the market liberalization

1.1 Strong unbundling rules

1.2 Strong power and independence to NRAs

## 2. Integration of national markets

2.1 New institutional framework: creation of new EU bodies:  
**ACER and ENTSOs**

2.2 **Network codes** to harmonize market and network operation rules at pan-European level

2.3 Coordinated infrastructures development: TYNDP

## 3. Decarbonization and renewable energy

3.1 Binding national targets

3.2 EU leader on fighting climate change



# 2020 targets

---

1. **20% of EU final energy consumption from renewable energy**
  - Divided in national binding targets
2. **20% CO2 emission reduction** wrt 1990 levels
  - to be reach mainly with the EU Emission Treading Scheme (ETS)
3. **20% improvement in energy efficiency** wrt Primes 2007

# The 3rd energy package: 10 years later

---

## 1. Successful in market integration

# ELECTRICITY MARKET COUPLING

---



1990s – NORD POOL



2006



2011



FEBRUARY 2014



MAY 2014



FEBRUARY 2015

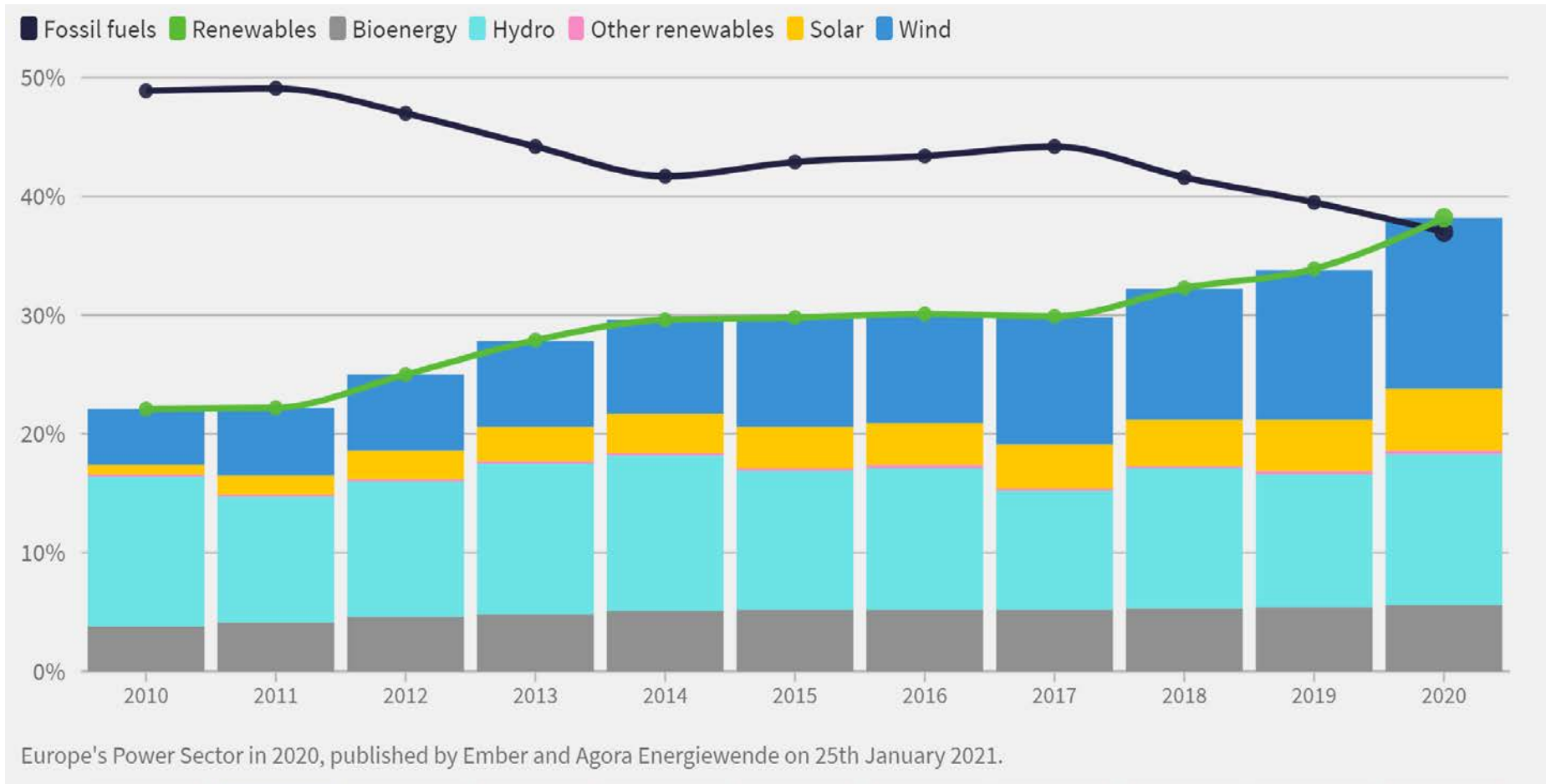
Most of the national electricity market are coupled in a single market

