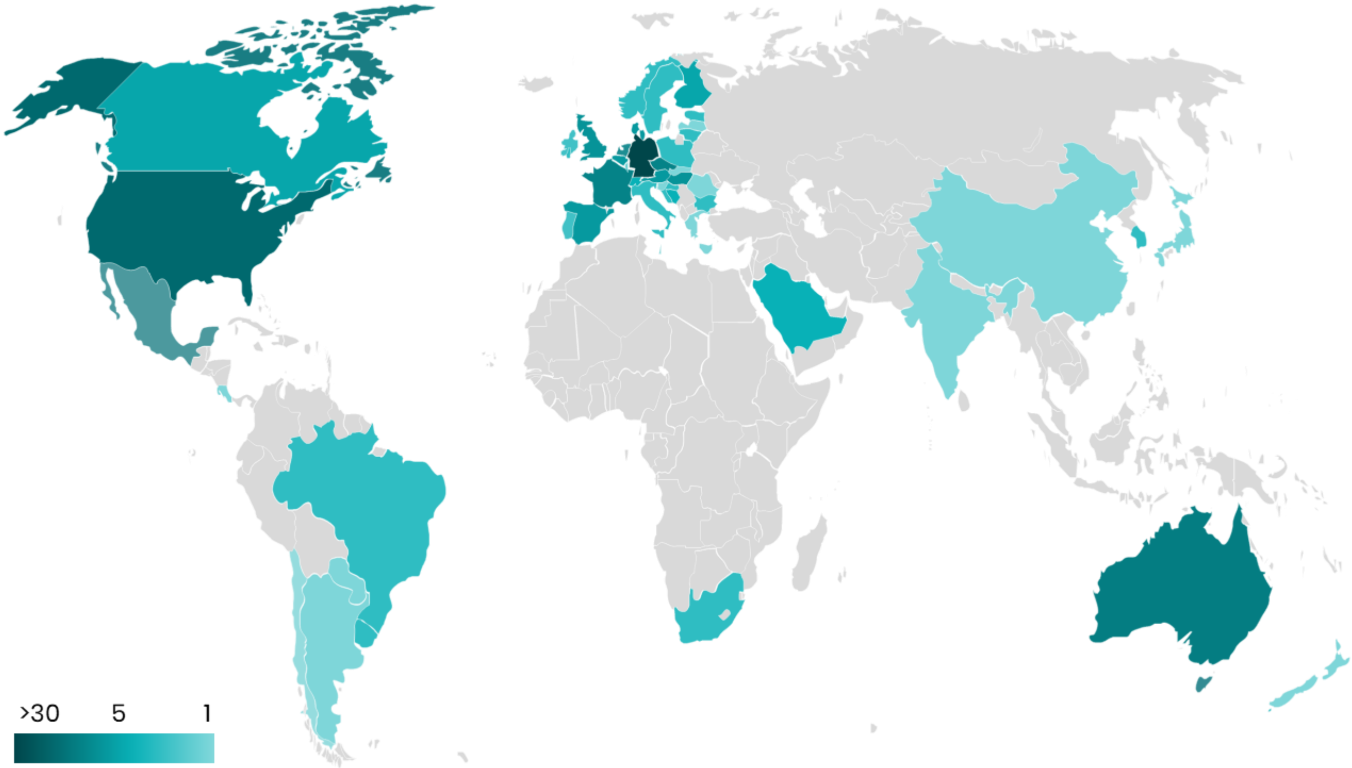
Public Funding for Powerfuels Projects Vol. II

Developments since summer 2021 and recommendations for policymakers



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Cover page: Colour shades indicate number of funding programmes per country

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Executive Summary

The total volume of public funding programmes for powerfuels projects has increased to more than € 660 billion globally.

This report is based on an extended and updated version of the Global Alliance Powerfuels' database of public funding programmes for green hydrogen and other powerfuels. It now comprises 224 programmes from 44 countries and the EU. This represents a significant increase from the 116 programmes from 31 countries included in the previous version of the database, for which data was collected until summer of 2021 and the report published in February 2022.[1] Consequently, the total volume of the included funding schemes has increased from €200 billion to €663 billion. The report differentiates between funding structures, categorising programmes into stand-alone (independent) and overarching programmes with partial / sub-programmes. Stand-alone programmes are more likely than overarching programmes to be dedicated exclusively to powerfuels.

Despite an increase in funding in the US, Europe still leads in terms of absolute funding volume; new developments are seen in South America and Africa.

In a comparison between countries or regions, Germany is leading the way in terms of the number of programmes, while the EU is ahead in terms of absolute funding volume. South America and Africa stand out as regions with a number of newly established funding programmes. Out of all powerfuels, hydrogen emerges as the one eligible for funding in the most programmes.

Changes in funding trends, such as increased OPEX funding and increased funding for market deployment reflect the maturing of the market.

Funding programmes listed in the database cover all value chain steps. Funding for manufacturing has improved, catching up with other value chain steps. With regard to the type of funding, the share of loans and OPEX funding has increased since the last report, reflecting the higher maturity of the technologies and the profitability of the projects. The volume of funding per programme has increased more at the high end than at the low and medium ends, reflecting the inclusion of larger programmes.

Although funding and project announcements have increased, still only 10% of projects have reached FID and a significant funding gap remains.

Along with the significant increase in funding programmes for renewable hydrogen and other powerfuels worldwide, the number and production capacity of announced projects has also surged in recent years. The COVID-19 pandemic and the Russian invasion of Ukraine, which highlighted the importance of energy security and resilient supply chains, are driving factors for these increases. However, this growth trajectory is not yet sufficient to reach targets such as those set by the EU. The modest amount of final investment decisions opposed to the necessary steep

[1] "Public Funding for Powerfuels Projects: Closing the gap towards economic viability," 2022.

growth trajectory is another central challenge that requires fast and significant responses. It is estimated that between $700 billion and $1.2 trillion will need to be invested in hydrogen alone by 2030 in order to be aligned with the goal of reaching net-zero emissions by 2050.

Deep dives into specific funding programmes show how the design of programmes reflects the priorities of the funding agency or government.

A best-in-class assessment was carried out for both powerfuels-exclusive and broader programmes, taking into account the size, scope and number of funding calls. Programmes identified as best in class include the Innovation Fund (EU), the Inflation Reduction Act (USA), the Green Innovation Fund (Japan), the CEFC Green Hydrogen Fund (Australia) and the Green Sectorial Fund (Uruguay). It is clear that the design of the funding programmes is influenced by the priorities associated with them, such as research towards deployment, promotion of innovation in general, activation of private capital, rapid market introduction or generation of practical experience with project implementation in a specific context.

Public funding needs to be well-designed to ensure activation of private capital and further ramp-up of the market.

An overarching finding is that public funding serves two crucial functions: it de-risks hydrogen projects, reducing the gap in their market competitiveness while at the same time attracting private capital. Well-designed support programmes are needed to ensure the effectiveness of public funding, and policy instruments need to be harmonised to increase the simplicity and predictability of funding streams. In addition, definitions of green hydrogen or powerfuels and their certification will affect funding programmes by providing a regulatory basis for eligibility criteria. Finally, a more mature powerfuels market will require support programmes to focus more on OPEX funding and on hydrogen transport infrastructure, although R&D funding still has a role to play.

1 Key results

Introduction

Powerfuels, i.e. hydrogen produced from renewable electricity and its derivatives such as ammonia, methanol or methane, are an important building block for a decarbonised energy system. Scaling up their production and use is necessary to achieve climate neutrality by 2050, but powerfuels projects are generally not yet economically viable. For this reason, public funding has an important role to play in developing the powerfuels market. Due to the fragmented nature of public funding programmes, it is difficult to gain an overview of existing support schemes and their impact on market development. As many international companies are already investing in powerfuels and the products are expected to be traded globally, the evaluation of support programmes needs to be global as well. For this reason, the Global Alliance Powerfuels started mapping existing funding programmes worldwide in 2020.

Public funding programmes for powerfuels that had been announced globally were gathered and analysed up to the summer of 2021, and a report on the findings of this analysis published in February 2022.[2] In the report, it was recommended that funding programmes broaden their technological scope and address multiple stages of the value chain. It was also concluded that the creation of international supply chains requires public funding programmes to be more inclusive for companies from other countries. Finally, diversification over time was encouraged, with programmes designed for multiple calls, in order to benefit from learning over time.

In this follow-up report, the results of our updated database of public funding programmes for powerfuels projects are presented, which includes programmes announced up to November 2022. During the writing of the report newer information, e.g. on the EU Hydrogen Bank, was also taken into account. A more granular assessment of the included programmes and an in-depth analysis of selected funding programmes is also provided, and policy recommendations for public funding programmes are elaborated on.

Scope of the updated database

The database underlying this report was compiled from literature research of publicly available policy datasets (e.g. the IEA "Policies database"), national and regional hydrogen strategies, other government publications/reports and press releases up to November 2022. Programmes were generally included if hydrogen or powerfuels were eligible for funding. Programmes that are designed to provide funding to powerfuels or hydrogen only were noted as such.

With the update of the database, the number of funding programmes included increased from 116 in 31 countries to 224 in 44 countries. Of the 116 programmes previously included, 13 were removed due to changes in their structure and focus. With the larger number of programmes, the total funding volume increased almost threefold, from €200 billion to €663 billion. The newly included programmes amount to €314 billion. The remaining changes in the volume can be traced back to changes in the volume of programmes that were already previously included.

Structure of the funding programmes

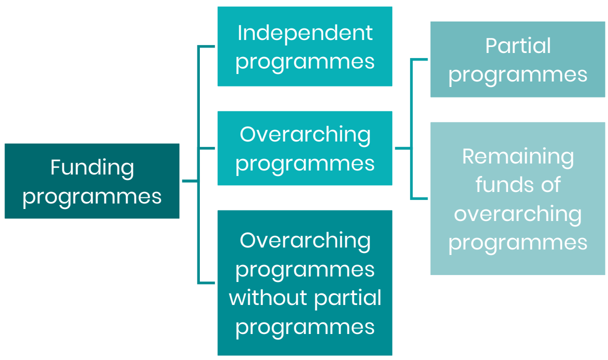

Figure 1: Structure used to classify funding programmes

[2] GLOBAL ALLIANCE POWERFUELS (February 2022).

The updated database now includes information about the funding structures of the included programmes. This is necessary since many programmes are subdivided into smaller, more focused partial programmes. In addition, this allows single calls of broader funding rounds to be mentioned separately if necessary, which allows for a more granular analysis if these calls include powerfuels-exclusive funding rounds. The differentiation used can be seen in Figure 1. Programmes that are not embedded in wider funding schemes or structures are classified as independent. The overarching programmes are listed along with their partial programmes, and any unallocated funds are listed separately for calculation purposes. Programmes are classified as overarching if no smaller programmes are listed in the database yet. The total number and volume of programmes classified as overarching with partial programmes, allocated partial programmes, overarching programmes without specific partial programmes, and independent programmes are shown in Figure 2.

