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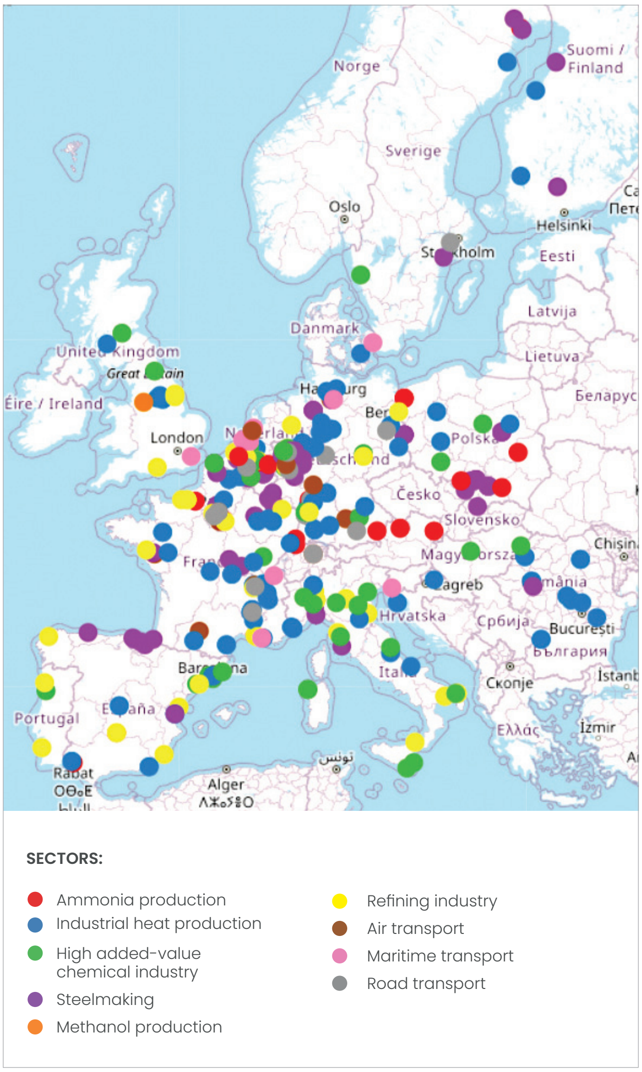
SISYPHE STUDY: EUROPEAN TRENDS FOR DEMAND OF LOW-CARBON HYDROGEN UNTIL 2040

TRANSITIONS

KEY MESSAGES OF THE STUDY

The REPowerEU plan, launched by the European Commission in 2022, sets an ambitious consumption target of 20 million tons per year of renewable hydrogen by 2030 in the EU, with 10 million tons to be produced in Europe. By way of comparison, 9 million tons of hydrogen (mostly of fossil origin) are consumed in Europe today, mainly by the refining and chemical industries. Through the SISYPHE study, the CEA has tried to evaluate the trends of demand for low-carbon hydrogen in Europe up to 2040.



1 | A GAP BETWEEN EUROPEAN TARGETS AND ESTIMATED DEMAND

CEA's SISYPHE study shows a significant gap between the European target and the projected demand for low-carbon hydrogen in Europe by 2040. This projection is based on projects actually underway and on the forecasts of some 70 European industrials or stakeholders questioned about their potential hydrogen needs.

The study evaluates the demand for electrolytic hydrogen at 2.5 million tons in 2030 and 9 million tons in 2040. This shows a high risk of not achieving the targets set at European level, even if the uncertainties underlying the projections are numerous.

The study highlights very different trends among potential hydrogen-consuming sectors. As things stand, steel industry and air transport are likely to have the largest demand for electrolytic hydrogen over the 2030-2040 period.

A study based on a broad panel of stakeholders

The SISYPHE study is based on a large panel of players throughout Europe, who either are current hydrogen consumers or are likely to become so in the future.

EHT workshop. *View of the cleanroom dedicated to EHT cell preparation and printing.*

2 | DOUBTS REGARDING THE ABILITY TO ACCESS TO AFFORDABLE ELECTRICITY OVER THE NEXT DECADE

The annual European consumption of low-carbon electricity for electrolytic hydrogen production estimated by the study in 2030 and 2040 is 120 TWh and 420 TWh respectively. By way of comparison, France's current electricity consumption is roughly 400 TWh.