# The 3rd energy package: 10 years later

---

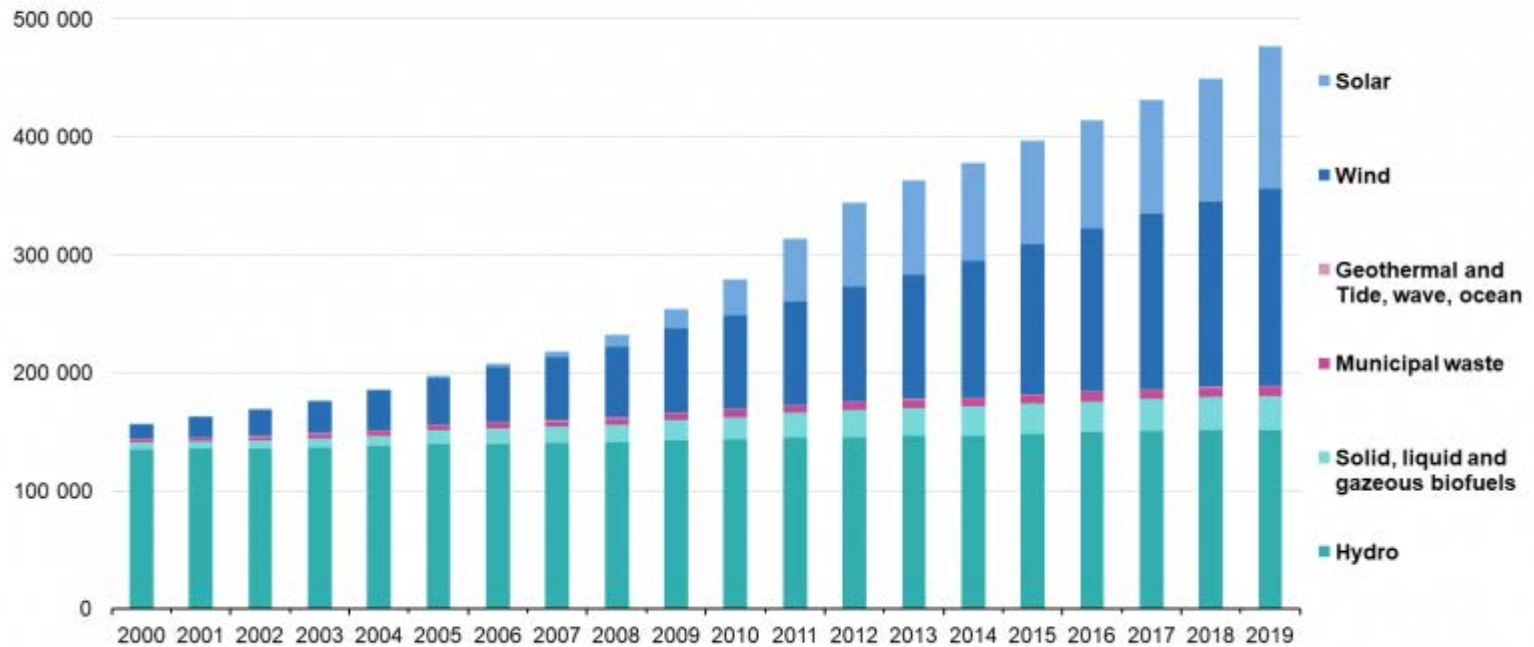
1. Successful in market integration
2. High development of REN, in line with the target