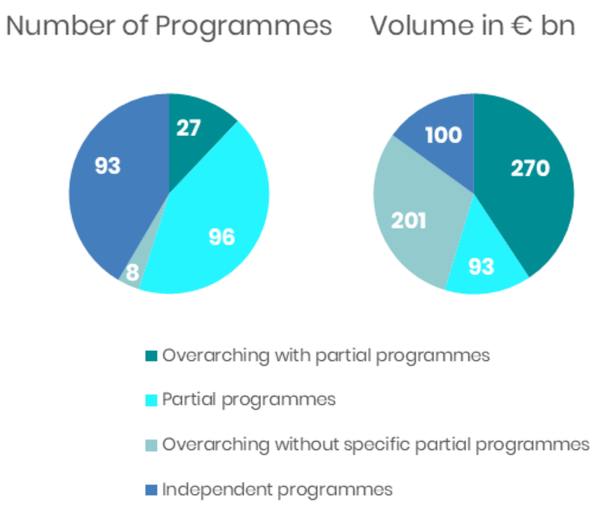

Figure 2: Number of programmes and volume by funding structure.

Regional scope

From Figure 3, it can be seen that Germany leads the way in terms of the number of programmes. Due to the very granular funding structure, containing many small programmes with a narrow focus, the number of programmes is high despite their aggregated volume being smaller than that of funding programmes of the EU, which leads the way in terms of volume of funding (Figure 4). Compared to the previous report, the biggest increase in funding programmes is observed in the US and the biggest increase in funding volume is seen in the EU in absolute terms. South America and Africa are regions in which a number of policies in support of hydrogen have recently been developed or are currently under development. This is reflected not only in funding but also in the preparation and publication of hydrogen strategies and international partnerships.[3] Public funding programmes are still lower both in terms of number and volume than in other regions of the world. Nevertheless, direct interaction with companies and MOUs with importing countries show the importance of these regions.

[3] Weltenergierat, "International Hydrogen Strategies", 2022, https://www.weltenergierat.de/publikationen/studien/international-hydrogen-strategies/, accessed March 2023.

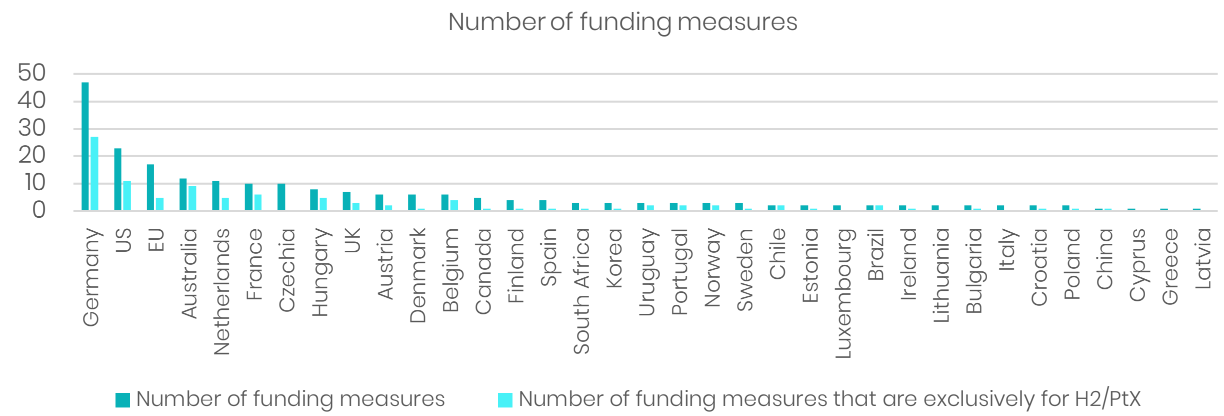

Figure 3: Number of funding programmes per country.

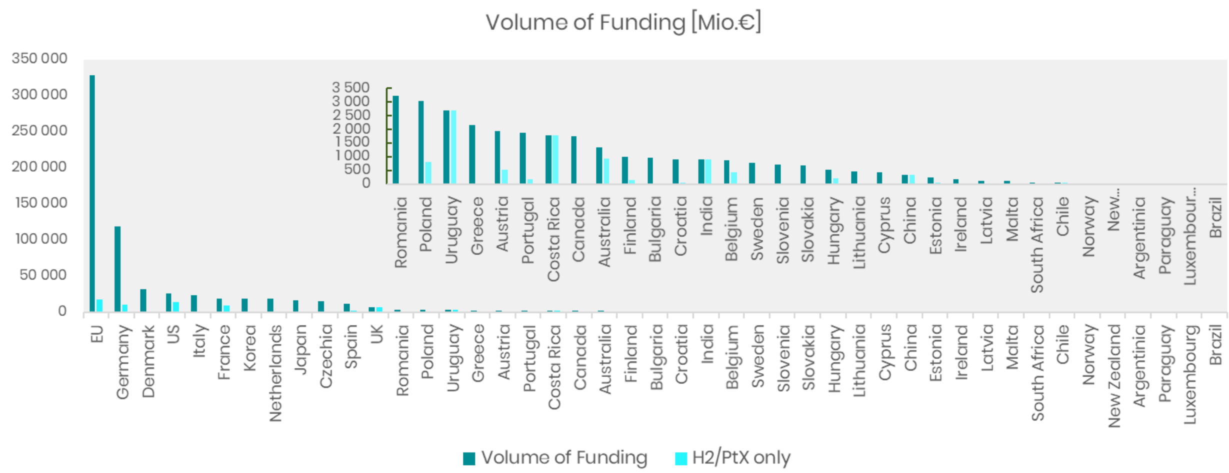

Figure 4: Volume of funding programmes per country.

Technological scope

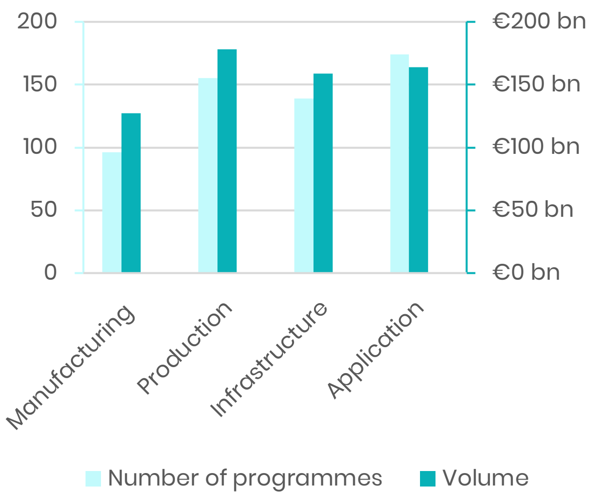

Figure 5: Number and volume of programmes for each value chain step.

The technological scope is evaluated in terms of the value chain steps, energy carriers and project phases covered by a programme. The value chain steps covered by number of funding measures and volume can be seen in Figure 5. It can be seen that the existing funding programmes cover all value chain steps, with manufacturing receiving less support than the other steps. However, this gap has narrowed since the previous publication, in which manufacturing was lagging behind further.

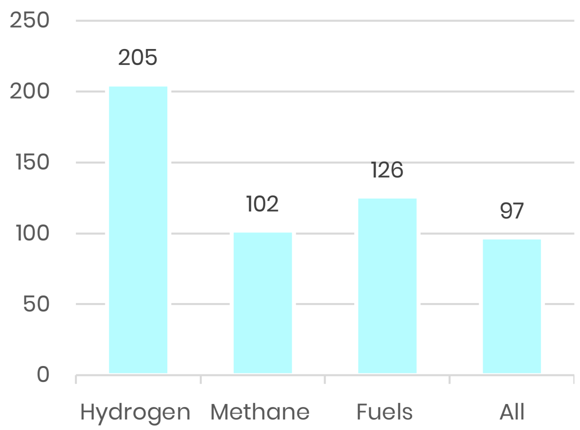

Figure 6: Number of programmes applicable to different powerfuels.

In a comparison between covered energy carriers (Figure 6), hydrogen is eligible for funding in most programmes, with funding for methane and other powerfuels only provided by half as many programmes. Interestingly, over 40% of programmes that provide funding for powerfuels projects are technologically open and fund all green hydrogen-based energy carriers. This can enable access to funding for projects with innovative approaches which might not produce or use hydrogen directly.

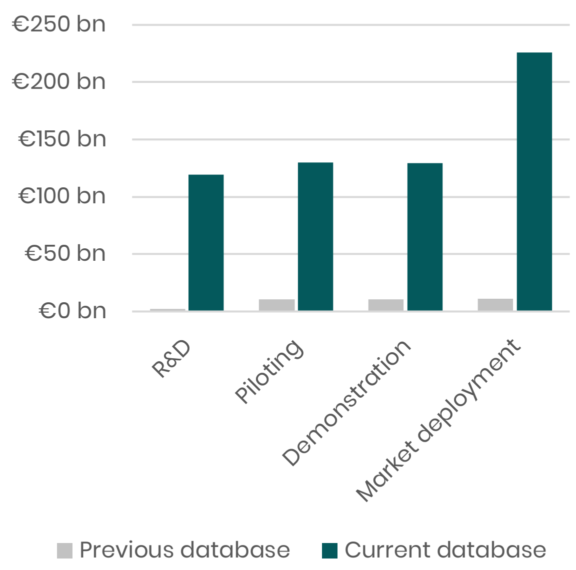

Figure 7: Volume of programmes by funded project stage in the previous and updated database.

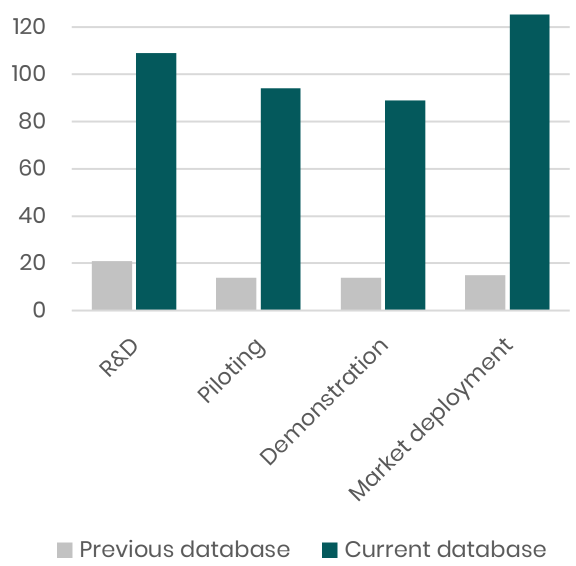

Figure 8: Number of programmes by funded project stage in the previous and updated database.

Before, R&D activities were less funded than other project stages in terms of volume of funding (Figure

7), despite being addressed in a large number of programmes (Figure 8). In the updated database, the volume of funding has caught up with other project stages. This shift can to some extent be explained by the inclusion of funding measures for green R&D allocated by EU Member States' Recovery and Resilience Plans, which, while not specific to powerfuels, often have large volumes. Market deployment also shows an interesting development, with both funding volume and number of programmes increasing rapidly. This reflects the growing maturity of hydrogen applications, many of which can now be brought to market.

Overall, the current funding landscape covers powerfuels technologies more broadly than when the previous report was published. This could be an effect of the general increase in funding, which makes it possible to develop more granular programmes covering specific stages and flexible programmes applicable to various technologies and value chain steps.

Beneficiaries and type of funding

The beneficiaries of public powerfuels funding have not shown many changes since summer 2021, with businesses leading as the beneficiaries, followed in descending order by academia, public institutions, research, and private institutions.