The commitment of industrialists to use electrolytic hydrogen could be held back by the high cost of low-carbon hydrogen, as a consequence of possibly too high prices for low-carbon electricity in Europe.

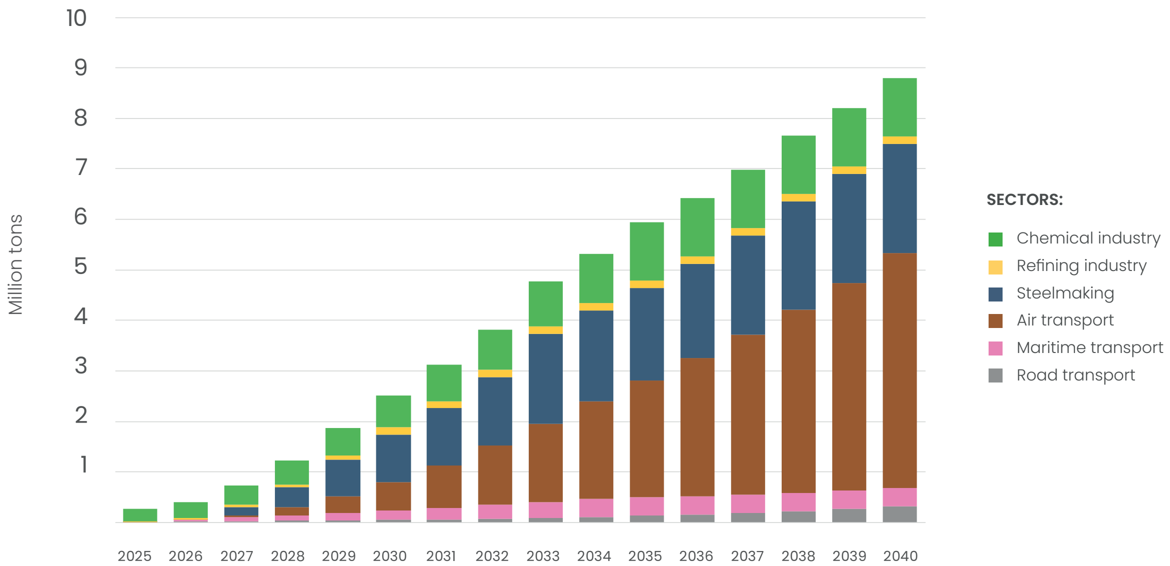
3 | QUESTIONS ABOUT THE AVAILABILITY OF ELECTROLYZERS

The SISYPHE scenario implies the installation of a minimum of 3 to 5 GW of electrolyzers every year from 2028 onwards, subject to access to low-carbon electricity for a large number of hours a year. Failing this, even greater electrolysis capacity would be required, which raises **the question of the availability of high-powered electrolyzers by the end of the decade.**

WHAT IS ELECTROLYTIC HYDROGEN?

Electrolytic hydrogen is hydrogen produced by electrolysis of water, a process that breaks down water (H_2O) into dioxygen (O_2) and dihydrogen (H_2) gas, using electricity. The electrolytic hydrogen thus obtained can also be qualified as low carbon when the electricity used by the electrolysis process is itself low-carbon.

A SECTOR-BY-SECTOR VIEW



ELECTROLYTIC HYDROGEN. *SISYPHE scenario for European demand.*

1 | TWO COMMITTED SECTORS: STEELMAKING AND AIR TRANSPORT

By 2030, **the steel industry could be the main driver of demand for electrolytic hydrogen.** This sector has a very ambitious and organized decarbonization plan, based in part on shifting production processes to DRI - Direct Reduction of Iron - using hydrogen.

From 2030 onwards, the air transport sector will be subject to e-kerosene incorporation targets imposed by European ReFuelEU Aviation regulations. These targets imply a growing need for hydrogen until 2050. As a result of these regulatory targets, given the volumes involved, **it could represent more than half of hydrogen demand** from 2035 onwards.

2 | MAJOR UNCERTAINTIES OVER THE SWITCHOVER OF CURRENT FOSSIL HYDROGEN USERS: CHEMICAL AND REFINING INDUSTRIES

The **chemical sector will be subject to renewable hydrogen incorporation targets as of 2030.** Interviewed industrials emphasized the absence of a viable economic model. Moreover, **these regulatory targets may not apply to ammonia producers,** who account for almost two-thirds of the sector's fossil hydrogen consumption today. A switch to electrolytic hydrogen would imply a major change in their production facility, which is not envisaged before 2040 by most respondents.

