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Developing hydrogen for decarbonisation in Europe: how relevant are contracts for difference?

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Hydrogen could play a key role in decarbonising certain industry segments and long-distance transport in Europe. However, associated technologies are largely at an early stage of deployment and are not very competitive with fossil fuel alternatives, and the hydrogen consumed today is mostly derived from fossil fuels. Public policies to drive the deployment and cost reduction of certain technologies therefore seem unavoidable.

In particular, the European Union and its Member States have recently reasserted their intention to implement Contracts for Difference (CfDs) to support hydrogen production. These contracts between public authorities or private actors and project developers would accelerate hydrogen production, particularly *via* electrolysis, by financing the first commercial-scale projects through a guaranteed income for producers, as has been achieved for renewable energy.

This *Policy Brief* defines CfDs, describes the challenges of their development, and proposes guiding principles for their design, which build on European experiences of renewable energy deployment since the early 2000s.

KEY MESSAGES

Investment in new technologies to enable to the use of hydrogen are necessary for decarbonisation but remain risky because of uncertainties about producer revenues. To encourage rapid deployment, a public support framework must be implemented, including incentives for demand development in priority sectors (industry and air and maritime transport) and production, and based on a shared definition of the hydrogen that is eligible for support.

Supporting hydrogen production by electrolysis in France *via* CfDs could generate up to €5 billion while costing the French state up to €3 billion by 2030, according to central scenarios; this amount is lower than before the rise in energy prices. These costs could increase significantly if the price of CO_2 plateaus or declines, if natural gas prices return to low levels, or if electrolysis is more widely deployed.

On the production side, Contracts for Difference (CfDs) are an important tool for European public stakeholders. They can help lower hydrogen production costs by stimulating technological learning through de-risking and financing initial projects, while helping to select important technologies for decarbonisation and favouring direct commercialisation (without support) in the long term.

CfDs should be limited to hydrogen production technologies compatible with a pathway to climate neutrality, with electrolysis as a priority. To ensure that all important technologies for decarbonisation are developed, these contracts could prioritize key projects for the deployment of certain transport and hydrogen storage infrastructure linked to key uses or certain technologies that are not yet mature.

POLICYBRIEF

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1. CfDs, ONE OF THE FOUNDATIONS OF THE HYDROGEN PUBLIC SUPPORT FRAMEWORK

Some hydrogen technologies are key to the decarbonisation of industry, including electrolysis for hydrogen production and the direct reduction of iron ore with hydrogen for steel production (Bouacida & Berghmans, 2022; IEA, 2019; Ueckerdt *et al*., 2021).

Currently, although alkaline electrolysis and polymer electrolyte membrane (PEM) electrolysis are fairly mature technologies, they remain sparsely deployed; while other electrolysis technologies, such as solid oxide electrolysis (SOEC), are still not at the commercial stage but could significantly contribute to decarbonisation (IEA, 2023).

The fact that these technologies are immature or under deployed creates a "green premium", an extra cost compared to existing fossil fuel alternatives (mainly steam methane reforming), suggesting that private actors are unlikely to invest without a support framework to bridge the gap. With natural gas prices at pre-crisis levels of €40/MWh, hydrogen by electrolysis is not competitive, even if it benefits from cheap electricity at €20/MWh, given the costs of electrolysers (Bouacida & Berghmans, 2022).

This underlines the importance of financial support for hydrogen production for decarbonisation. The objective of such policies is, for existing hydrogen uses, to ensure that hydrogen production from renewable or nuclear electrolysis is competitive with its fossil-fuel counterpart, and, for new hydrogen uses, to stimulate the deployment of initial commercial projects that develop economies of scale and help build experience in currently underdeveloped hydrogen technologies.

As suggested in the existing work on hydrogen, but also by the lessons learned from the experience of renewable energy deployment, the set of support mechanisms for hydrogen should include financial support, which among other things enables the de-risking of investments, incentives for the creation of demand markets, and the definition of market standards (Agora Energiewende & Guidehouse, 2021; IRENA, 2021).