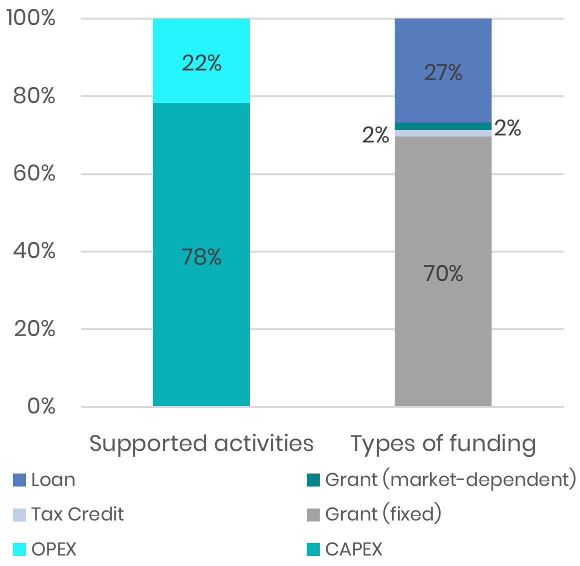

Figure 9: Supported activities and types of funding in the updated database.

With regard to the way in which funding is provided (Figure 9), a shift compared to the previous report can be observed. This is true both for the supported activities, where the share of OPEX funding increased from 9% to 22%, and for the types of funding, where loans increased their share from 8% to 27%. This shows that operational costs become more significant as technologies mature, which means the ability to cover them also becomes more relevant. In addition, with increasing profitability of powerfuels projects, public funding programmes are more often at least partially loan-based, since projects are deemed able to repay the granted funding.

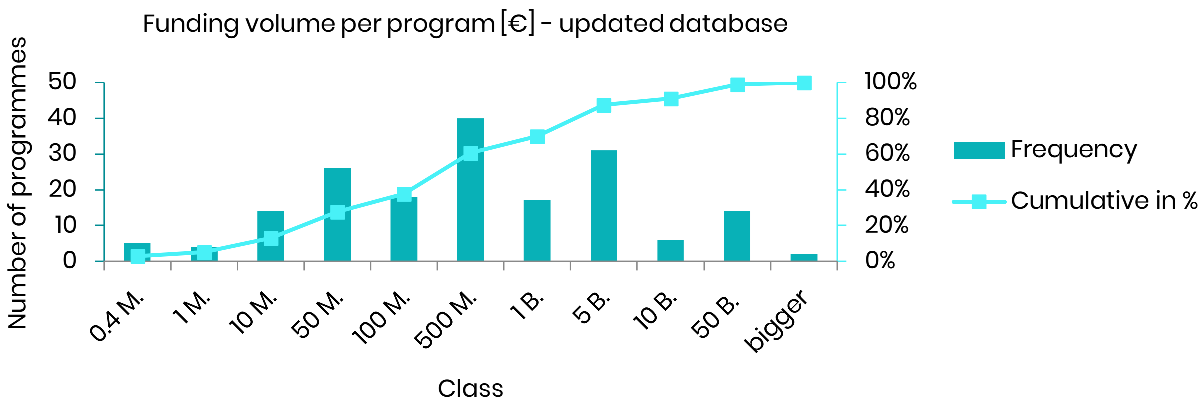

Figure 10: Histogram of funding volume per programme in the updated database.

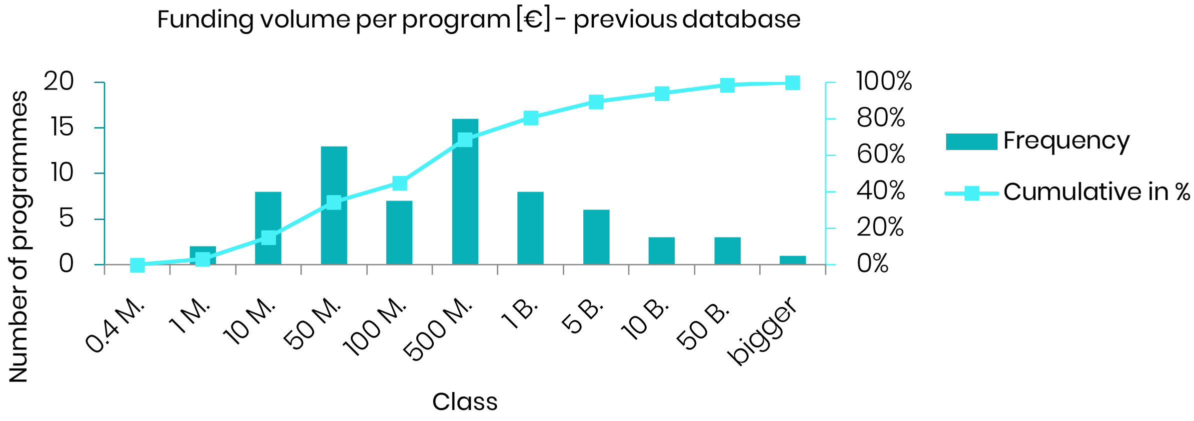

Figure 11: Histogram of funding volume per programme in the previous database.

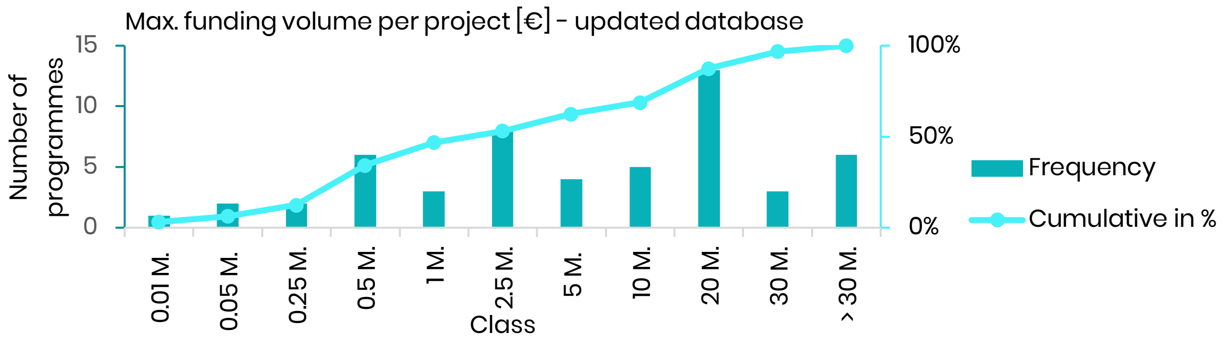

Figure 12: Histogram of maximum funding volume per project in the updated database.

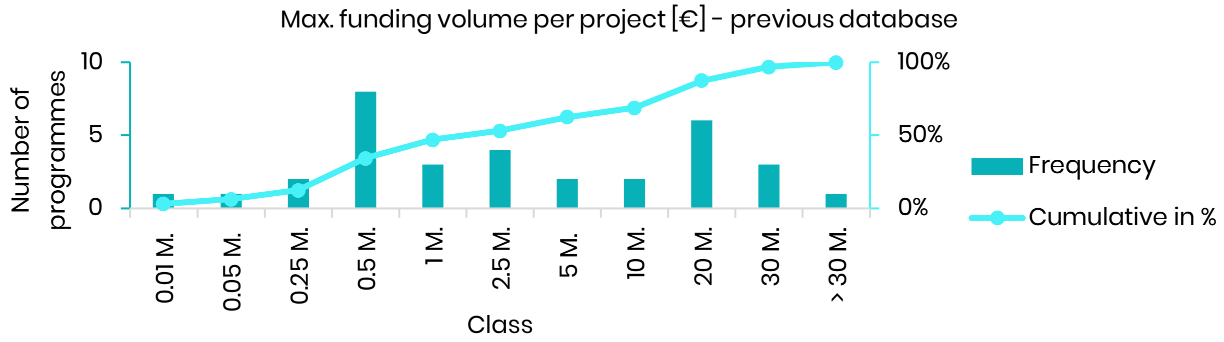

Figure 13: Histogram of maximum funding volume per project in the previous database.

The funding volume per programme class has increased across all values. However, the relative increase was bigger at the higher end than at the lower end and middle of the histogram compared to the previous database (Figure 10 and Figure 11). This reflects the inclusion of larger programmes that have been established since summer 2021 and additional funding allocated to existing programmes. Similarly, the maximum funding per project (Figure 12 and Figure 13) is now more heavily weighed towards higher values, as project size increases as well.

Funding dedicated exclusively to powerfuels

Volume of all programmes and powerfuel-exclusive programmes in € bn

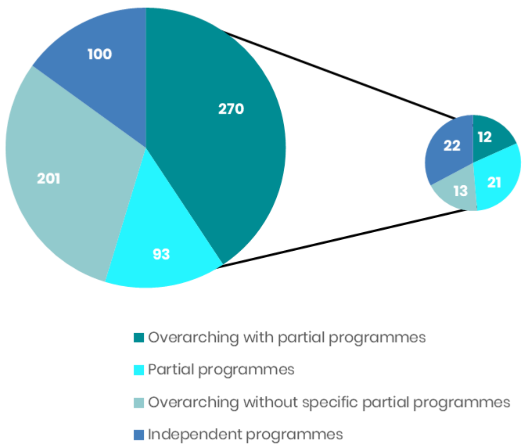

Figure 14: Funding structure of all programmes and powerfuels-exclusive programmes by volume.

It is evident that many programmes include powerfuels in their scope but are not dedicated exclusively to them. Often, other decarbonisation options can also be funded. Programmes that aim to encourage consumers buying "clean" or "green" cars instead of traditional combustion engines are one example of this. In many cases, both electric and fuel cell vehicles can be supported by this. Electric vehicles have a lower total cost of ownership and are therefore being deployed at a faster rate.[4] It thus seems reasonable that programmes which fund with similar incentives will be used more often for electric vehicles.

In the underlying database, this effect is only reflected by around 50% of programmes (10% by volume) being dedicated exclusively to powerfuels. The country with the most exclusive programmes by number is Germany, while the EU leads by volume. Focusing on countries that have at least three programmes listed in the database, Australia has the highest percentage of programmes dedicated to powerfuels by number (75%), with Germany achieving only 57% exclusivity despite the large number of powerfuels programmes.

As seen in Figure 14, of the often large-volume overarching programmes, only a small amount is dedicated exclusively to powerfuels. Partial programmes and independent programmes make up a larger share of the exclusive programmes despite having a lower share in all programmes. Programmes that are not overarching and thus do not include more specific smaller programmes are likely to be more specific themselves. This includes the dedication to powerfuels.

Overall, the assessment of available public funding programmes, especially when comparing the updated database to the previous one, shows the increasing maturity of powerfuels projects. The funding landscape is more complex, with a stark increase in programmes and countries that provide financial support for powerfuels projects. Funding tends to be larger in volume and more evenly distributed along measures of technological scope. While the larger volume of programmes is a positive sign for the ramp-up of the powerfuels market, the high complexity and fragmentation of the funding landscape also comes with challenges. Due to granular funding structures, it can be difficult for project developers to be aware of the programmes that are relevant to them and the requirements they need to meet in order to be awarded funding. The trends in funding programmes thus might not directly correlate with trends in market development, which will be discussed in detail in the next chapter.