With the ongoing electrification of road transport, **the future of some refineries is uncertain**, which discourages some industrials to invest in low-carbon hydrogen. Some will be converted to biorefineries, with an associated need for hydrogen that is difficult to quantify today.

3 | A LIMITED DEMAND OUTLOOK FOR MARITIME AND ROAD TRANSPORT BY 2030

The maritime transport sector is showing a willingness to make the transition, even though it is currently only subject to a low e-fuel incorporation target by 2034, with no additional constraints beyond that. Based on this regulatory target, demand would remain limited, despite the sector's considerable potential.

In the **road transport sector, hydrogen technology for light vehicles is mature, but today, BEV (battery electric vehicles) has taken the lead in the electric vehicle market.** Hydrogen-powered trucks are only at the demonstrator stage for most European manufacturers. Conversely, the **industrial-scale production of hydrogen-powered light commercial vehicles** could boost demand between now and 2030, subject to the development of refuelling stations, but the network is currently nascent.

4 | PRIORITY TO ELECTRIFICATION FOR PETROCHEMICAL INDUSTRY AND INDUSTRIAL HEAT PRODUCTION

Hydrogen as fuel could be used for industrial heat production as a replacement for natural gas. However, this is not the preferred option for those surveyed in these two sectors. Most are considering electrifying their processes.

A major need for electrolytic hydrogen could come from the production of plastics from e-naphtha, replacing petroleum-derived naphtha. However, the use of e-naphtha is not envisaged in the short or medium term by the petrochemical sector.

A STUDY METHODOLOGY BASED ON INDUSTRY FEEDBACK AND REGULATORY CONSTRAINTS

To date, few of the industrialists surveyed have a tprecise vision today of what their hydrogen consumption will be over the decade 2030-2040. For this reason, the SISYPHE study is based on a quantitative framework reflecting the **current** trends as revealed by the interviews.

The trajectory of demand for electrolytic hydrogen has been defined on the basis of the following assumptions:

- A flat demand for fuel in maritime and air transport, as well as for hydrogen in the chemical sector;
- A compliance with European regulations imposed on the air transport, shipping and chemical sectors (excluding ammonia);
- The inclusion of projects undertaken today in the steel, ammonia production and refining sectors;
- A very gradual development of road mobility, mainly driven by the deployment of light commercial vehicle fleets.

This trajectory therefore **reflects the trends of the projects underway and the regulations set for 2023**. It does not prejudge any new regulations that may arise.

IDENTIFIED BARRIERS... BUT ALSO LEVERS FOR ACCELERATION

R&D ON EHT. *Facility for chemical vapor deposition of anticorrosion coatings.*

1 | BARRIERS: PRICE, REGULATIONS AND AVAILABILITY OF ELECTROLYTIC HYDROGEN

While many industrialists are keen to switch to electrolytic hydrogen, the SISYPHE study identifies a number of barriers that are currently limiting its development:

- **High prices for electrolytic hydrogen and its derivative molecules** (ammonia, methanol, etc.) **compared with their fossil fuel equivalents.**
- **European regulations deemed too restrictive or fluctuating.**
- **Short- and medium-term supply difficulties for electrolytic hydrogen**, notably due to:
  - Low availability of low-carbon electricity;
  - Risks of delays in connecting sites to the high-power electrical grid;
  - Lack of hydrogen transport infrastructure;
  - Limited supply of high-power electrolyzers.

These obstacles could lead to relocating outside Europe not only of the production of hydrogen and derivative molecules, but also of certain 'final' products (nitrogen fertilizers, steel, etc.) that are easier to transport. **Limited development of hydrogen increases the risk of de-industrialisation in Europe, leading to a loss of sovereignty.**

2 | LEVERS: MORE LOW-CARBON ELECTRICITY AND ELECTROLYZERS, SIMPLE AND INCENTIVE BASED MECHANISMS

To accelerate project development and make the transition to electrolytic hydrogen in Europe a success, a number of changes are essential. Activating some levers would enable to exceed the figures projected in the study in order to achieve the EU objectives:

- **Accelerating the development of low-carbon electricity production capacity (from renewable and nuclear sources) in Europe.**
- **Scaling up hydrogen and hydrogen-derived molecules production facilities**, notably by developing applied R&D to accelerate the reliability and industrialization of high-power electrolyzers.
- **Clarifying and stabilizing support mechanisms**, with financial allocations in line with objectives. The interviewed industrialists advocate rules inspired by the Inflation Reduction Act (IRA), which is perceived as much simpler and more incentive-based.

