The transition to low-carbon hydrogen:

benefits and challenges for the electricity system by 2030

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Research framework

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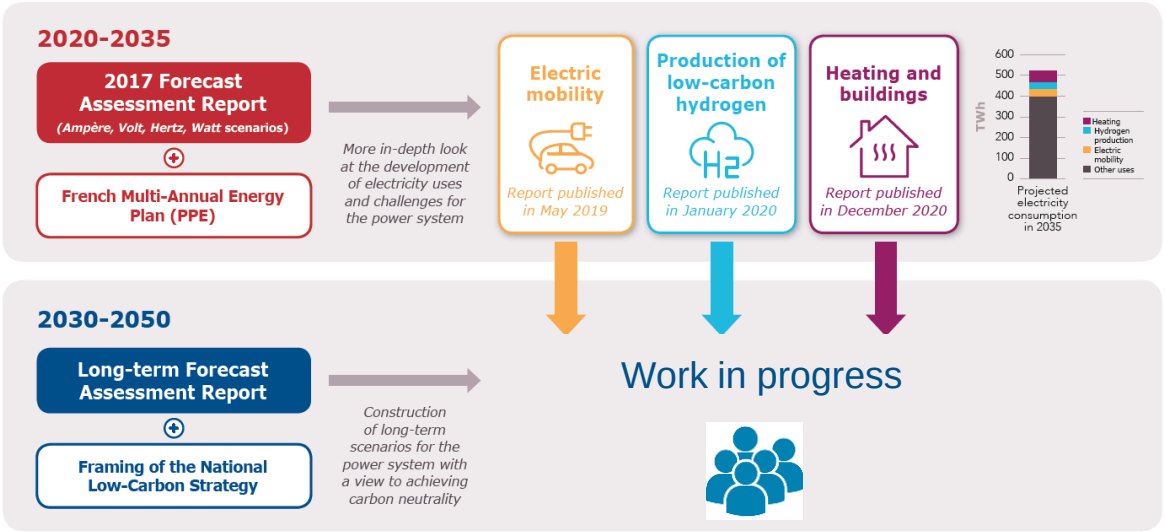
1. This paper is a part of the work program on **new end uses of electricity** carried out by RTE (French TSOe) in recent years:
   - **electric mobility** impacts on the electric system, published in 2019
   - **hydrogen production by electrolysis**, published in 2020
   - **heating in the building sector** (in collaboration with ADEME), published in 2021

2. This study is a part of the **national hydrogen plan** published by the government in 2018, by responding to the energy minister's request regarding the services that electrolysers can provide to the power system. Framework is consistent with the **France Hydrogen** strategy published in September 2020.

3. Finally, it contributes to the work and consultation of the **energy mix 2050 scenarios**, which will be published at the end of 2021.



RTE report in French available here:
https://assets.rte-france.com/prod/public/2020-07/rapport%20hydrogene.pdf

English version here:
https://assets.rte-france.com/prod/public/2021-03/Hydrogen%20report_0.pdf

