Background paper
Recommendations for a climate-friendly hydrogen ramp-up

Background and WWF recommendations

By ratifying the Paris Agreement, Germany has pledged to make its contribution to limiting global warming to 1.5°C if possible – and to becoming climate neutral by 2045 at the latest. Decarbonisation of industry is one of the key tasks in this process. Central to these efforts is establishing a green hydrogen economy. How much hydrogen will contribute to achieving climate neutrality in the coming decades will be determined by the decisions and course set in this decade. The production, import and use of hydrogen as a source of energy are currently the subject of highly political debate.

From WWF's point of view, the following principles are essential if the structure of the hydrogen economy is to benefit the climate and the natural environment:

- *Recommendation 1:* Only **green hydrogen** is truly climate-friendly in the long run. Green hydrogen must be ramped up now – with the highest priority being the **expansion of renewable forms of energy**.

- *Recommendation 2:* Hydrogen may only be used for applications where no reasonable alternatives (e.g. direct electrification) exist and where there is significant potential for reducing GHG emissions. The rule of thumb is: **efficiency first**.

- *Recommendation 3:* In addition to economic criteria, comprehensive **climate, environmental and social sustainability criteria** must also be applied to the production of hydrogen.

- *Recommendation 4:* **Hydrogen purchase agreements** should be introduced at national, European and international level to ensure long-term supply and price stability.

- *Recommendation 5:* Public funds may **not** be channelled into **subsidising blue hydrogen**, as otherwise lock-in effects could arise until well beyond 2030.

- *Recommendation 6:* Comprehensive **climate criteria** in **green public procurement** should be introduced to increase the demand for green hydrogen.

- *Recommendation 7:* Grid and infrastructure planning must be geared towards **climate-friendly investments in infrastructure** and preventing stranded assets.

Recommendation 1: Only green hydrogen is truly climate-friendly in the long run. Green hydrogen must be ramped up now – with the highest priority being the expansion of renewable forms of energy.

The production of green hydrogen is based on a chemical process called electrolysis which uses electricity from renewable energy and water. With the current German electricity mix, hydrogen in this process has a carbon intensity of 16t CO_2/tH_2. “Sustainable” hydrogen is defined in current European legislation as having a maximum intensity of 3t CO_2/tH_2.[1] Hydrogen produced from today’s electricity mix is therefore not climate-friendly and actually generates more emissions than grey hydrogen, which is based on the fossil fuels natural gas or coal. Only green hydrogen produced from renewable energy by means of electrolysis is virtually CO_2-free and therefore the only form that is truly climate- and environmentally friendly in the long term. If 100% renewable electricity were used, the carbon intensity would be 0t CO_2/tH_2 (not including upstream emissions).

This is why, in the long term, only green hydrogen should be produced, supported and used, and the ramp-up of green hydrogen should be the focus of the German government’s hydrogen policy. At the same time, the availability of hydrogen for potential applications in industry must be guaranteed. Industry needs reliable planning to guide investments as it shifts its processes to the use of hydrogen.

The rapid and systematic expansion of renewable energy is a basic prerequisite for the ramp-up of green hydrogen. Not only does the electricity sector need to be fully decarbonised through renewables, the additional demand for renewable electricity also needs to be met through the hydrogen economy.

By way of comparison: According to the study “Klimaneutrales Deutschland bis 2045” (Towards a Climate-Neutral Germany by 2045) conducted by Agora Energiewende, approx. 265 TWh of hydrogen will be needed in 2045. Assuming that this is electrolysis-based green hydrogen with an efficiency loss of approx. 30%, this translates into demand for electricity from renewable energy of approx. 345 TWh. This stands in contrast to total electricity production from renewable energy of 244 TWh in Germany in 2022.[2] Hydrogen demand will therefore be met by both domestic production and imports.

Without the expansion of renewable electricity generation domestically and globally, the hydrogen economy will therefore not be able to gain momentum. **The massive expansion of renewable energy must be implemented quickly to ensure a successful and climate-friendly ramp-up of the hydrogen economy.**

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[1] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=PI_COM:C(2021)2800 / https://network.bellona.org/content/uploads/sites/3/2021/06/Impact-Assessment-of-REDII-Delegated-Act-on-Electrolytic-Hydrogen-CO2-Intensity.pdf.
[2] Fraunhofer ISE (2023): Öffentliche Nettostromerzeugung in Deutschland im Jahr 2022; Stromerzeugung_2022.pdf

Recommendation 2: Hydrogen may only be used for applications where no reasonable alternatives (e.g. direct electrification) exist and where there is significant potential for reducing GHG emissions. The rule of thumb is: efficiency first.

Hydrogen is and will continue to be a scarce resource. For this reason, its availability must be prioritised for applications that have significant potential to reduce CO_2 emissions and cannot be directly electrified. It should only be used to a very limited extent in the building sector or in road transport.