# Share of electricity production in EU-27



# REN electricity capacity

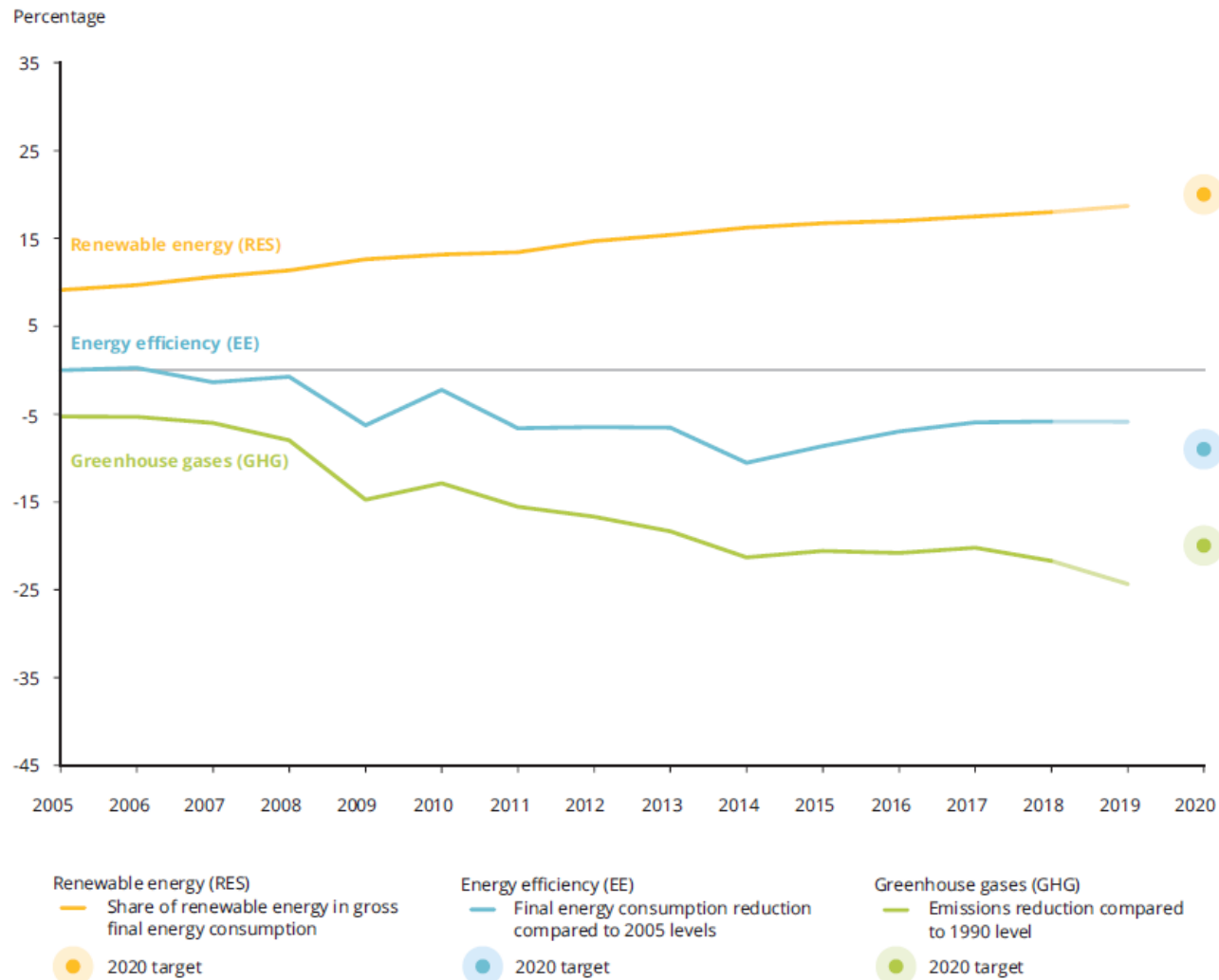
Evolution of net maximum electrical capacity for renewables and renewable waste in EU-27 (MW), 2000-2019



Source: Eurostat ([nrg\\_inf\\_epcrw](#))

eurostat 

# EU progress towards 2020 targets



Source: European Environmental Agency

# The 3rd energy package: 10 years later

---

1. Successful in market integration
2. High development of REN, in line with the target

**BUT...**



# The 3<sup>rd</sup> energy package: new challenges

---

- **Different level of integration** and market efficiency among Member States
- Large development of intermittent and locally distributed **renewable energy** poses new challenges
  - High cost of REN energy policy
  - Need of flexibility and adapting the market design
- Problem of **adequacy** in some electricity markets: need of capacity remuneration mechanism
- Most final **customers are inactive** and do not reap the advantage of the free market

---

## 3. The Clean Energy Package (2018-2019)

# Clean energy package: new legislation

---

Revision of all the EU legislation in the energy sector **excluding gas:**

- Renewable Energy Directive
- Energy Efficiency Directive
- Electricity Regulation
- Electricity Directive
- ACER regulation
- Risk Preparedness Regulation
- Energy Performance in Buildings Directive

# Clean energy package: objectives

---

- **Stronger environmental targets**

# EU 2030 energy climate strategy

---

## New targets:

- **40%** cut in **greenhouse gas** emissions wrt 1990 levels (Paris agreement)
- **32%** of EU final energy consumption from **RES**
- **32.5%** improvement in **energy efficiency** wrt Primes 2007

Plus the EU has the **long-term target of 80-90%** GHG emission reduction by **2050**

Targets in line with the Paris agreement

# Clean energy package: objectives

---

- **Stronger environmental targets**
- **New energy governance**

# New energy governance

---

## Whole system approach

- **Integrated 10-years national plans** for climate and energy that define targets, policies, and measures
- 5 dimensions: decarbonization, energy efficiency, energy security, internal energy market, R&D

## Balance between national flexibility and EU target

- **No binding national targets but** only at EU level
- Analysis and monitoring of plans by the Commission
- Assignment of powers to the Commission to ensure the collective achievement of EU objectives

# Clean energy package: objectives

---

- **Stronger environmental targets**
- **New energy governance**
- **Empowering consumers:** Active customers/Renewable self-consumers/Citizens energy community/Renewable energy community



# Clean energy package: objectives

---

- **Stronger environmental targets**
- **New energy governance**
- **Empowering consumers:** Active customers/Renewable self-consumers/Citizens energy community/Renewable energy community

# Clean energy package: objectives

---

- **Stronger environmental targets**
- **New energy governance**
- **Empowering consumers:** Active customers/Renewable self-consumers/Citizens energy community/Renewable energy community
- Upholding **energy-only market approach** but allowing for generation adequacy instruments
- Continuing **national market integration** with a **stronger role for ACER**
- Integration of **renewable energy into the market**