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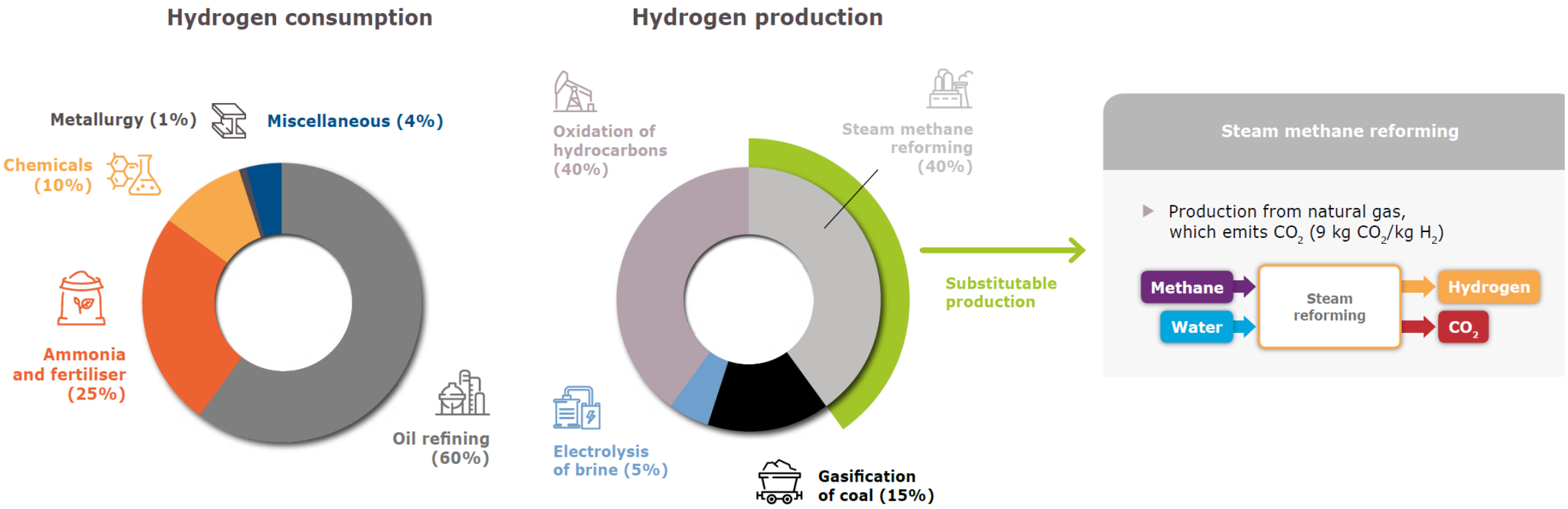
State of the art and perspectives

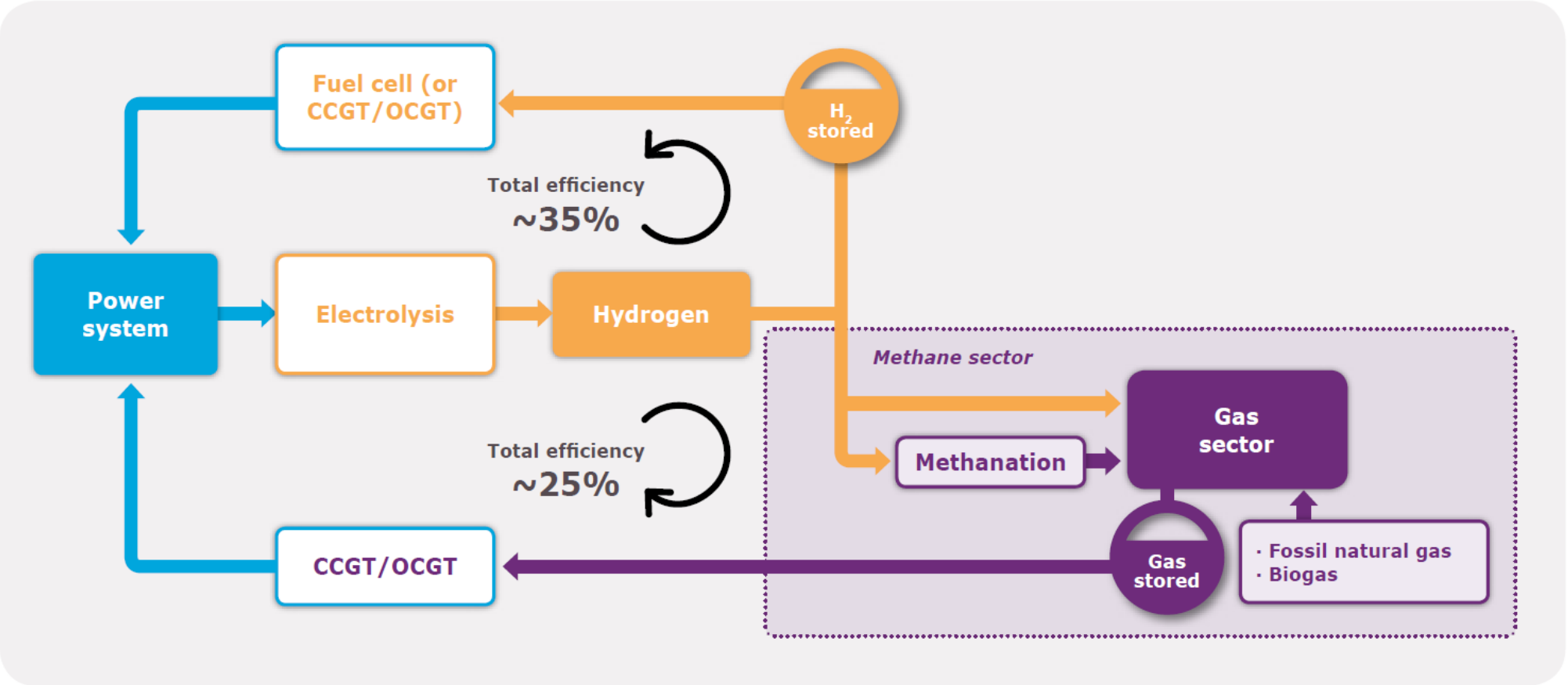
Public policies give priority to decarbonising the hydrogen used in industry by 2030