3 | THE IMPORTANCE OF HYDROGEN PRODUCTION LOCATION

If our study focuses on European demand for hydrogen, it necessarily raises the question of the location of the production associated with this demand:

- **Local hydrogen production is envisaged for countries with low-carbon electricity and/or high renewable energy potential (Nordic countries, France, Iberian Peninsula).**
- On the other hand, **the Benelux countries and Central and Eastern Europe, with a more limited renewable energy potential, could turn to hydrogen imports**, implying a major infrastructure development challenge.

I-TÉSÉ
CEA'S INSTITUTE FOR RESEARCH AND STUDIES IN ENERGY ECONOMICS

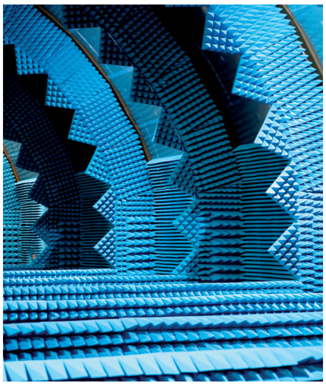
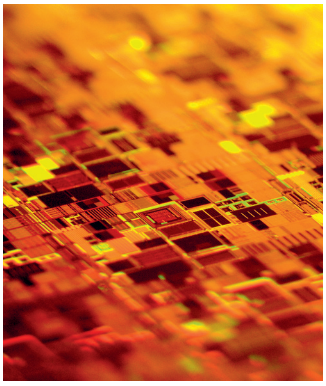
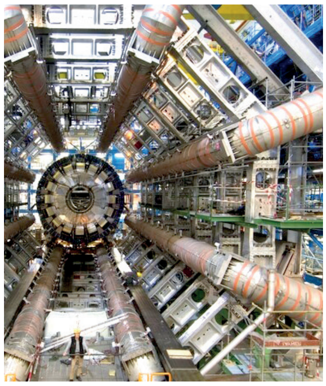
The SISYPHE study benefited from the expertise of the I-Tésé teams, whose work focuses on the economics and sustainability of the energy transition to carbon neutrality. I-Tésé research areas focus on the following themes:

- Tech-economics of low-carbon production and storage solutions (nuclear, renewable energies, hydrogen, batteries...).
- Key resources for the transition.
- Impact of changing lifestyles on demand.
- Market organisation and regulation.

The systemic vision proposed by I-Tésé is supported by the use of numerical models and methods developed within the Institute.

ABOUT THE CEA

As France's largest government research organization, the CEA informs public policy and provides public- and private-sector organizations with access to science and technology research so that our society can more effectively navigate the transformations currently underway in energy, health, technology, and global security and defense. This 20,000-person-strong organization possesses nine world-class research facilities across France and engages in partnerships with academic research laboratories and businesses around the globe.

The CEA is a major center for R&D and innovation in:

- LOW-CARBON ENERGY (NUCLEAR AND RENEWABLE)
- SECURITY AND DEFENSE
- TECHNOLOGY RESEARCH FOR INDUSTRY
- FUNDAMENTAL RESEARCH (MATERIALS AND LIFE SCIENCES)

The organization's throughline is research in service of national and European scientific, technological, and industrial sovereignty for a safer, more resilient world for all, now and in the future.

Specifically, we provide public- and private-sector stakeholders with knowledge and innovations vital to building a low-carbon energy system. Our energy-systems research is holistic and integrated. We look at existing low-carbon energy production technologies like nuclear and solar PV, as well as new emerging/energy technologies; investigate the interactions of different energy vectors in the storage, management, and conversion solutions that will enable tomorrow's grids; and study how circular economy principles can be applied to energy.

Beyond the science, we always consider the technical, economic, environmental, and societal costs and benefits of our research and results.

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