[4] International Energy Agency, "Trends in electric light-duty vehicles: Global EV Outlook 2022 - Analysis", 2022, https://www.iea.org/reports/global-ev-outlook-2022/trends-in-electric-light-duty-vehicles, accessed March 2023.

2 Project funding and market development trends

In 2021, the number of funding programmes worldwide that can be applied to powerfuels increased by 159% (182% for powerfuels-exclusive programmes), while the volume of these funding programmes increased by 139% (+99%) compared to their cumulative number and volume in 2020. In 2022, there was a further increase by 23% (+33%) in the number of programmes and 11% (+54%) in the volume of funding compared to the cumulative number and volume in 2021. Figure 15 and Figure 16 show the development over the years. The big increase in funding programmes in 2021 is linked to programmes to ease the effects of the COVID-19 pandemic coming into action, which often also have a decarbonisation or energy transition component. Further increases in the volume of programmes with start dates in 2022 and 2023 can at least partially be traced back to funding made available to end the dependence on (Russian) fossil fuels as a response to Russia's invasion of Ukraine.[5] Publicly available data for these years is more limited, as fewer comprehensive analyses have been published and, as such, both the number and volume of additional programmes since 2022 is likely to be underestimated. Interestingly, for programmes with application start dates in 2021 and later years, funding programmes shift more towards market deployment rather than earlier project stages, both in terms of funding volume and number of programmes, as illustrated in Figure 17.

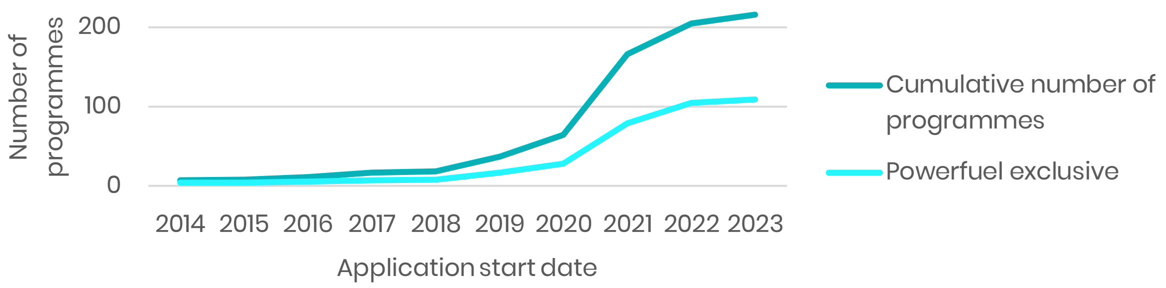

Figure 15: Development of the number of funding programmes from 2014 to 2023.

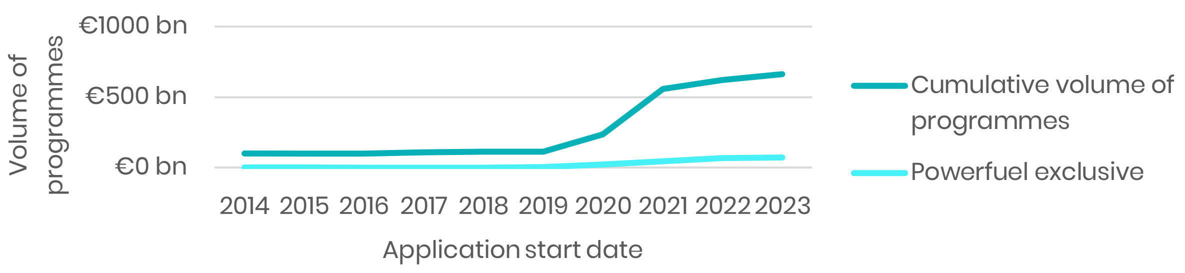

Figure 16: Development of total volume of funding programmes from 2014 to 2023.

[5] Dominic Ellis, "Ukraine war spurs $73bn of fresh investment in green hydrogen", *H2 View*, October 20, 2022, https://www.h2-view.com/story/ukraine-war-spurs-73bn-of-fresh-investment-in-green-hydrogen/, accessed April 2023.

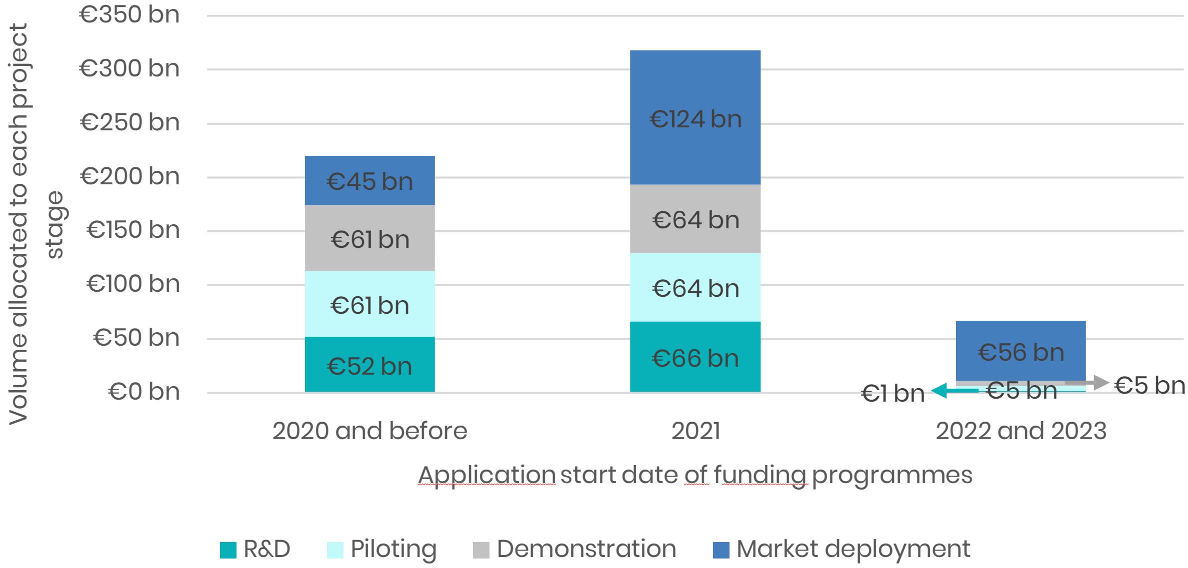

Figure 17: Volume of funding allocated to each project stage over the years.

According to the Hydrogen Council's Hydrogen Insights 2022 report,[6] the number of clean hydrogen projects worldwide (defined as both "green" hydrogen produced from renewable electricity via electrolysis, and low-carbon from fossil fuel reforming with carbon capture and storage) that were announced increased from 520 to 680 (31%) between November 2021 and September 2022. The associated investment increased from $160 billion to $240 billion (50%), while the production capacity of announced projects worldwide increased by 44% to 26 Mt per year. In addition, the number of announced GW-scale projects worldwide increased by 42% (from 43 to 61). At the end of 2022, the IEA estimated an increase of commissioned electrolysers from slightly less than 270 MW_{el} in 2021 to an estimated 670 MW_{el} in 2022.[7]

Committed projects with final investment decisions (FIDs) also increased by 10% between September 2021 and November 2022 (from $20 billion to $22 billion) according to the Hydrogen Insights Report, although this is still only a small share of total investments. In both years, most investment went to production and supply projects, followed by end-use and offtake projects and infrastructure, although the exact proportions of each category varied according to maturity.

In terms of project maturity, there were no major shifts between 2021 and 2022.

Overall, the Hydrogen Insights Report estimates that $700 billion will need to be invested in clean hydrogen up to 2030 in a scenario aligned with a net-zero 2050 economy. The IEA's Global Hydrogen Review[8] estimates a higher investment need of $1.2 trillion of cumulative investment up to 2030 for a net-zero emissions 2050 scenario, although this figure includes the additional renewable energy deployment needed. Both values do not include other investments along the powerfuels value chain, such as those for carbon capture and transport. In comparison, global investment in fossil fuels in 2022 alone was estimated to be over $800 billion, while renewable power generation saw investment of approximately $440 billion in 2022.[9]

[6] Hydrogen Council and McKinsey & Company, "Hydrogen Insights 2022: An updated perspective on hydrogen market development and actions required to unlock hydrogen at scale", 2022, accessed November 2022.

[7] "World Energy Investment 2022", 2022, accessed March 2023.

[8] IEA, "Global Hydrogen Review 2022", 2022, accessed November 2022.

[9] International Energy Agency (IEA) (2022).

The lack of FIDs is a key challenge for the hydrogen industry, with 90% of announced projects still lacking an FID, according to the Hydrogen Insights Report.[10] The development of the maturity of planned and operational hydrogen projects over time can also be derived from the IEA's Hydrogen Project Database,[11] as reported in Figure 18. In addition to the values shown, 317 GW of projects are planned for the following years. Including all planned projects, the rate of FID is below 1%.

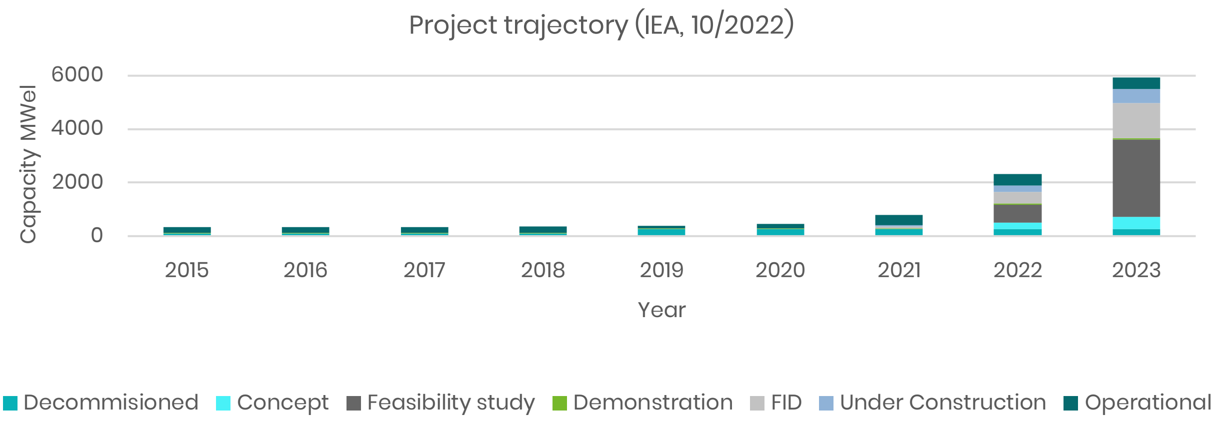

Figure 18: Hydrogen projects by maturity stage in the IEA database.

It is further noted that the industry's growth trajectory is not compatible with EU targets. Based on the current trends, 8 Mt of clean hydrogen per year will be produced in the EU by 2030,[12] which is below the consumption target of 20 Mt of green hydrogen (of which 10 Mt is to be produced in the EU).[13] When assessing the role that public funding can play in closing the gap between political targets and planned production capacities or industry announcements, it is important to consider whether the current level of funding is too low, despite recent growth, or whether the way that programmes are designed is hindering the deployment of hydrogen projects. Other factors such as regulatory uncertainty might also play a role in the growth trajectory of green hydrogen production volumes. It is also worth noting that the impact of inflation is not yet reflected in the funding volumes, as the devaluation of the euro due to inflation stands at 3.8% in 2023 compared to 2019.[14]

In conclusion, the hydrogen industry has seen significant growth in funding programmes and announced projects worldwide, leading to an increase in the number of programmes and the maturity and production capacity of announced projects. However, the lack of FIDs and the growth trajectory of the industry are significant challenges that need to be addressed. It is also important to consider the regional project structure and the potential impact of inflation on funding volumes. Overall, there is still much to be done to meet global consumption targets for green hydrogen and other powerfuels.