# INDEX

---

## 4. The EU Green Deal (2019-present)

# Higher ambitions

---

- **Stronger environmental targets:**
  - 55% GHG emissions reduction target by 2030
  - 2050 climate-neutrality already in the EU Climate Law
- Actions in **all sector of the economy**: energy, agriculture, circular economy, transport, international cooperation...
- It will require additional investments of the order of €260 billion per year, equivalent to around 1.5% of 2018 GDP
- **Stronger financial instruments:**
  - 25% of the EU budget dedicated to programs dealing with issues related to climate change or the environment to
  - 37% of the Next Generation EU recovery fund (750 B€)
  - Just transition mechanism with funds from the EU budget and from the EIB (European Investment Bank)

# Main initiatives to come

---

More than 40 initiatives planned, among them:

- Revision of the EU Emissions Trading System (ETS)
- Carbon Border Adjustment Mechanism
- Revision of the Energy Tax Directive
- Amendment to the Renewable Energy Directive and Energy Efficiency Directive
- Revision of the Regulation setting CO<sub>2</sub> emission performance standards for vehicles
- Revision of the energy performance of Buildings Directive (EPBD)
- **Hydrogen strategy and the revision of the Third Energy Package for gas**

# INDEX

---

## 1. The energy transition

1.1 From national energy sector to an EU sector

1.2 The third package

1.3 The Clean energy package

1.4 The EU Green Deal

## 2. Hydrogen

2.1 Why hydrogen?

2.2 Cost of hydrogen production

2.3 The European Commission's Hydrogen strategy

# INDEX

---

## 2.1 Why hydrogen?

# Hydrogen production and use today

---

- Hydrogen is the most widespread element on earth, but it does not exist in pure form
- Main method of production:
  - From **fossil sources** (methane and coal)
  - From **electrolysing**
- 70 Mt of hydrogen (2,333 TWh) are produced annually in the world: 76% from methane, 23% coal
- EU production to 280 TWh almost all from methane: **2% of energy consumption**
- Almost all hydrogen is currently produced and used locally in the **chemical industry and oil refining**