As part of the reform of the Buildings Energy Act, hydrogen was and is being widely discussed as an energy source for heat in buildings. In the coalition agreement, the German government set the target that every new heating system is to be operated on the basis of at least 65% renewable energy by 1 January 2025. As a result of the Russian war of aggression on Ukraine and the ensuing fossil energy crisis, this target was moved forward by one year and will already take effect from 1 January 2024. Hydrogen and other "green" gases are expected to be considered a basic option for meeting the 65% requirement once the Buildings Energy Act is passed. We are clearly opposed to this.[3] For reasons of efficiency, lack of availability and other conflicts of use, hydrogen should be used in the coming years in peak load power plants and other areas where electrification is not possible. Particularly in the building sector, the use of hydrogen and its derivatives would become a very expensive option as it is. The use of hydrogen in the building sector is a financial trap, not only from the point of view of climate change mitigation, but also from the point of view of consumer protection. In the medium and long term, hydrogen will be about twice as expensive as buying and using heat pumps in combination with solar technology, for example.[4]

Not only in the building sector, but also in the transport sector, the use of hydrogen competes directly with electricity solutions. For example, the efficiency of battery-powered e-mobility is significantly higher (69% overall, compared to 26% for fuel cells and 13% for internal combustion engines with e-fuels).[5] This is why comparatively speaking the most environmentally responsible and economical approach for the building and transport sector is the direct use of electricity (efficiency first/electricity first), e.g. through heat pumps for heating buildings or electric vehicles for transport. In addition, green hydrogen is not yet available on a scale that would be sufficient to convert all sectors from fossil fuels to green hydrogen, especially since the limited capacity of renewable electricity will remain a scarce resource in the future. Hydrogen should therefore be available for applications that can only make their processes more climate-friendly as a result.

Wherever possible, priority must be given to direct electrification. In some areas of application, however, this is not (yet) technically possible, which is why

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[3] WWF and others (2023): Wasserstoff und grüne Gase im Gebäudesektor?; https://www.wwf.de/fileadmin/fm-wwf/Publikationen-PDF/Klima/wasserstoff-und-gruene-gase-im-gebaeudesektor.pdf
[4] WWF, BUND, DUH (2023): "H2-ready: Die Kostenfalle im Gebäude; https://www.wwf.de/fileadmin/fm-wwf/Publikationen-PDF/Klima/h-2-ready-die-kostenfalle-im-gebaeude.pdf
[5] Agora Verkehrswende (2018): Die zukünftigen Kosten strombasierter synthetischer Brennstoffe; Die zukünftigen Kosten strombasierter synthetischer Brennstoffe (agora-energiewende.de)

alternatives to the indirect use of renewable energy must be resorted to. This is where hydrogen and its derivatives come into play.

The use of hydrogen should only be incentivised where more energy-efficient electricity solutions or alternatives are not available in the long term.

Deep dive into the use of hydrogen:

Many industries are dependent on hydrogen-based derivatives to replace oil and gas and their products, in other words, on synthetic basic materials and fuels made with green hydrogen. Methane, methanol, ammonia and other products are important components in the future chemical and fuel industries.

Today, these sectors are still fully or largely dependent on the use of fossil sources: 83% of all processes in steel production are based on fossil sources, 71% in cement production, 87% in chemical production and 99.9% in aviation and shipping.[6] [7] The use of hydrogen is necessary for decarbonisation and defossilisation in the following sectors:

Steel production

The steel industry can drastically reduce its harmful emissions by saying goodbye to the coal-based blast furnace process. The new direct reduction process can be operated with natural gas; during the blast furnace process, the reducing gases are released when coke is heated to high temperatures. This alone would lower emissions by 60%.

If hydrogen is used for the direct reduction process in the blast furnace, no more CO_2 emissions are produced. Hydrogen is used in the blast furnace process as a reducing agent for the iron ore. The hydrogen reacts in the process with iron oxides to form water vapour. The product is sponge iron which is processed to become crude steel in what is called an electric arc furnace. The by-product is water, which can be used in turn for other processes, enabling a GHG saving of approx. 90%.

Cement production

Conventional cement production is one of the most energy-intensive industrial processes. 35% of the total emissions from cement production are released during the combustion process and 49% from calcination of the clinker.[8] The raw material limestone is heated up to very high temperatures (1,450°C to form (cement)

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[6] Federal Ministry for Economic Affairs and Climate Action (BMWK) (2019): Energiewende in der Industrie. Potenziale und Wechselwirkungen mit dem Energiesektor; https://www.bmwi.de/Redaktion/DE/Downloads/E/energiewende-in-der-industrie-ap2a-branchensteckbrief-zement.pdf?__blob=publicationFile&v=4.