[10] Hydrogen Council and McKinsey & Company (2022).
[11] International Energy Agency, "Hydrogen Projects Database", 2022, https://www.iea.org/data-and-statistics/data-product/hydrogen-projects-database, accessed March 2023.
[12] Hydrogen Council and McKinsey & Company (2022).
[13] European Commission, "Hydrogen", 2023, https://energy.ec.europa.eu/topics/energy-systems-integration/hydrogen_en, accessed March 2023.
[14] Inflation Tool, "EUR Inflation Calculator - Euro", 2023, https://www.inflationtool.com/euro/, accessed March 2023.

3 Best-in-class assessment

To compare the existing funding programmes, a best-in-class assessment was carried out for each continent by scoring relevant aspects and ranking the programmes according to their cumulative score. The following aspects were considered in the assessment:

- Volume of funding in relation to other funding programmes in the region
- Number of announced or expected calls for proposals
- Scope (covered energy carriers and value chain steps)

In addition, the assessment was repeated considering only funding programmes that are exclusively dedicated to powerfuels. The top funding programme in each region for both exclusive and non-exclusive sets is listed in Table 1. This assessment determined which programmes were selected for the deep dives that follow in the next chapter.

In general, the highly rated programmes have a larger volume than other programmes in the region, with the exception of the Green Hydrogen Sectoral

Fund. In addition, they are often long-term programmes with the potential to fund many projects over their lifetime. A technological openness, both in terms of the potential energy sources covered and the value chain stage covered, is also common to all these programmes. Even the Green Innovation Fund, with its focus on R&D, is open to funding activities up to the deployment of technologies. It is not surprising that two large and widely discussed funding instruments in Europe and North America, the Innovation Fund and the Inflation Reduction Act, are included as "best-in-class programmes" in the assessment. On the other hand, it may be surprising that the country with the most funding programmes, Germany, does not appear with a best-in-class programme. This is partly due to the reason for the large number of programmes. Germany has many very specific, smaller programmes, which are therefore less highly rated in our system.

Some of the highly rated projects are selected for a closer look at their structure and characteristics in the following chapter. Information on these programmes was retrieved from publicly available data, e.g., on the programmes' scope, goals, and previous funding calls. In addition, exchanges with funding agencies and other organisations involved in the design or implementation of the programmes took place.[15]

[15] Exchanges took place with representatives of the Directorate-General for Climate Action (DG CLIMA) of the European Commission, Green Hydrogen Coalition, Ministry of Industry, Energy and Mining of Uruguay (MIEM) and the Australian Clean Energy Finance Corporation (CEFC).

Table 1: Results of the best-in-class assessment

Best in class		
Region	**All programmes**	**Powerfuels-exclusive programmes**
Africa	Green Fund (South Africa)	HySa (South Africa)
Asia	Green Innovation Fund (Japan)	IH2A Fund (India)
Australia	CEFC Advancing Hydrogen Fund	CEFC Advancing Hydrogen Fund
Europe	EU Innovation Fund	Decarbonised Hydrogen Strategy Funding (France)
Europe (excluding EU institutions)	Grønne Fremtidsfond (Denmark)	Decarbonised Hydrogen Strategy Funding (France)
North America	Inflation Reduction Act Clean Tech Investments	Inflation Reduction Act Hydrogen Tax Credit
South America	Green Hydrogen Sectorial Fund (Uruguay)	Green Hydrogen Sectorial Fund (Uruguay)

4 Deep dives into selected programmes

EU Innovation Fund[16]

The Innovation Fund (IF) was established in 2020 as the successor to the New Entrants Reserve (NER300) programme. Resources for the IF come from the auctioning of allowances under the EU Emissions Trading System (EU ETS) of the period 2021-30, as well as some unspent funds of the predecessor programme NER300. The total size of the Innovation Fund therefore depends on the carbon price in the EU ETS. In addition, the amount of allowances allocated to the IF has changed during the recent revision of the EU ETS Directive. The volume of the IF was estimated at €38 billion for the period 2020-2030 from the sale of 450 million allowances and the remaining NER300 budget, before December 2022. After the revision, the budget is now estimated at €40 billion (530 million allowances).[17] The IF supports projects focusing on low-carbon technologies/processes in energy-intensive industries, carbon capture, use and storage (CCUS), renewable energy generation, or energy storage, as well as innovative technologies in aviation and the maritime sector since the latest revision.

Within the IF, there are on average two calls for proposals per year, one for small projects (CAPEX < EUR 7.5 million, small-scale call (SSC)) and one for large projects (large-scale call (LSC)). Unsuccessful projects can also receive project development support to advance their project maturity and improve their applications for future rounds. From 2024, the calls will be divided into three different tranches according to project size, with thresholds that are yet to be defined. In addition, from 2023 onwards, the IF will be running EU-wide auctions, in the first iteration for the production of renewable hydrogen, as part of the EU Hydrogen Bank. The first pilot auction, with an indicative funding volume of €800 million, will be launched towards the end of 2023.[18] It will provide a subsidy to hydrogen producers in the form of a fixed premium per kg of certified renewable hydrogen production for a maximum of 10 years of operation. The EU Green Deal Industrial Plan[19], first presented in February 2023, mentions the possibility of extending such auctions to other clean technologies. These could also be organised under the IF.

More detailed information is available on the criteria and design of previous grant funding calls under the IF, which will not apply to auctions under the EU Hydrogen Bank. Past IF calls had a total volume of €5.8 billion, although the awarded amounts under each of the calls have in some cases differed from the allocated volumes due to the 20% budget flexibility. Projects need to be located in the European Economic Area and be operational for at least five years (LSC) or three years (SSC). Grants are awarded based on the approximately equally weighed criteria shown in Figure 19[20]:

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[16] European Commission, "Innovation Fund", 2023, https://climate.ec.europa.eu/eu-action/funding-climate-action/innovation-fund_en, accessed February 2023.
[17] European Commission (02/02/2023).
[18] "Communication on the European Hydrogen Bank: European Hydrogen Bank Concept", in.
[19] "A Green Deal Industrial Plan for the Net-Zero Age: Green Deal Industrial Plan", in.
[20] "Innovation Fund call for Large-Scale Projects: INNOVFUND-2022-LSC", 2022, accessed February 2023.

Innovation	Project maturity	GHG avoidance	Scalability	Cost-efficiency
• New/changed technologies, etc. compared to state-of-the-art • Overcoming of major barriers or level of uncertainty	• Technical • Operational • Financial	• Compared to a reference scenario	• Efficiency gains • Further technology or solutions deployment • Knowledge sharing	• Requested grant divided by absolute GHG emission avoidance

Figure 19: Criteria for project selection in the Innovation Fund

The IF covers a maximum of 60% of the relevant costs of the projects supported. These costs are determined by the capital expenditure (CAPEX) for SSC. For LSC, the levelised costs over the first 10 years or, if a reference price for the product is not readily available, a comparison with a reference installation that emits exactly at the ETS benchmark is used, or if such installation does not exist, a no reference plant calculation is carried out directly from the estimated CAPEX, OPEX and benefits over 10 years of operation. Payments for the projects are given as lump sums at specific milestones of the project execution, such as financial close (maximum 40%), entry into operation and, following this, at the end of each monitoring period, depending on verified greenhouse gas emissions avoided.

The 3rd Large Scale Call of the IF was open until mid-March 2023.[21] It covered four topics with a total volume of €3 billion, of which €1 billion is earmarked for the topic "Industry-elec-H2", which supports projects focusing on hydrogen production and applications, as well as direct electrification in industry. With regard to the eligibility of powerfuels projects, the aim is to fund the production of renewable hydrogen and derivatives and their use in industry. Transport and storage activities can only be funded under this topic if they are part of an integrated project. Non-fossil low-carbon hydrogen from CCUS can also be funded if it is used in industry. Other hydrogen projects may be eligible for funding under another LSC topic entitled "General Decarbonisation". This includes, for example, hydrogen storage in stand-alone projects or the use of fossil hydrogen with CCUS.

The IF aims to support the commercial demonstration of innovative technologies that are essential for the EU's transition to climate neutrality by closing the funding gap and complementing (non-public) debt and equity used to finance the projects. As energy and industrial installations are generally CAPEX intensive, and some (including powerfuels production plants and applications) are still high risk, these projects tend to find it more difficult to secure traditional financing. As the grants provided by the IF do not cover all the relevant costs, the activation of private capital is also encouraged.

The large volume of funding and targeted calls make the IF a powerful tool for financing climate-friendly projects in line with the EU's changing Green Deal priorities. On the other hand, the exact amount of funding available is uncertain, as it depends on the evolution of the carbon price in the EU ETS and further changes to the allocation of allowances cannot be excluded. In addition, the revision of the ETS Directive agreed on by the Parliament and Council in December 2022 lead to changes in the number of allowances allocated to the Fund.[22] Firstly, the one-off cap decrease ("rebase") in 2024 and in 2026, together with the increase of the linear reduction factor, will lead to an accelerated reduction in the total number of allowances available; secondly, as the free allocation of allowances is phased out with the phase-in of the Carbon Border Adjustment Mechanism (CBAM), the corresponding allowances will be transferred to the Innovation Fund. While the IF has been allocated a fixed number of allowances for the current period, future developments may lead to adjustments or reallocation of ETS revenues. In addition, the fluctuating carbon price in the ETS can be a disadvantage, as call volumes may need to be adjusted accordingly. The contribution to the domestic part of the European Hydrogen Bank by the IF enhances its scope and flexibility, but it also increases uncertainty about the size and design of future calls or auctions under the fund.

[21] European Climate, Infrastructure and Environment Executive Agency (CINEA) (03/11/2022).

[22] "Directive 2003/87/EC amended by Decision 2023/136: EU ETS Directive", in.

Another point of criticism is the "innovation" criterion included in the evaluation of project proposals. Although the calls for projects contain a definition of the criterion, the evaluation of the degree of innovation of each proposal, which is carried out by four experts using company-provided information, is still difficult for companies to estimate in advance. There are also climate-friendly technologies that are not innovative per se, as they are well researched and even commercially available for a high price but not yet economically viable. These run the risk of not being covered by the IF despite their importance for achieving climate neutrality, although future auctions can be designed to close that gap.

Inflation Reduction Act (USA)[23]

The IRA is a $430 billion package passed into law in August 2022. It allocates $369 billion to energy and climate funds, which are further broken down as shown in Figure 20.[24] Additional funds are also expected to come from state matching programmes. The funds are divided into a variety of measures, both grants and tax credits, in the areas of zero-carbon energy, transportation, clean technology, manufacturing and others. In addition, local requirements relating to content and to wage levels and apprenticeship quotas are aimed at strengthening the US economy.