→ In France, hydrogen production results in emissions total close to **10 MtCO2/year**, which represents about **2 to 3% of the country's total emissions**.

The first challenge is to reduce carbon emissions for these industrial applications.

Develop a storage solution to help balance electricity supply and demand as a long term solution



- From a technical point of view, the power-to-gas-to-power electricity storage solution is penalised by the low energy efficiency of the loop for transforming electricity into hydrogen and then back to electricity.

- There is good reason to explore its long-term potential, particularly for providing seasonal storage in electricity mixes with a high percentage of variable renewable sources.

Two distinct reasons to develop hydrogen are often confused

Scenarios proposed in the report

1

Decarbonising gas uses (hydrogen, methane…) or mobility

To help meet French and international decarbonisation targets

→ **Opportunities in 2020-2035**

Power-to-X

≠

Possible needs specific to each electricity mix

2

Helping achieve a supply-demand balance on the power system by offering a storage/discharge solution

Seasonal storage via a power-to-gas-to-power loop

→ **Possibly of interest as a long-term solution**

X-to-Power & flexible load

2035

- No absolute need for seasonal storage in France.
- A clear interest in decarbonizing the hydrogen used in industry, **replacing natural gas steam reforming**.
- Potential use of hydrogen for heavy mobility.

Two alternatives considered for obtaining low carbon hydrogen: "blue" hydrogen or low carbon electrolysis

- In Germany, CCS will play a role for economic reasons.
- In France, the SNBC requires a limited use of CCS solutions.
- Issues of technical and economic feasibility and acceptability.

Steam methane reforming

or

Gasification of coal

+

Carbon capture

France choice

Electrolysis powered by decarbonised electricity

- Local production in France : possibility of different operating schemes
- Imported from areas suitable for renewable electricity production (Spain, North Africa, …)

Scope of the study

3

Methods and main results

Methodology

- The study focuses on the **different modes of H2 production** and their characteristics
- **ANTARES** software is used for the **simulation of the operation of the European power system**

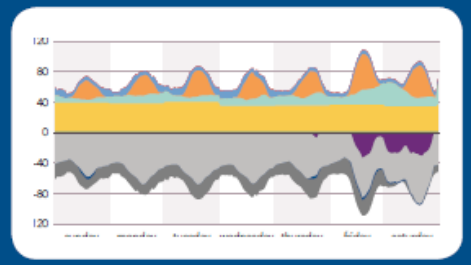
Electricity mix scenarios (Draft Multi-Annual Energy Plan, *Ampère, Volt*…)