1.1. Carbon pricing, an important but insufficient tool at this stage of deployment

One of the pillars of the EU's decarbonisation strategy is the EU Emissions Trading Scheme (EU ETS), which since 2005 has limited GHG emissions in most energy-intensive industry sectors, establishing a cost for such emissions and enabling the trading of allowances.

However, this carbon pricing is insufficient to trigger the necessary investments in the hard-to-decarbonise industrial sectors, despite the announced ending of free allocations, the implementation of a carbon border adjustment mechanism proposed in 2022, and the recent rise in carbon prices to around €60-100/t CO_2.[1]

The higher fossil fuel prices since the end of 2021 have improved the competitiveness of hydrogen electrolysis projects (at least those where the electricity does not come from the market) according to initial analyses (Calthrop, 2022; Zheng *et al.*, 2022), but the uncertainties of carbon and energy prices still represent a significant risk for investors (Richstein & Neuhoff, 2022; Sartor & Bataille, 2019).

1.2. Standardization of "sustainable" hydrogen

In terms of standardisation, defining the hydrogen eligible for public support is the subject of political disagreement at the European level, notably as to whether to include hydrogen produced from natural gas with CO_2 capture and storage (CCS) and nuclear electricity.

The "gas package" currently under discussion at the European level could define "low-carbon" hydrogen similarly to the definition adopted in the revision of the Renewable Energy Directive (RED) to be adopted in early 2023, namely hydrogen with a GHG emission balance of less than 3.38 kg CO_2/kg H_2, which is consistent with the 3 kg CO_2/kg H_2 threshold adopted in the taxonomy. The advantage of this threshold is that it represents a large reduction compared to fossil hydrogen (70%) and could be lowered in future as the European electricity system decarbonises, to ensure that the hydrogen produced has the smallest possible carbon footprint. However, at present, hydrogen must also be renewable to count towards the sectoral targets of the RED, which is currently under review, while the taxonomy does not place any restrictions on the production method.

It is essential that the European texts provide a clear definition that is sufficiently demanding in environmental terms to trigger investment in the first hydrogen projects.

1.3. Encouraging demand

On the demand side, the RED proposes renewable hydrogen quotas for the EU in industry and transport, but does not include sunset clauses for certain fossil fuel technologies, such as coal-based steel, or public procurement policies for "green" products, which could have better stimulated demand (Agora Energiewende & Guidehouse, 2021). This is also the case in most Member States.

While these measures are important to create demand during the early deployment stages, they do not mitigate the full financial risk to investors, partly due to the higher operating costs for many low-carbon hydrogen technologies (e.g. the direct reduction of iron ore with hydrogen), and the uncertainty around hydrogen production costs (e.g. electricity cost of hydrogen production, carbon price).

1 A recent scientific publication indicates that over the period 2020-2025 electrolytic hydrogen can only be competitive with natural gas and fossil fuels at a cost of between €800 and €1,200/t CO_2 (Ueckerdt *et al.*, 2021).

Complementary tools are therefore needed for an effective hydrogen support policy, particularly by transferring part of the hydrogen investment risk to public authorities (Pahle & Schweizerhof, 2016). The EU and several Member States are exploring the implementation of Carbon Contracts for Difference (CCfDs)–not to be confused with CfDs–which help reduce the investment risks in downstream hydrogen technologies, for example steel, by guaranteeing a remuneration linked to avoided GHG emissions. Thus, manufacturers of "green" products that utilize electrolytic hydrogen receive the difference between their production costs and the (lower) price at which they sell their product on the market, allowing them to compete with their fossil fuel counterparts. Public authorities or private actors will pay the "green premium" of electrolytic hydrogen (Richstein & Neuhoff, 2022) such as steel, chemicals, or cement. A variety of technology options exist – but they face the challenges of (i. These CCfDs would be used mainly for industrial decarbonisation, including through technologies that are not related to hydrogen.