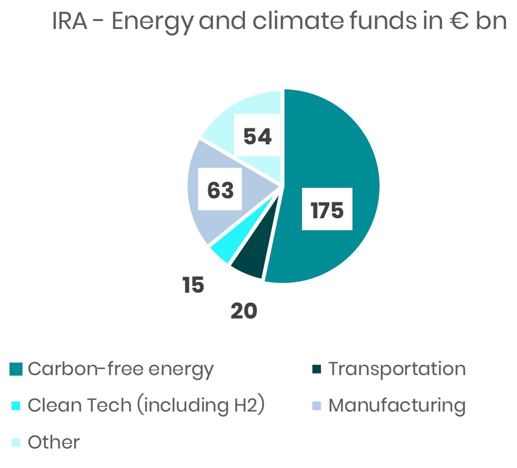

Figure 20: Energy and climate funds in the IRA.

Most important for powerfuels are the Clean Hydrogen Tax Credits,[25] with a planned volume of about $5 billion, which can be used annually for new installations until 2032.[26] Up to $3/kgH2 can be obtained through the Production Tax Credit (PTC) under Section 45V, which is in a section that deals with business-related credits, including other clean technology credits. It is tiered according to carbon intensity (Table 2) and the full credit can only be claimed if employment and apprenticeship requirements are met. For example, if less than 12.5% (2023, 15% 2024) of a project's labour hours are spent with qualified apprentices from a registered programme, only one-fifth of the credit is available.[27] As an alternative, an Investment Tax Credit (ITC) is provided, which is structured as shown in Table 2. This allows hydrogen projects and storage to be treated as energy property (Section 48). Again, only one-fifth of the credit is available if the wage and training requirements are not met or the project has a thermal or electrical energy output greater than 1 MW. Additional bonuses for the ITC are available for meeting domestic content requirements (10%) or for locating in an energy community (10%). These two tax credits cannot be used in conjunction with each other or with the Carbon Capture Tax Credits (Section 45Q) created in the IRA, for example, when used to produce blue hydrogen. Tax credits for renewable energy installations (Section 45) can be combined with the PTC or ITC, even if they only generate electricity for a hydrogen production facility that claims these credits. It may also be possible to combine tax credits with the grants described below. The decision to claim the ITC or PTC will depend heavily on the business case of the projects involved.

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[23] "H.R.5376 - Inflation Reduction Act of 2022: IRA", in.
[24] "US Inflation Reduction Act: Climate & Energy Features and Potential Implications", Executive Perspectives, 2022, accessed February 2023.
[25] Heather Cooper, Carl Fleming, and Allison Perlman, "Clean Hydrogen Tax Benefits Under the Inflation Reduction Act", *The National Law Review*, 9 September 2022, https://www.natlawreview.com/article/clean-hydrogen-tax-benefits-under-inflation-reduction-act, accessed February 2023.
[26] "Estimated Budgetary Effects of Public Law 117-169", 2022, accessed March 2023.
[27] Ari Natter, "Fine Print on Labor in US Climate Bill Complicates Rush for Tax Credits", *Bloomberg*, 23 January 2023, https://www.bloomberg.com/news/articles/2023-01-23/biden-s-climate-tax-credits-rile-industry-over-wage-labor-rules, accessed February 2023.

Table 2: PTC and ITC credits per emission reduction.

kg CO_2e per kg H_2	Emission reduction (grey H_2)	PTC as $/kg$H_2$ [1]	Energy percentage of ITC[1]
< 4	> 60%	0.6	6%
< 2.5	> 75%	0.75	7.5%
< 1.5	> 85%	1	10%
< 0.45	> 95%	3	30%

[1] if apprenticeship requirements are fulfilled

The credits apply to qualified clean hydrogen, defined only by its carbon intensity. The IRA thus operates with a technologically open definition of hydrogen. The methodology for calculating GHG emissions will be based on a well-to-gate model developed by Argonne National Laboratory (the Greenhouse gases, Regulated Emissions, and Energy use in Technologies (GREET) model)[28] or its successors, and will seek alignment with the Hydrogen Production Analysis Task Force of the International Partnership for Hydrogen in the Economy (IPHE), led by the US. It includes Scope 1 and 2 emissions and some Scope 3 emissions.[29] Unfortunately, the question of how to most accurately account for emissions when using grid electricity is still open, and there are concerns about under-reporting of emissions, e.g. related to methane leakage. If emissions are accounted for inaccurately, the installations could in theory claim full credit even if they only have marginally better emissions than grey hydrogen.[30] Solutions include requiring power purchase agreements for renewable electricity and strict verification of methane leakage.

According to an analysis carried out by the Boston Consulting Group (BCG), [31] the levelised cost of hydrogen (LCOH)[32] produced in the US varies depending on the price of natural gas and is currently $0.8-1.3/kg for grey hydrogen and $1-1.6/kg for blue hydrogen. This means that using the PTC, blue hydrogen is already cost-competitive even at the highest threshold of achieving a GHG intensity of below 4 kg CO2e/kg H2 (i.e. qualifying for a cost reduction of $0.6/kg$H_2$). With an LCOH of $3.9-4.2/kg, green hydrogen is in most cases not yet competitive compared to grey hydrogen. However, it could be in 2025, with expected production cost reductions resulting from higher maturity of electrolyser technologies and economies of scale, for example. Assuming that green hydrogen would be eligible for the full tax credit of $3/kg, its production in the US could even become cost-negative by 2032. A comparison of expected LCOH for local green hydrogen production in a range of countries in 2030 based on data from the Institute of Energy Economics at the University of Cologne (EWI) [33] shows that green hydrogen produced in the US has a mid-range average LCOH of $3.8/kgH2, which is competitive with other countries, depending on transport costs to the US (Figure 21). Taking into account the support from the PTC, US hydrogen could outcompete production in other countries cost-wise, even when considering that transport costs need to be added to the LCOH.

[28] Argonne National Laboratory, "GREET Model: The Greenhouse gases, Regulated Emissions, and Energy use in Technologies Model", 2023, https://greet.es.anl.gov/, accessed February 2023.
[29] "U.S. Department of Energy Clean Hydrogen Production Standard (CHPS) Draft Guidance", 2022, accessed March 2023.
[30] Rachel Fakhry, "IRA Hydrogen Incentives: Climate Hit or Miss? TBD", NRDC, 2022, https://www.nrdc.org/experts/rachel-fakhry/ira-hydrogen-incentives-climate-hit-or-miss-tbd, accessed February 2023.
[31] Boston Consulting Group (August 2022).
[32] The cost for production of hydrogen over the lifetime of a production plant, including up-front investment costs.
[33] Gregor Brändle, Max Schönfisch, and Simon Schulte, "Estimating long-term global supply costs for low-carbon hydrogen", *Applied Energy* 302 (2021).

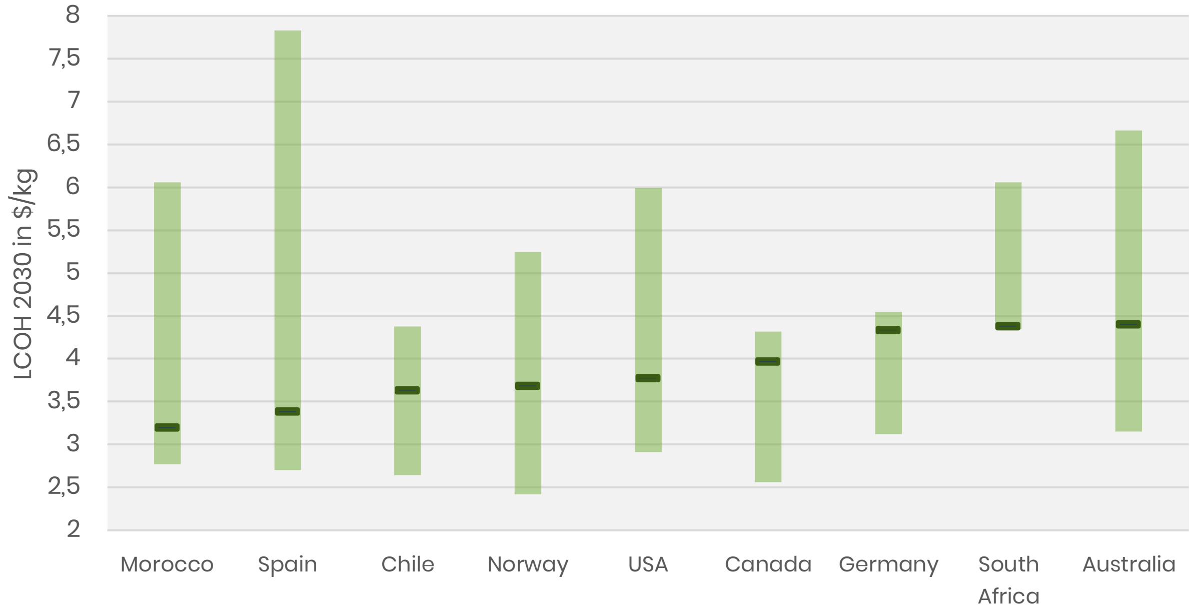

Figure 21: Levelised cost of green hydrogen in different countries in 2030 assuming baseline cost assumptions and low temperature electrolysers.

There are other tax credits that can be applied to hydrogen and powerfuels, such as those for sustainable aviation fuel or for clean fuel production. For carbon-based fuels such as methanol and e-kerosene, the carbon capture and utilisation (CCU) option of the Carbon Capture Tax Credit can be more economical than the Hydrogen PTC. It is capped at a maximum of \$60/tCO2, or \$130/tCO2 when Direct Air Capture (DAC) is used.[34] Grant opportunities also exist. Details of eligibility and volume are available, but further information on the structure of the funding calls has not yet been published. Most interestingly for powerfuels, there are grants for SAF (\$244,530,000) and associated technology (\$46,530,000). In total, there are seven tax credits and seven (\$9,502,760,000) grant or loan opportunities that may benefit hydrogen and powerfuels in some way.

The impact of the IRA on the development of a green hydrogen economy in the US is predicted to be unprecedented. In addition to the funds provided directly, it also acts as an incentive for other areas of the world, particularly the EU, to increase their own support or to see projects built in the US instead. The EU's Green Deal Industrial Plan proposed by the European Commission in February 2023[35] is part of the EU's first response. The IRA has the advantage of being much less bureaucratic and fragmented than the funding landscape in the EU and its Member States. It allows for easy planning over the next 10 years. At the same time, the broad applicability of tax credits encourages less competition than grant funding, has the potential to be very expensive and could over-finance companies, especially in the later years, to the point of providing windfall profits. It is also unclear how effective the US incentives will be in reducing emissions. The open-ended requirements for both production and end-use technologies could end up incentivising less efficient and environmentally friendly processes. Discussions on criteria for so-called renewable fuels of non-biological origin (RFNBOs) in the EU show that the question of how to incentivise the most efficient clean technologies can be a complicated one. Points of contention during the drafting of the delegated acts defining RFNBOs (i.e. green hydrogen and derivatives) in the EU included "additionality", i.e. how to ensure that renewable energy installations for the production of green hydrogen are (mainly) newly-built, and "temporal correlation", i.e. how closely aligned renewable electricity generation and hydrogen production have to be. The same question of temporal correlation is now also

[34] Peter Marrin, "What the IRA Means for Carbon Capture and Storage", Guidehouse, 2022, https://guidehouseinsights.com/news-and-views/what-the-ira-means-for-carbon-capture-and-storage, accessed February 2023.