Electrolysis development scenarios

- **Volumes (TWh)**
- **Operating modes**
- **Uses…**

Simulation of the operation of the European power system and electrolysis

Models used in Forecast Assessment Report – supply-demand balance



Technical impacts

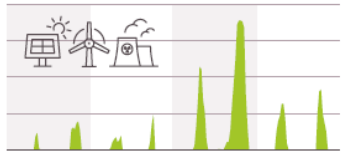
Environmental concerns

Economic issues

Impacts on power system strongly dependent on the electrolysis operating modes

The study explores 3 distinct operators' business models :

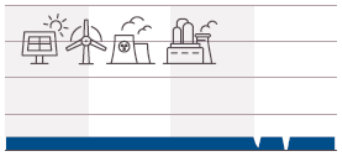
1 Periods of marginal RES or nuclear



Operation when prices are low

- ➕ Carbon-free and inexpensive electricity
- ➖ Low operating time
  Highly variable and unpredictable

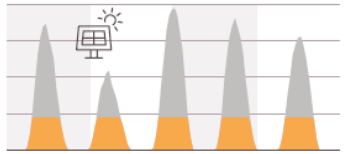
2 Baseload electricity, except peak periods



Operation all year except when prices are high

- ➕ Long operation times
- ➖ Potential impact on CO2 emissions and high electricity supply costs

3 Coupling with self-generation (e.g. photovoltaic)



Operation at the production site

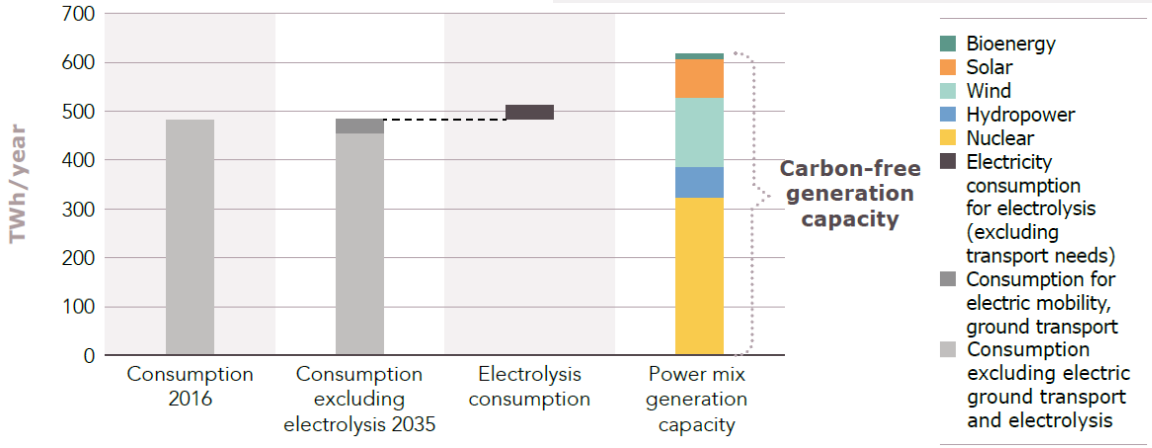
- ➕ Limited cost of supply (fixed cost of PV panels)
  Operating times potentially significant
- ➖ Potentially isolated sites
  Sensitive to revenues from electricity sales

Different electrolysis capacities, needs for storage, load factor, CO_2 impacts, …