In theory, CCfDs could also be used on the production side. However, one tool considered by many Member States is the CfD, a contract where public authorities or private buyers provide additional remuneration to hydrogen producers according to the volume produced, under certain conditions. Compared to CCfDs, which are based on avoided emissions, CfDs guarantee a certain level of production. Electrolytic hydrogen producers can sell their hydrogen at a price that is competitive with fossil fuel-based hydrogen. This guarantees a certain volume of hydrogen production and theoretically lowers the cost of electrolysis by encouraging technological learning.

This instrument has been widely used to support the deployment of renewables in Europe, most often in the form of auctions. It is generally recognized that it has been effective in reducing the cost of technologies and ensuring their deployment (European Commission, 2022; Mora *et al.*, 2017). It is essential to study the precise conditions for defining CfDs because they are expected to trigger long-term industrial investments, and because they generally mobilize significant volumes of public funding, and thus represent one of the main tools for hydrogen deployment.

2. DEFINING CfDs, TO SECURE INITIAL INVESTMENT

At the European level, the Commission announced in its summer 2020 hydrogen strategy the importance of a "*regulatory framework for a liquid and well-functioning hydrogen market [...] including through bridging the cost gap between conventional solutions and renewable and low-carbon hydrogen*", which was confirmed by the adoption in 2021 of the new state aid rules for energy (already under review to deal with the US Inflation Reduction Act).[2] In practical terms, a proportion of the REPowerEU plan (at least €3 billion) will be used to finance projects that are dedicated, among other things, to hydrogen for industrial decarbonisation; the first of which should receive funding at the beginning of 2024. Many European states, such as the Netherlands, are currently drafting CfDs, whose first call for proposals for hydrogen production closed last October, while Germany, France, and the UK are at an earlier stage. CfDs should aim for three main objectives, namely:

2.1. Ensuring hydrogen is used for priority applications

Funding should be given in priority to hydrogen development in sectors where it is vital for decarbonisation, i.e. existing uses of fossil-fuel hydrogen (chemical industry and refineries), steel, maritime and air transport, as shown in a 2022 IDDRI study.

This can be achieved by coupling production support with incentives or obligations to sell only to certain consumers. For example, the German H2 Global mechanism, under development, aims to financially support foreign renewable hydrogen producers through long-term contracts (ten years), agreed with a third party, financed by the German government among others, which pays the "green premium", and then resells this hydrogen to consumers in the industry, transport and energy sectors, who thus gain access to cheaper electrolytic hydrogen. Funding for producers could also be conditional on having purchase contracts with priority hydrogen consumers.

Financial support for hydrogen can be combined on the production and consumption side, but the support must be well proportioned to ensure sufficient incentive on the industry side without unbalancing public expenditure. For example, CfDs on the production side could be combined with CCfDs on the industry side, which guarantee consumers a remuneration linked to avoided GHG emissions (see Section 1).

2.2. Encouraging technological learning for decarbonisation

One objective of financial support mechanisms for electrolytic hydrogen is to stimulate technological learning to lower production costs and eventually make public support unnecessary. To achieve this, the eligibility criteria and the selection of supported projects are crucial. The challenge–as for renewable electricity–is to support the deployment of emerging and immature technologies which will result in the expected cost reductions, while ensuring that the "winning" technologies are chosen.

To be eligible for CfDs, hydrogen production technologies must significantly reduce GHG emissions compared to existing fossil fuel technologies and avoid technological deadlocks. Thus, natural gas-derived hydrogen applications with CO_2 capture and storage, which are inconsistent in the long term with an emission-neutral system, can be candidates in a transitional period, but must meet strict conditions: (1) capturing a high proportion of the CO_2 emissions produced, (2) ensuring that the natural gas used is compatible with European efforts to reduce dependence on Russian gas as quickly as possible, and (3) minimise leakage along the natural gas supply chain (Bouacida & Berghmans, 2022).