[35] "A Green Deal Industrial Plan for the Net-Zero Age: Green Deal Industrial Plan." (01/02/2023).

discussed for the production of clean hydrogen in the US.[36] There are also global discussions about whether aspects of the fund create unfair market distortions. An analysis by Bruegel[37] of actionable subsidies under WTO rules (such as local content requirements in the IRA, e.g. materials or technologies that must be produced in the US) shows that up to 86% of the funding volume in clean tech manufacturing support could be violating WTO rules.

Green Innovation Fund (Japan)[38]

The Green Innovation Fund is a broad 2 trillion yen (€16.4 billion) support scheme announced in 2020 to provide funding to companies and other organisations over 10 years. Funding will be provided for green technologies, especially for corporate R&D activities, but also up to the implementation phase. Universities are also expected to participate in the funding calls. Priority will be given to areas identified in Japan's Green Growth Strategy, including the second focus topic listed in the strategy, namely "Hydrogen, Fuel, Ammonia".[39] Ambitious goals for technology or project advancement for 2030 are expected from applicants.

Plans for projects and subsequent themes are formulated by the New Energy and Industrial Technology Development Organization (NEDO), a national research agency. These are then presented to companies and other bodies in a public consultation process. As at March 2023, 25 projects have been published and others are in the planning stage. Among the supported projects, those linked to green hydrogen and other powerfuels are:[40]

- "Large-scale Hydrogen Supply Chain Establishment": reducing costs by developing transport technology and demonstrating hydrogen power generation
- "Hydrogen Production through Water Electrolysis Using Power from Renewables": large-scale water-electrolysis and PtX and establishing performance evaluation technologies
- "Hydrogen Utilization in Iron and Steelmaking Processes": iron reduction using hydrogen in blast furnaces and directly
- "Fuel Ammonia Supply Chain Establishment": reduction of ammonia supply cost and development of combustion for ammonia power generation
- "Development of Technology for Producing Raw Materials for Plastics Using CO2 and Other Sources": using hydrogen and ammonia in naphtha cracking furnaces, producing functional chemicals from CO_2 and H_2
- "Development of Technology for Producing Fuel Using CO2, etc.": fuel production from CO_2 or CO and H_2 for synthetic fuels, SAF, synthetic methane and green LPG
- "Next-generation Aircraft Development": development of core technologies for hydrogen aircrafts
- "Next-generation Ship Development": development of hydrogen- and ammonia-fuelled ships

Selected projects can be funded over a period of up to 10 years. The achieved CO2 emission reductions and costs of implementing the projects are evaluated each year. These evaluations determine the amount of funding, which is paid out accordingly in annual tranches.

The overall aim of the programme is to guide research and development on green technologies in Japan. An implicit goal is to maintain Japan's role as a technology leader, especially in the Asian market. To this end, a large amount of money is being allocated to a wide range of topics. By assigning topics mainly to companies and allowing R&D through to implementation, the programme is able to ensure a focus on solutions that are not only technically feasible but also marketable.

[36] Leigh Collins, "US green hydrogen definition | 'Annual, rather than hourly matching could cut H2 costs by up to 175% and still be net zero'", *Hydrogen Insights*, 13 March 2023, https://www.hydrogeninsight.com/policy/us-green-hydrogen-definition-annual-rather-than-hourly-matching-could-cut-h2-costs-by-up-to-175-and-still-be-net-zero/2-1-1417840, accessed March 2023.
[37] David Kleimann et al., "How Europe should answer the US Inflation Reduction Act", *Policy Contribution* 2023, No. 04 (February 2023), https://www.bruegel.org/policy-brief/how-europe-should-answer-us-inflation-reduction-act, accessed March 2023.
[38] New Energy and Industrial Technology Development Organization, "NEDO Green Innovation Fund Projects", 2023, https://green-innovation.nedo.go.jp/en/, accessed March 2023.
[39] METI Ministry of Economy, Trade and Industry, "Green Growth Strategy Through Achieving Carbon Neutrality in 2050", 2022, https://www.meti.go.jp/english/policy/energy_environment/global_warming/ggs2050/index.html, accessed March 2023.
[40] New Energy and Industrial Technology Development Organization (2023).

CEFC Advancing Hydrogen Fund (Australia)[41]

The Advancing Hydrogen Fund was established in 2021 by the Australian Clean Energy Finance Corporation (CEFC), which invests its funds on behalf of the Australian Government to provide loans and equity finance to companies and projects that enable the transition to net-zero emissions. The Advancing Hydrogen Fund has a volume of AUS$300 million (€188 million) to drive the expansion of the hydrogen market and support Australia's National Hydrogen Strategy.

Eligible projects may include the production of hydrogen for both domestic and export use, development of supply chains, establishment of hydrogen hubs or hydrogen infrastructure, and domestic offtake/demand-side activities. Australia's hydrogen strategy focuses on developing both the domestic market and export opportunities with the goal of creating jobs, lowering emissions, increasing prosperity and increasing the security of Australia's energy supply.

Criteria for approving projects include the ability to deliver a positive return to taxpayers, market impact (e.g. by catalysing additional private funding) and emissions reduction potential. Given the focus on projects that can deliver returns for investors, investment provided under the Advancing Hydrogen Fund is at the current stage of market development particularly relevant for projects that are able to use existing infrastructure. This includes the production of ammonia, for example.

At the federal level, the CEFC and ARENA (the Australian Renewable Energy Agency) work together to unlock the barriers to investment for the advancement of Australia's hydrogen economy. They have complementary but distinct roles. While ARENA provides grants (including through specific green hydrogen calls), the CEFC can provide debt or equity to hydrogen projects but requires a return. Both agencies can provide funding for the same projects. Specifically, the Advancing Hydrogen Fund will seek to invest in projects identified in the ARENA Renewable Hydrogen Deployment Funding round, under which ARENA has conditionally approved $103.3 million towards three commercial-scale projects.

The CEFC aims to bridge the gap to traditional loan structures, which are often not yet available for hydrogen projects. By having the ability to provide loans and equity at below market rates (concessional finance), it is possible to finance higher-risk projects with a smaller return on investment compared to conventional energy projects, thereby enabling projects that are already commercially viable but that private sector financiers are not (yet) willing to fund. This allows for an efficient market introduction. Overall, the Advancing Hydrogen Fund is an effective instrument designed to bridge the gap between grants and private loans/equity.

Green Hydrogen Sectorial Fund (Uruguay)[42]

The Green Hydrogen Sectoral Fund is a joint programme of the National Agency for Research and Innovation (ANII), the Ministry of Industry, Energy and Mining (MIEM) and the Uruguayan Technological Laboratory (LATU). Established in 2022, it aims to support the construction, production and use of green hydrogen and its derivatives, with its first two-stage call for a pilot project closing on 23 February 2023. At $10 million, it is smaller than other programmes discussed in this chapter and has a lower volume than other public funding programmes in South America, but the long funding period of 10 years and technological openness made it one of the schemes in the region rated most highly in our assessment.

A number of high-priority applications have been identified in line with the country's hydrogen roadmap and are given priority in the evaluation process. These are heavy-duty vehicles and busses, e-methanol, e-kerosene and green fertilisers. Electrolysers must have a capacity of at least 1.5 MW and use renewable electricity or electricity from the grid (which, depending on the definition, is 79-97% renewable in Uruguay). While the funds will be disbursed annually for 10 years, cash flow must be demonstrated for 20 years of the project's lifetime, with operations commencing no later than December 2025. In order to meet the self-

[41] Clean Energy Finance Corporation, "Advancing Hydrogen Fund", 2021, https://www.cefc.com.au/where-we-invest/special-investment-programs/advancing-hydrogen-fund/, accessed March 2023.

[42] Agencia Nacional de Investigación e Innovación, "Convocatoria a proyectos de hidrógeno verde", 2023, https://www.anii.org.uy/apoyos/innovacion/303/convocatoria-a-proyectos-de-hidrogeno-verde/, accessed March 2023.

imposed milestones, at least 50% of the produced hydrogen must already be commercialised - this can be demonstrated through an MoU or a purchase agreement.

Following the first phase of the call for proposals, the programmes that submitted their applications were published. Of the nine proposals, three plan to use green hydrogen in forestry transport, four will use it to fuel heavy-duty trucks and three will blend it with natural gas. In addition, one will use it to hydrogenate vegetable oils and another will use it to produce green fertiliser. In a second stage, these nine project proposals were evaluated to select the funded pilot project. In addition to the prioritised use (20%), the evaluation criteria include company experience (20%), project maturity (15%), related industrial development (12%), financing model (25%), early entry (10%), production for both domestic and export markets (4%) and capacity building (4%).

The overall objective of the Green Hydrogen Sectoral Fund is to support a first pilot project. The focus will be on generating insights for both project developers and government agencies on how to implement green hydrogen projects in the country. Uruguay aims to become both a domestic user and an exporter of green hydrogen. With a small population, a largely decarbonised grid and stable economic conditions, the country is well placed to produce more hydrogen than is needed for domestic applications. This funding programme can contribute to working towards this goal.

5 Funding gaps and recommendations

As shown in Chapter 2, there is still a significant gap between current public and private funding (about $240 billion) and the investment in hydrogen that is needed by 2030 to be on course for climate neutrality ($700 billion to 1.2 trillion depending on the report). Both public and private funding need to be stimulated further to close this gap. Final investment decisions are also not keeping pace with increased funding opportunities. Smart funding design and reduction of other barriers (e.g. reduced complexity) are necessary to ensure a fast ramp-up of the hydrogen market.

Public funding can help to de-risk hydrogen projects so that project developers can attract sufficient funding for the realisation of their projects. Some of the risks that remain for green hydrogen and other powerfuels projects include:

- Uncertainty of future prices and the associated willingness of consumers to pay a higher price for green products.
- The speed and extent to which powerfuels will be deployed and consequently the volumes that will be available.
- The timeliness of the development of the infrastructure needed to transport hydrogen and other fuels between producers and consumers.

Public funding needs to do both: address these remaining risks and bridge the remaining economic viability gap of powerfuels projects.

Powerfuel technologies are not expected to be fully established before 2030. As can be seen in Table 3, the technology readiness levels (TRL) of different powerfuel technologies vary widely, suggesting that some will still need to be supported by public programmes beyond 2030.

Table 3: Selected powerfuels technologies and their TRL.[43]

Powerfuels technology	TRL
Alkaline electrolysis	9
Polymer electrolyte membrane electrolysis	9
Solid oxide electrolyser cells	7
Seawater electrolysis	3
Hydrogen pipelines	10
Repurposing of natural gas pipelines	8
CO_2 pipelines	10
CO_2 direct air capture	6-7
Direct reduced iron reduction with green H_2	6
Synthetic hydrocarbons via CO_2 Fischer-Tropsch synthesis	6
Fuel cell vehicles	7-9
Ammonia engines for ships	9

Although the results presented in Chapter 2 show a gradual shift away from R&D funding, it remains important, particularly for technologies at lower TRL levels. At the same time, further process optimisation of established technologies with already high TRL, e.g. in terms of efficiency, recycling or sector coupling, is needed to further reduce LCOH. Hence, public funding schemes need to keep an eye on both support needs.