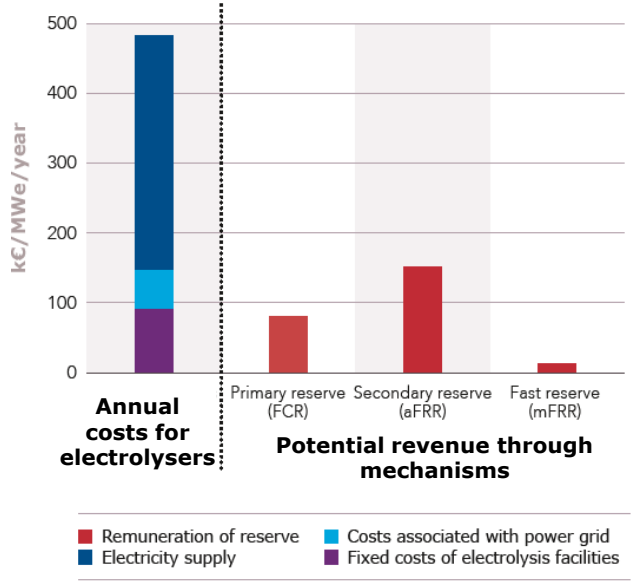
The power system planned under the French Multi-Annual Energy Plan can accommodate the development of electrolysis without any real difficulty

Technical impacts

- **In terms of energy needs** :
  - The French Multi-Annual Energy Plan puts the **carbon-free electricity** generation potential at **615 TWh** by **2035**.
  - The French electricity mix would be more than able to produce the power needed to meet the country's low-carbon hydrogen targets (**30 TWh_e**), regardless the operation mode of electrolysis.



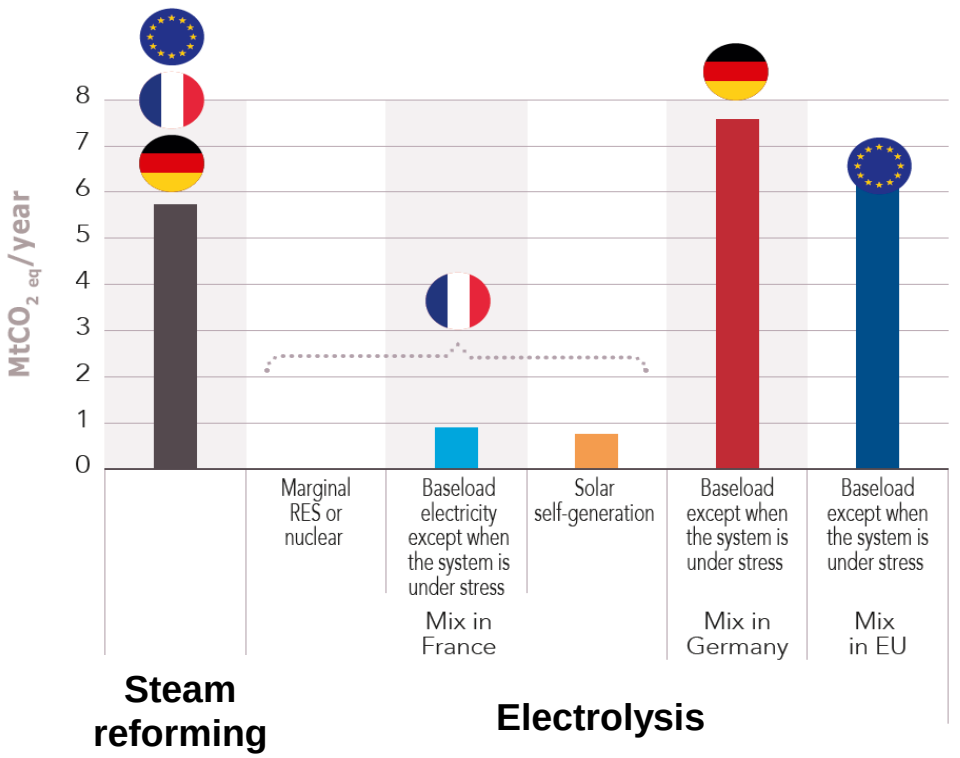
- **In terms of adequacy** :
  - A technical analysis of how electrolysers function reveals that they have the capability to **provide flexibility services to the system** for supply-demand balance and for grid operation.
  - This services could represent an additional source of remuneration, though **this alone would not justify the development of electrolysis**.