2 https://www.iddri.org/en/publications-and-events/blog-post/three-priorities-green-deal-industrial-plan

Apart from eligibility, hydrogen production technologies that are important for decarbonisation, even when immature, must also have access to support mechanisms. It could also be important to prioritize calls for projects that allow for infrastructure investment that is necessary for the transition, for example integrated projects that develop storage or transport infrastructure in identified areas, or projects that provide for the construction of dedicated renewable electricity capacity (Agora Industrie *et al.*, 2021).

However, mechanisms proposed so far tend to grant CfDs based on auctions, where the winners are the cheapest projects per volume of hydrogen produced or per tonne of CO_2 avoided. The aim is to encourage competition between industrial actors and to obtain the lowest costs for public authorities, however, auctions disadvantage more expensive, more innovative technologies and new entrants, which may nevertheless have important decarbonisation potential. For example, the solid oxide electrolyzer cell (SOEC) and anion exchange membrane (AEM) electrolysis are still in the pre-commercial phase, but could constitute more energy efficient solutions in the long term, while alkaline electrolysis and polymer electrolyte membrane (PEM) electrolysis are in the early commercial phases. The renewables experience underlines that these effects can be limited by adjusting the parameters for granting subsidies (European Commission, 2022).

An attractive option, sometimes used with renewables, would be to limit the size of projects eligible for auctioning. Another possibility is to award CfDs through technology "baskets" by separating the production technologies that are considered unavoidable, while maintaining a form of competition (European Commission, 2022). Each basket could have a guaranteed budget envelope to determine competition between baskets, as proposed by the new SDE++ CCfDs system in the Netherlands and the CfD system for renewable electricity in the UK.

CfDs could also be allocated in an open window format rather than an auction, where all eligible projects can receive support, as is currently the case in France for some renewable electricity installations–but which are restricted to small-scale projects under current EU state aid rules. The disadvantage of open windows at the early deployment stage of technologies such as hydrogen is that funders are uncertain about the cost of the technologies and the financial volumes to be deployed.

2.3. Optimizing risk sharing and controlling public finance costs

CfDs allow the financial risk to be shared between public authorities and private investors. Given the relative immaturity of hydrogen technologies and the high uncertainties surrounding energy costs, a cautious approach should be adopted and the risk should ultimately be transferred to the project developers (Pahle & Schweizerhof, 2016).

A complementary or alternative way of limiting investment risk is to require hydrogen project developers to cover part of their electricity consumption with long-term power purchase agreements (PPAs). However, PPAs are relatively scarce (lack of supply), which suggests they are unlikely to be a substitute for CfDs for de-risking production. The state could play an intermediary role in providing PPAs to hydrogen producers *via* CfDs for electricity production.

Current investments by public actors in hydrogen should be part of a technology deployment strategy, with quantified targets, translated into an investment pathway over time and sufficient financial envelopes by 2030. In addition, investment plans should include review clauses where support levels can be adjusted to match the needs of the technology, and to assess existing projects and the development of barriers to hydrogen deployment, as recommended by the French Energy Regulatory Commission following the first experiences of support to renewable electricity (CRE, 2014).

IDDRI has calculated the cost of sustaining all hydrogen production by 2030 according to different scenarios for electricity prices, natural gas prices, CO_2 prices and the hysdrogen production level (see Figure 1 and methodological supplement, available online).