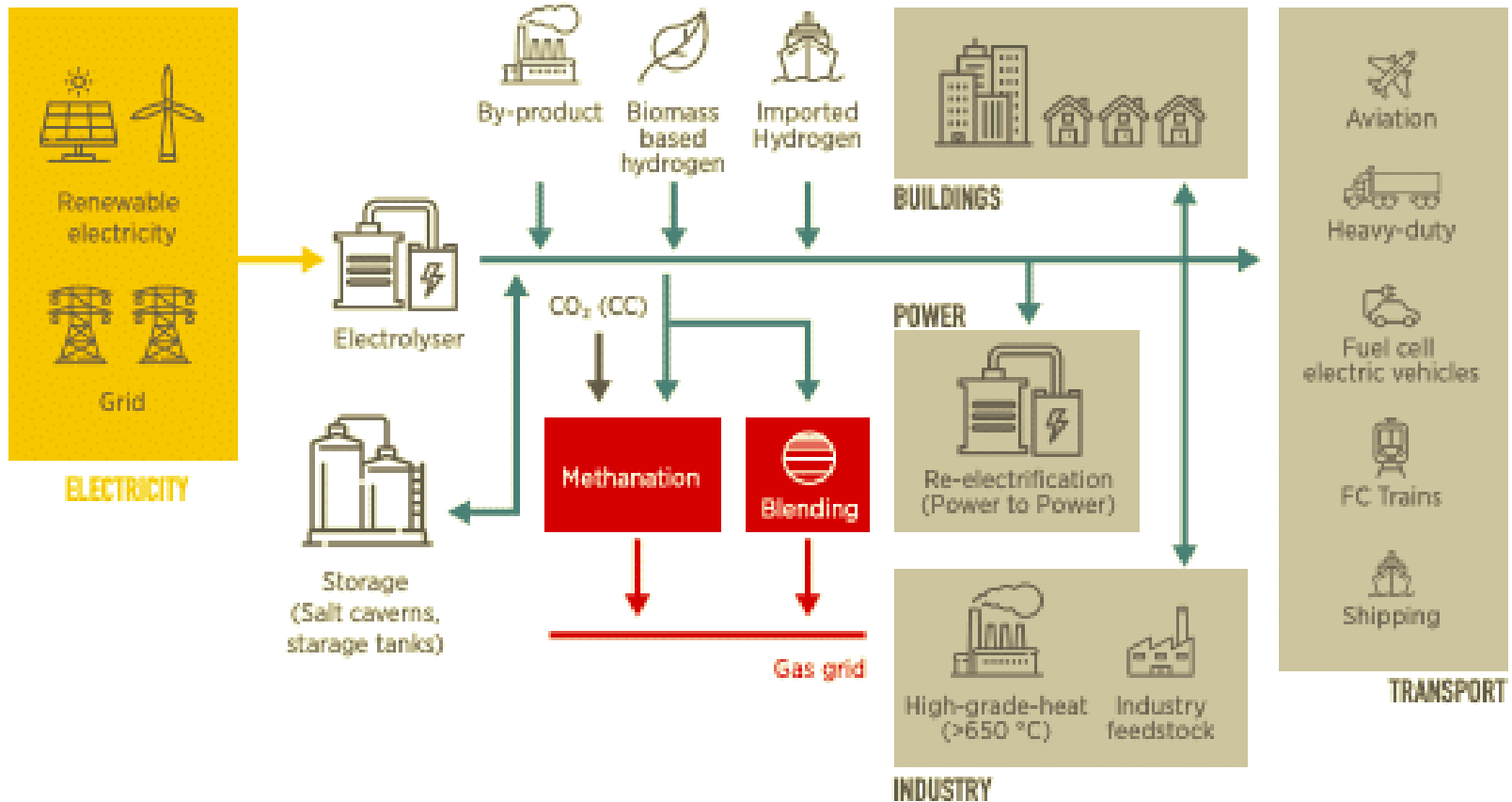


# Why producing more hydrogen?

---

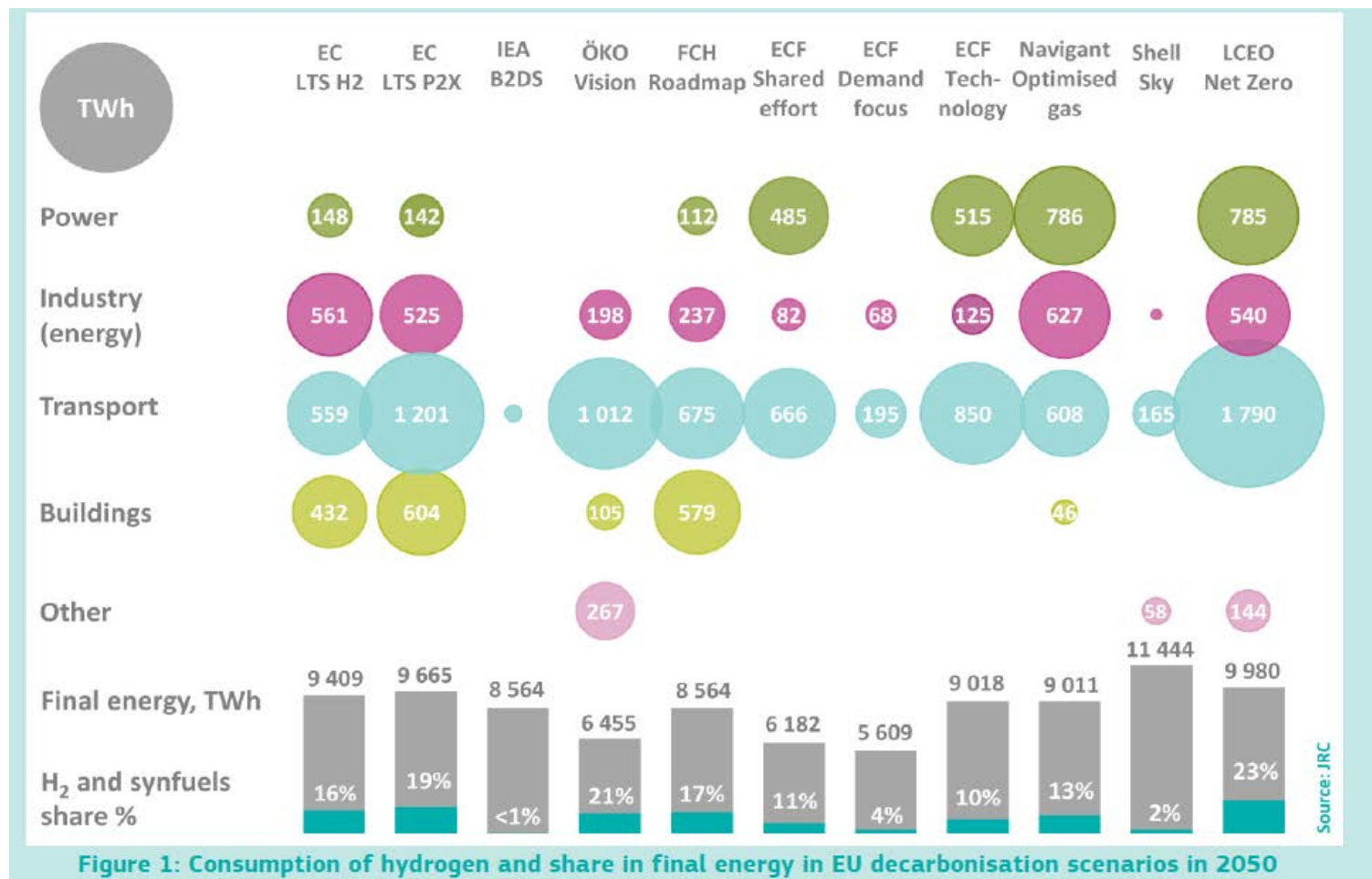
- We can produce **H2 with low GWG emissions**
  - From fossil sources with CCS (but 5-15% of losses)
  - from electrolysis with electricity from a zero-emission sources
- for **hard-to-abate sectors** where electrification is not the solution
  - the transport sector for heavy vehicles
  - Industry: iron and steel production, ceramics, paper mills
  - residential in areas where electrification is not convenient
- Furthermore, H2 could provide:
  - **flexibility** to the entire system
  - **long-term storage**

# Why producing more hydrogen?



Source: IRINA

# Consumption of H2 and share in final energy in EU decarbonisation scenarios in 2050



Source: JRC

In most scenarios, H<sub>2</sub> and derived fuels add up to between 10% and 23% of the 2050 EU final energy consumption.