Replacing fossil hydrogen by electrolysis leads to a reduction in CO_2 emissions …

Environmental concerns

- **… in France, in all scenarios**
  - Electricity generation in France is to a large extent **already carbon-free**.
  - Significant reductions in CO2 emissions in France, **5 to 6 $MtCO_2$/year**, comes essentially from the substitution of steam reforming with of carbon-free electricity.
- **… in Europe, if the power mix is adapted with more carbon-free generation**
  - All other things being equal, **exporting carbon-free electricity** appears to be a **more efficient way to reduce European emissions** than replacing steam reforming with electrolysis of water.
  - But if the carbon-free power mix is **developed**, the carbon balance is positive at European scale.



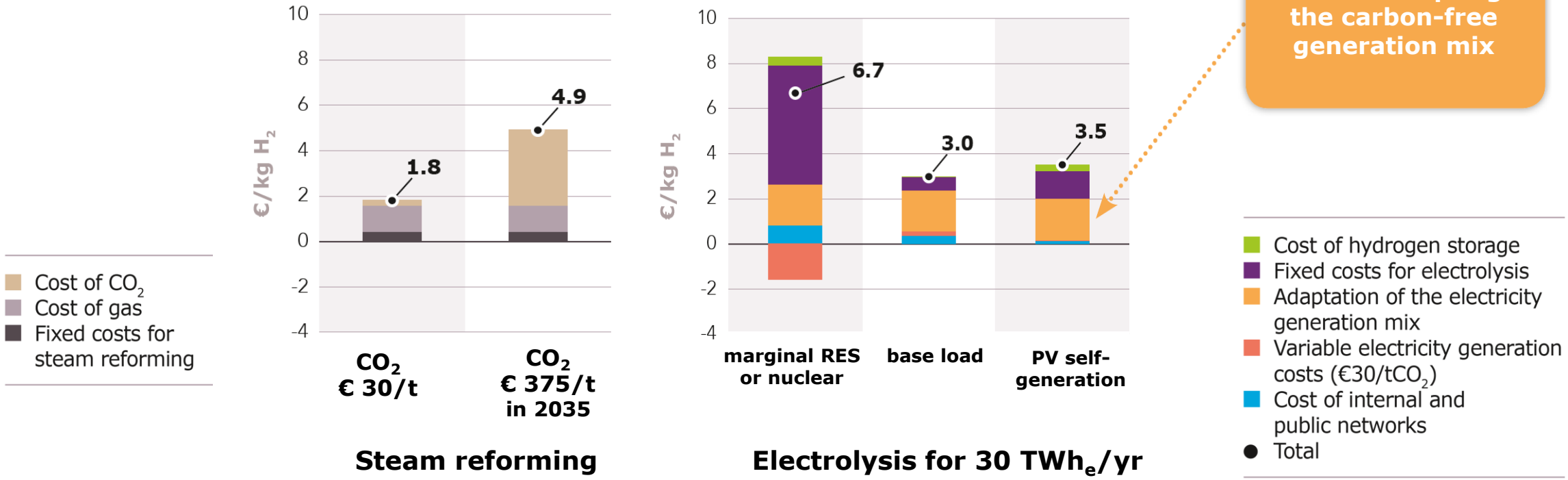
CO_2 emissions in a given country or area (France, Germany or EU, excluding effects on imports and exports) producing 630 ktH_2, with no change in the power mix

The cost of transitioning to electrolysis is high but justified by the reduction in CO_2 emissions

Economic issues

- The cost of hydrogen produced by electrolysis (€ 3 /kg to € 6,7 /kg depending on the mode) appears to **be higher by 2035** than hydrogen produced by steam reforming ...
- … except if CO_2 is based on the **shadow price of carbon** (€ 375 /t in 2035)

Comparison of welfare costs of electrolysis vs. steam reforming



Thanks for your attention