Another aspect of programme design noted in this report is the eligibility of operational costs (OPEX) for funding. Compared to the previous report, more programmes are now funding OPEX as well as CAPEX, but this still only accounts for 22% of programmes. As the powerfuels market continues to mature, projects are scaling up, which is also important for cost reduction. As scale increases, OPEX becomes a larger part of the

[43] International Energy Agency, "ETP Clean Energy Technology Guide", 2022, https://www.iea.org/data-and-statistics/data-tools/etp-clean-energy-technology-guide?, accessed March 2023.

total projected financing costs.[44] It is therefore important that funding programmes continue to open up towards OPEX funding. While initial hydrogen projects are concentrated in clusters or hubs with production and application in close proximity, the long-term development of the hydrogen market will require powerfuels to be traded over longer distances and, hence, the development of corresponding infrastructure. While funding programmes allocated only slightly less funding to infrastructure (€159 billion) than to production (€178 billion) and application (€164 billion) and more than to manufacturing (€127 billion), the Hydrogen Insights Report shows that less overall funding is flowing towards infrastructure projects. Additional funding focus on this value chain step is therefore necessary.

However, the amount of public funding available is limited and highly contested in times of multiple crises. Hence, enhancing efficiency of public funding is key (i.e. to achieve the biggest possible GHG emission reduction per funding amount). In order to avoid over-funding and to leverage as much private capital as possible, funding programmes need to be designed intelligently. This requires programme designers to have the necessary information to accurately determine priority areas of funding, funding volumes, types and award criteria. Activating private capital is important for two reasons: to increase the number of projects that can be deployed and hence to increase the cost-efficiency of public support schemes, and to stimulate the transition to a self-sufficient hydrogen market (i.e. where the bankability of projects is not dependent on public funding) already at an early stage. For mature technologies, a public/private investment ratio[45] of 1:5 or even 1:10 is recommended.[46] This is not a short-term goal to be achieved by 2030, but a strategic indicator to look out for.

Recently, instruments based on auctions have been promoted, such as H2Global[47] and the EU Hydrogen Bank[48]. Such auctions, with different bidding designs, are known from the deployment of renewable energy.[49] They are an effective tool to increase cost efficiency, as usually the cheapest bids are awarded funding one after the other until the funding volume is fully allocated. Through competition among companies, greater activation of private capital can be achieved compared to grant funding, as they aim to win the bid by lowering the public funding needed. One example for auction designs are carbon contracts for difference (CCfDs). There, the participants bid for the amount needed to close the cost gap with fossil alternatives. In addition, they can include the provision that the awardee pays a portion of the profits back to the funding agency if the green alternative achieves a higher price than the fossil alternative during the lifetime of the contract. They therefore are an instrument quite resilient to over-funding. An additional advantage of auctions is that first market prices for hydrogen can be discovered through this process, which also addresses one of the remaining risks for hydrogen project developers. Auctions are more able to determine economically viable prices, especially in combination with offtake agreements. Nevertheless, the auction design, i.e. through ceiling prices, will still influence the price at which companies bid. With the maturing of the powerfuels market, we expect an increase in the use of different auction designs. Other funding options worth mentioning in this context are tax credits and public procurement. Tax credits, such as in the IRA, are simpler in design and use existing governance structures and thus reduce complexity. They also are generally not fit to define as many criteria for receiving funding as grant calls or auctions and can therefore lead to over-funding. Public procurement is not a funding programme per se, but rules on the green characteristics to be met by public contracts can serve to create visible demand for powerfuels, even at a higher price than fossil alternatives. The decision on one funding measure over another depends on several factors, such as the amount of funding available, the timeframe and how

[44] Hicham Idriss, "Toward Large-Scale Hydrogen Production from Water: What Have We Learned and What Are the Main Research Hurdles to Cross for Commercialization?", *Energy Technology* 9, No. 2 (2021).
[45] World Bank Group, "Financing renewable energy: Options for Developing Financing Instruments Using Public Funds", 2011, accessed March 2023.
[46] Stephan Brand and Daniel Römer, "Öffentliche Investitionsbedarfe zur Erreichung der Klimaneutralität in Deutschland", KfW Research - Fokus Volkswirtschaft No. 395, 2022, https://www.kfw.de/PDF/Download-Center/Konzernthemen/Research/PDF-Dokumente-Fokus-Volkswirtschaft/Fokus-2022/Fokus-Nr.-395-Juli-2022-Oeffentliche-Investitionsbedarfe.pdf, accessed April 2023.
[47] "Vergabeverfahren zum Ankauf von grünen Wasserstoffderivaten - Los 1 (Ammoniak): Los1_26 Leistungsbeschreibung", 2022, https://ted.europa.eu/udl?uri=TED:NOTICE:675894-2022:TEXT:EN:HTML&tabId=1#id0-I, accessed December 2022.
[48] "Communication on the European Hydrogen Bank: European Hydrogen Bank Concept." (16/03/2023).
[49] "Renewable Energy Auctions - A Guide to Design", 2015.

an agency evaluates the trade-off between specificity and simplicity of funding measures.

The auctioning mechanism in H2Global[50] comes with another interesting peculiarity, as it has a double-sided auction process for both the supply and offtake. The EU Hydrogen Bank's[51] pilot auctions are planned to be on the supply side only, but suppliers need to secure offtakers for their product in order to be eligible to bid in these auctions. This furthers the development of simultaneous ramp-up of production and use and, hence, kick-starts powerfuels trade. However, additional support for the simultaneous ramp-up of supply and offtake should be provided through the use of sector-specific offtake financing. As the cost of GHG emission abatement varies between industries, sector-specific funding calls ensure that a variety of applications in hard-to-abate sectors are decarbonised. It should be noted that this increases the amount of funding needed compared to broader offtake funding. Otherwise only sectors with lower abatement costs might benefit.

It is also important to note that support schemes do not operate in a vacuum. There are other policy instruments in the powerfuels market that influence how effective public funding can be. The programmes need to be harmonised with these. The most important one is the official definition of what constitutes green hydrogen and powerfuels and how they can be certified. Recent examples include the EU Delegated Acts on Articles 27 and 28 of the RED II, defining renewable fuels of non-biological origin (RFNBOs),[52] which are currently under scrutiny review, as well as the methodology for calculating greenhouse gas emissions of green and blue hydrogen, currently under development in the US.[53] Both have a direct impact on funding programmes in their respective regions, e.g. the EU Hydrogen Bank and the IRA, as these definitions are used to determine the requirements that companies must meet in order to be eligible for powerfuels funding or how high the respective funding will be. Quickly establishing definitions and reliable certification schemes are indispensable for ensuring investment and regulatory certainty. This is essential to enable companies undertaking these projects to plan for long-term investments.

As seen in Chapter 2, both our funding report and global project announcements show that countries in the Global North can provide more funding for powerfuels than the Global South. At the same time, the potential for producing hydrogen and other fuels is greater in the Global South, where renewable energy is more abundant. Many countries in the Global South are beginning to position themselves as future powerfuels exporters, but public funding tends to be scarce and capital costs higher due to higher risk ratings.[54] In addition, the private/public funding ratio is lower in developing nations than in developed ones.[55] Future importing nations in the Global North are developing funding programmes both to directly fund projects in exporting countries and to provide guarantees to companies wishing to invest internationally. While this is good news, two additional challenges need to be kept in mind when developing funding schemes for projects in the Global South. Firstly, it is important to ensure that exporting countries also retain control over project developments and foreign investment in their countries by other nations or foreign companies. This requires efforts to enable exporting countries to develop their own powerfuels financing, such as through international development banks, but also to support development of local powerfuels strategies, regulations and laws and the respective skills required for that. Secondly, sustainability dimensions (beyond the GHG footprint) need to be considered in funding designs (e.g. as eligibility criteria). Building up green hydrogen and other powerfuels value chains must bring co-benefits for local economies and sustainable development in order to be successful. The necessary expansion of renewable

[50] Timo Bollerhey, "900 million euros for the market ramp-up of green hydrogen: H2Global funding instrument launches first tender procedure", HINT.CO GmbH, 2022, https://www.h2global-stiftung.com/post/900-million-eur-market-ramp-up-green-hydrogen, accessed March 2023.
[51] "Communication on the European Hydrogen Bank: European Hydrogen Bank Concept", (16/03/2023).
[52] "Commission sets out rules for renewable hydrogen", European Commission press release, 13 February 2023, https://ec.europa.eu/commission/presscorner/detail/en/ip_23_594.
[53] Rachel Fakhry, "Success of IRA Hydrogen Tax Credit Hinges on IRS and DOE", 2022, https://www.nrdc.org/bio/rachel-fakhry/success-ira-hydrogen-tax-credit-hinges-irs-and-doe, accessed March 2023.
[54] IEA, "World Energy Outlook 2022", (2022), accessed November 2022.
[55] Intergovernmental Panel on Climate Change IPCC, ed., *Climate change 2022: Mitigation of climate change*. Working Group III contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (Geneva: IPCC, 2022), accessed March 2023.

energy can both accelerate the decarbonisation of the grid and, ideally, increase access to energy.[56] There are already financing programmes that combine funding for renewable installations and powerfuels production (e.g. H2U Offshore in Uruguay),[57] and the further development of this approach can serve to ensure decarbonisation of grids for local use at the same time as production of powerfuels for export. Ensuring benefits for local communities and sustainable development is not only a matter of development policy but of building resilient trade relations and enhancing local acceptability of powerfuels projects.

In conclusion, there is a significant gap between the current public and private funding for hydrogen projects and the investment required by 2030 to achieve climate neutrality goals. From our analysis of public funding programmes for powerfuels projects, we have derived the following policy recommendations:

- Public funding, including R&D funding, will still be necessary in the mid-term to further de-risk projects and support the market ramp-up.
- The funding programme design must ensure mobilisation of private capital, in order to reduce over-funding and accelerate economic viability of projects.
- Depending on the design, auctions can have several advantages compared to traditional grants, including: activation of private capital, resilience to over-funding, matching of supply and demand, and supporting the establishment of a market price.
- Other policy instruments, such as the definition of green hydrogen and powerfuels and their certification, intersect and are essential for the effectiveness of public funding. Hence, they need to be established quickly and reliably.
- As projects scale and grow, OPEX becomes a larger part of the total projected costs. Providing funding for operational costs is important but has not been sufficiently reflected so far.
- Funding for infrastructure development needs to be increased, and funding for supply and offtake must be coordinated effectively.
- Funding for projects in the Global South can face different and/or additional challenges than for projects in the Global North. Specifically, creating co-benefits for local economies and sustainable development are important.

[56] Delia Villagrasa, "Green hydrogen: Key success criteria for sustainable trade & production: A Synthesis based on Consultations in Africa and Latin America", 2022.

[57] International Trade Administration, "Uruguay Offshore Green Hydrogen Project", 2021, https://www.trade.gov/market-intelligence/uruguay-offshore-green-hydrogen-project, accessed March 2023.

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About the Global Alliance Powerfuels

The Global Alliance Powerfuels was founded in 2018 and is backed by 15 member organisations and an international network of partner institutions. It is coordinated by the German Energy Agency (dena). All members and partners are united by the common goal of advancing the development of sustainable markets for powerfuels. Further details about the Alliance and its activities can be found at **www.powerfuels.org**.