# Hydrogen: EU scenario for 2050

---

- There is a significant increase in the volumes of decarbonised gas
- The use of renewable or low-emission gases as energy vectors is estimated to approximately **18% of total final consumption, of which 10% from H2**
- The hydrogen produced in 2050 is estimated at 896 TWh and should be used for
  - 40% in transport
  - 10% in the residential sector
  - 38% in industry and
  - 12% as storage in the electricity sector.

# Hydrogen: classification

---

- There are no official classification, but a commonly used nomenclature is:
  - **grey hydrogen**: production involves GHG emissions
  - **blue hydrogen**: production involves GHG emissions, but these are (for the most part) captured and stored;
  - **green hydrogen**: production is carbon neutral
- Other definition
  - **renewable hydrogen** (or clean hydrogen): hydrogen produced through the electrolysis of water and with electricity from renewable sources or biomass;.

## 2.2 Cost of hydrogen production

# Hydrogen: current cost

---

- **From methane: 45 €/MWh (IEA)**
  - strongly influenced by natural gas prices (21€/MWh for the estimation)
- **From methane with CCS: 55-60 €/MWh (IEA)**
  - the addition of CCS leads to a 50% cost increase for CAPEX, by 10% for fuel.
- **From electrolysis 70 and 130 €/MWh, (Guidehouse, 2020)**
  - influenced by various technical and economic factors:
    - capital costs
    - conversion efficiency
    - electricity costs

# Electrolyzer

---

- **Only 2% of H<sub>2</sub>** is produced by electrolysis (IEA, 2019), but the number of plants is increasing
- In 2019, there were at least 142 active electrolysis plants in the world, with a total capacity of about 40 MW (Thema et al., 2019). Many of these are **pilot projects**.
- The countries with the largest number installed capacity are Germany (30.7 MW) and Denmark (2.53 MW)
- The H<sub>2</sub> production plant from electrolysis is often called **power-to-hydrogen or power-to-gas**



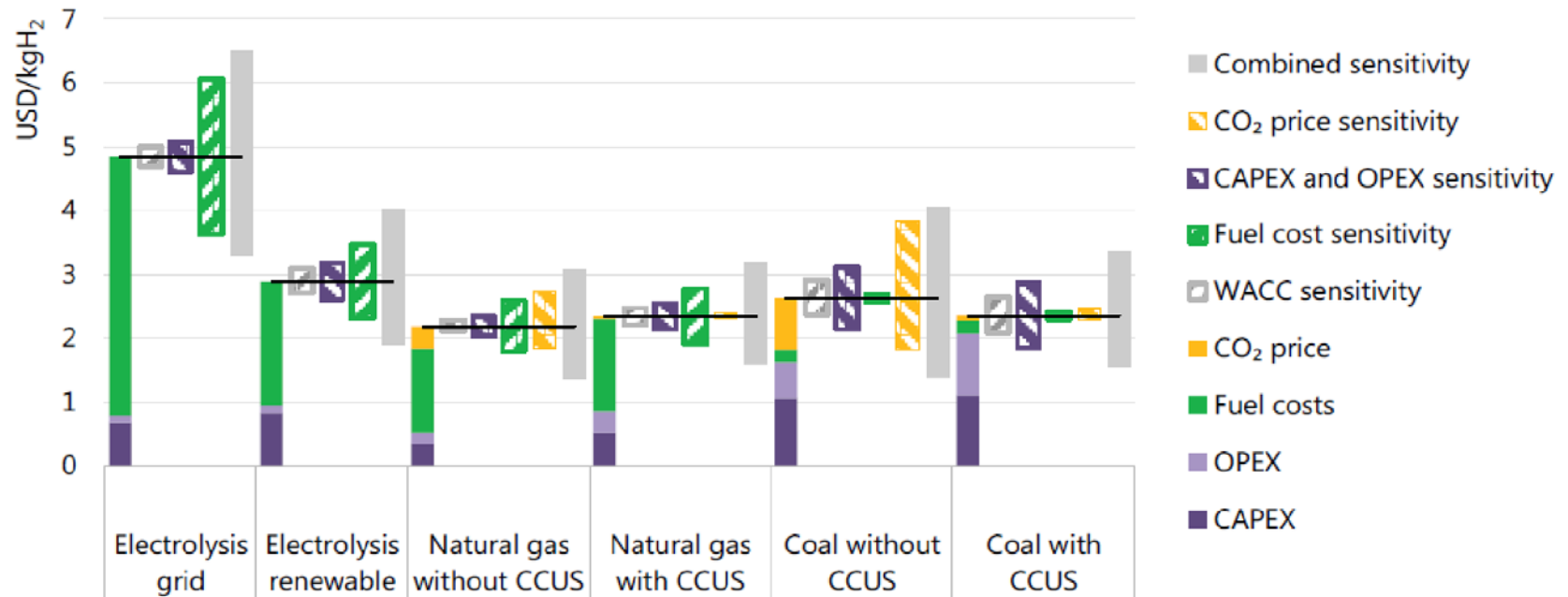
# Hydrogen: future cost of H<sub>2</sub> from electrolysis