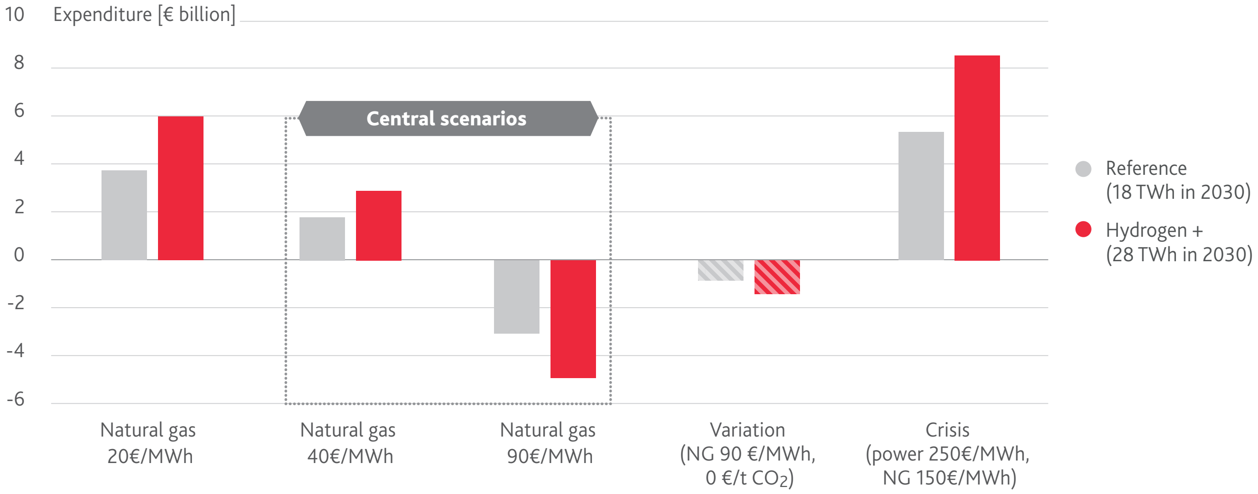
- Supporting hydrogen production *via* CfDs in France could generate up to €5 billion or cost the State up to €3 billion by 2030 according to a central scenario (natural gas between €40 and €90/MWh, the CO_2 price rising from €80 to €100/t CO_2, and hydrogen demand within the range of pathways proposed by RTE).
- If natural gas reaches a price above €90/MWh, support for electrolytic hydrogen would not be necessary in financial terms.
- Depending on the evolution of these parameters, electrolytic hydrogen may or may not need additional support to compete with fossil-fuel hydrogen after 2030.
- If electricity prices remain very high until 2030, the cost of support could increase significantly to a total of €9 billion.

Our estimates indicate that the costs of supporting hydrogen appear bearable for the public authorities considering the total amount committed to supporting hydrogen deployment (€9 billion by 2030 in France), although this relies on the price of CO_2 increasing to €100/t CO_2, natural gas remaining at over €40/MWh_{gas}, and electricity pricing corresponding to RTE's assumptions (between €90 and €95/MWh_{elec}), without which the costs could increase significantly. By way of comparison, over the first eight years of significant support for renewables (2003-2010), France committed around €15 billion in funding, which it should partly recover (approximately €11 billion) in 2023 because the market prices of electricity and natural gas are high (CRE, 2022).

To minimize expenditure, it would be appropriate to finance only part of the production of a given project. Regardless of the financial feasibility or otherwise of full support, it is a matter of encouraging developers to stimulate direct commercialization: CfDs are only intended to finance initial decarbonisation projects to trigger sufficient cost reductions to compete with fossil fuel options.

Furthermore, limiting contracts to relatively short durations (ten or fifteen years) limits the risks to public finances. Finally, the level of support can be capped and subject to a threshold to avoid excessive or unhelpful expenditure if the price conditions change significantly.

FIGURE 1. Cost of supporting hydrogen production for France *via* CfDs according to different price scenarios for natural gas, electricity, and hydrogen demand, cumulated over the period 2023-2030



Hypotheses: hydrogen demand from the two RTE pathways ("reference" and "hydrogen +") for 2050; it is assumed that France produces all the hydrogen it needs. Electricity price corresponds to the full cost of electricity in RTE's N03 production scenario, assuming that electrolyzers only operate for 90% of the year and only 80% of the full cost is paid. CO_2 price at €80/t CO_2 in 2023 to €100/t CO_2 in 2030.

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