---

- **Difficult to estimate**, it depends on:
  - on the cost of electrolysers
  - their efficiency and
  - the cost of electricity and
  - the # of hours it works
- A reduction in costs as the number of plants increases for **economies of scale and learning by doing** (although not as for REN)
- The IEA (2019) estimates that in 2030 with low electricity cost (34€/MWh) the cost are still around **75€/MWh**, considering 4000 hours of operation per year

# Hydrogen production cost in 2030

Figure 16. Hydrogen production costs for different technology options, 2030



Notes: WACC = weighted average cost of capital. Assumptions refer to Europe in 2030. Renewable electricity price = USD 40/MWh at 4 000 full load hours at best locations; sensitivity analysis based on +/-30% variation in CAPEX, OPEX and fuel costs; +/-3% change in default WACC of 8% and a variation in default CO<sub>2</sub> price of USD 40/tCO<sub>2</sub> to USD 0/tCO<sub>2</sub> and USD 100/tCO<sub>2</sub>. More information on the underlying assumptions is available at [www.iea.org/hydrogen2019](http://www.iea.org/hydrogen2019).

Source: IEA 2019. All rights reserved.

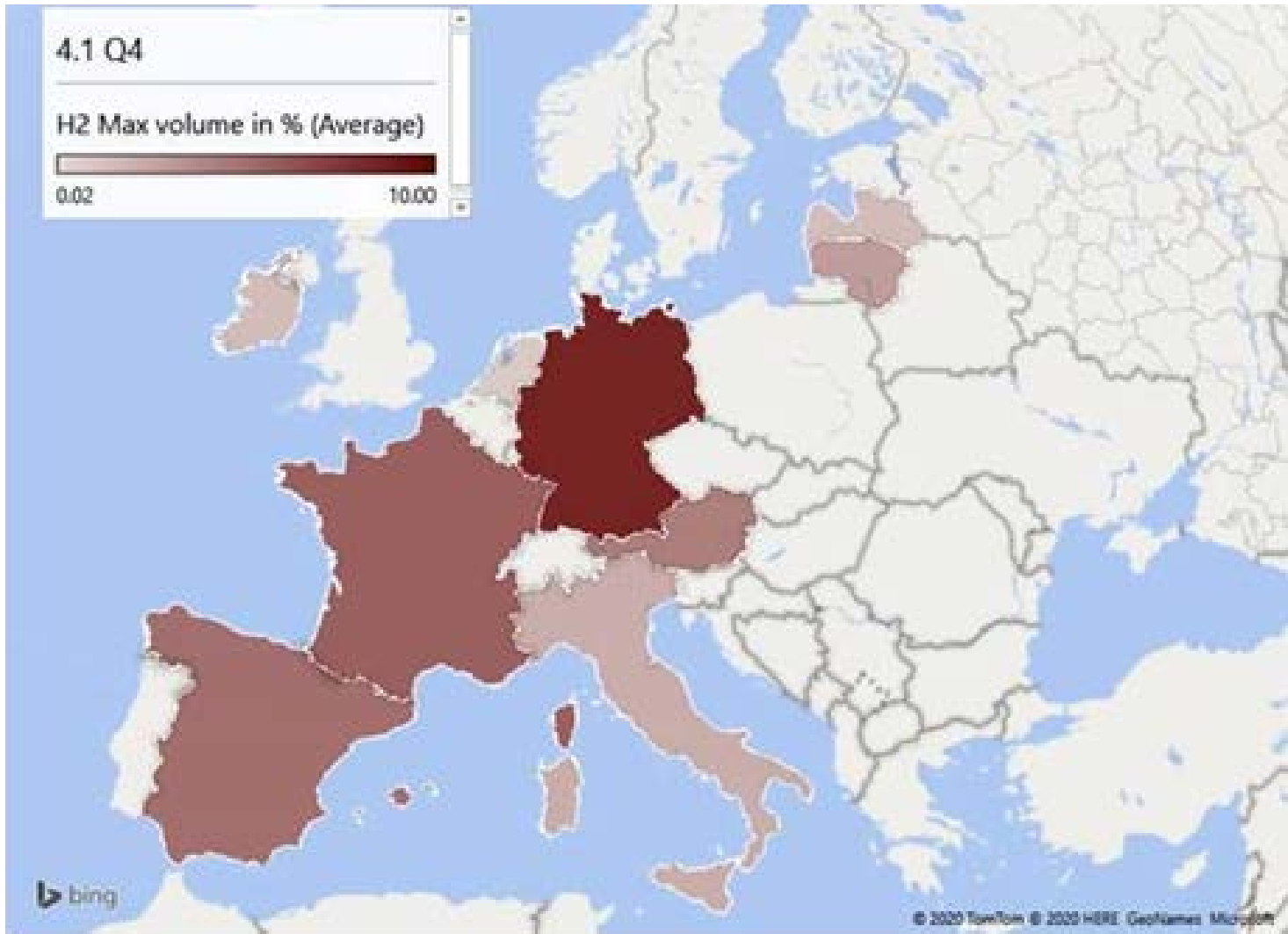
\$ 1/kg of hydrogen was considered equivalent to 25,5 €/MWh

# Hydrogen infrastructure

---

- H2 can be transported by **lorries and pipelines**
- Use of natural gas infrastructure:
  - H2 is different from natural gas: the gas infrastructure may require **refurbishment**
  - Most of end-use appliances cannot be used with H2
- **Blending**: mixing H2 natural gas in limited quantities
  - % blending that can be introduced without adaptations depends on many technical factors
  - The maximum % of H2 is considered 15% at most.
- Full **repurposing** of natural gas to 100% H2
  - Much lower cost than building new infrastructure

# Hydrogen acceptance and blending thresholds



*Source: ACER based on NRAs and TSOs input*

## 2.2 The European Commission's Hydrogen strategy

# Hydrogen strategy: objectives

---

- The European Commission (EC) published in July 2020 the *Hydrogen strategy*, and **by the end of 2021 it will propose a new gas legislation**
- Priority on **renewable H2**
- **3 phases:**
  1. 2020-2024: installation of at least 6 GW of electrolysers to decarbonise the existing hydrogen production; **local infrastructure**; encouraging both supply and demand;
  2. 2025-2030: installation of at least 40 GW of electrolysers; start to develop an **EU-wide hydrogen infrastructure**
  3. 2030-2050: renewable hydrogen technologies should reach maturity and be implemented on a large scale.
- **Blending** is not seen this as a long-term solution
- Stop investing EU funds on natural gas infrastructure

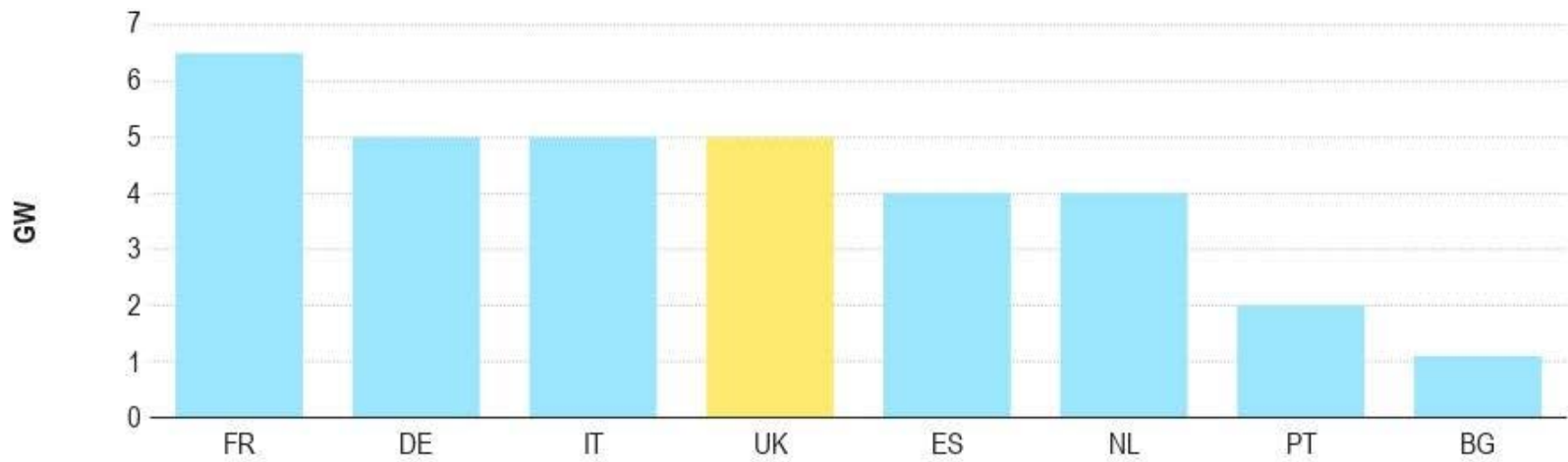
# Hydrogen strategy: investment

---

- **Large investment needed** by 2030:
  - 24-42 billion euros in electrolysers
  - 220-340 billion euros to connect
  - 65 billion euros for the transport, distribution and storage of hydrogen
- Need of **public support** (revision of the state aid framework): direct and transparent market-based policy
- Need of **EU-wide instruments**: minimum quotas for renewable hydrogen; common carbon standards for the promotion of hydrogen production plants, a strengthening of the ETS.

# Planned electrolyzers' capacity in 2030

---



*Source: ACER*



# Open issues

---

- How to **support the development** the H2 sector?
  - Avoid the mistakes made for RES policy
  - Need to mobilize private investment
- How to support **efficient investment** in H2 infrastructure?
  - Need of integrated planning
  - There may be different decarbonization solutions
- How to **regulate** the H2 sector?
  - Very different situation from when EU started regulating electricity and gas

# ACER-CEER documents on hydrogen

---

- Adopt a **gradual and flexible regulatory approach** to developments of the hydrogen sector
- Apply a **no-regrets policy** for investment decisions
- Respect the **beneficiary-pays principle** for infrastructure investment
- Guarantee **consumer rights** regardless of the energy carrier
- Not copy and paste gas regulation

## Documents:

- CEER *Response for the European Commission*, 22 June 2021
- ACER-CEER, *When and How to Regulate Hydrogen Networks?*, 7 February 2021
- CEER ACER, *Regulatory Treatment of Power-to-Gas*, 11 February 2021