[7] International PtX Hub/PtX Training (2021), based on IEA (2020): Iron and Steel; https://www.iea.org/reports/iron-and-steel; IEA (2020): International shipping; https://www.iea.org/reports/international-shipping; dena (2019): Feedstocks for the chemical industry; https://www.dena.de/fileadmin/dena/Publikationen/PDFs/2019/Feedstocks_for_the_chemical_industry.pdf

[8] WWF (2018): Klimaschutz in der Beton- und Zementindustrie - Hintergrund und Handlungsoptionen, p. 13; https://www.wwf.de/fileadmin/fm-wwf/Publikationen-PDF/WWF_Klimaschutz_in_der_Beton-_und_Zementindustrie_WEB.pdf.

clinker. It thus consumes significant amounts of fuel which leads to the high energy-related emissions. The chemical reaction when heating the limestone results in the release of CO_2 (calcination). As a result of the high temperatures, hydrogen alone cannot be used to completely heat the clinker kilns – but a mixture of, e.g. 70% biomass and 20% hydrogen – which would largely eliminate the fossil fuels.[9]

Emissions are also released as a result of the electricity used for grinding and the transport of the raw materials and end products. Overall, there is an average GHG potential of 587 kg CO_2-equivalents per tonne of cement in Germany.[10] Since it has not been possible to date to avoid process emissions (in other words, the CO_2 generated during calcination), carbon capture and storage (CCS) are particularly relevant here.[11]

In addition, alternative measures for cement production should be used, for example, the use of eco-friendly materials such as wood for building, lowering the cement content in concrete, the use of renewable energy, recycling, reducing transport distances and ambitious climate criteria for awarding public construction contracts that lower emissions.

Chemical industry

Hydrocarbons are the foundation of the (organic) chemical industry. 74% of the raw material basis of the organic chemical industry is based on naphta and other petroleum derivatives, 11% on natural gas, 2% on coal and only 13% on regenerative raw materials.[12] This means we cannot completely ban hydrocarbons from the chemical industry.

But the chemical industry can break its dependency on petroleum by using hydrogen and its derivatives. Today, large molecules present in petroleum are broken down in a process called "cracking" in systems known as "crackers". The small units produced in the process are called ethylene and are for all intents and purposes the legos of the chemical industry. The wide range of products in the chemical industry is gradually formed from ethylene and its modifications. Cracking is a very emissions-intensive process and is responsible for more than half of emissions harmful to the climate that stem from the chemical industry. It is, however, possible, to introduce a new basic component not dependent on petroleum, for example, methanol. This can be made from hydrogen and CO_2 and would be a more sustainable solution, especially in combination with durability of the final products and recycling.

Aviation and shipping

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[9] Austrian Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology (BMK); https://nachhaltigwirtschaften.at/resources/nw_pdf/schriftenreihe/steckbrief_wasserstoff-zementindustrie_bf.pdf.

[10] WWF (2018): Klimaschutz in der Beton- und Zementindustrie - Hintergrund und Handlungsoptionen, p.7; https://www.wwf.de/fileadmin/fm-wwf/Publikationen-PDF/WWF_Klimaschutz_in_der_Beton-_und_Zementindustrie_WEB.pdf.

[11] WWF (2018): Wie klimaneutral ist CO2 als Rohstoff | WWF

[12] Florian Ausfelder, Hanna Dura (2019): 2. Roadmap des Kopernikus-Projekts "Power-to-X": Flexible Nutzung erneuerbarer Ressourcen (P2X). Optionen für ein nachhaltiges Energiesystem mit Power-to-X Technologien, p. 36; https://www.kopernikus-projekte.de/lw_resource/datapool/systemfiles/elements/files/B0ECE55235C57831E0537E695E860A05/live/document/Power-to-X_Roadmap_2.0.pdf

The transport sector currently uses mainly fuels based on petroleum products (94%). Biofuels account for around 4% of the energy needed in the transport sector and electricity (mainly through rail transport and growing as a result of e-mobility) for about 2%.

When using hydrogen and its derivatives in the transport sector, a fundamental distinction can be made between the direct combustion of hydrogen in a fuel cell and the combustion of hydrocarbon-based, synthetic fuels. To date, most advances have been made in synthetic fuels in the context of Power-to-X and CCU technologies. Assuming CO_2-neutral production with electricity from renewable energy, Power-to-Gas/Power-to-Liquid technologies can reduce dependence on fossil energy sources and thus contribute to climate change mitigation in the transport sector. However, these processes are subject to high electricity intensity, and the CO_2 does not remain sequestered in the product, but is released again when combusted in an engine.[13]

By using direct air capture as a sustainable carbon source, the carbon cycle can be closed in the production and combustion of synthetic fuels known as e-fuels. Here, too, use should be limited to sectors with no alternatives, i.e. aviation and shipping as well as parts of the heavy goods transport sector.

[13] WWF (2018): Wie Klimaneutral ist CO_2 als Rohstoff wirklich: Carbon Capture and Utilization; https://www.wwf.de/themen-projekte/klima-energie/klimaschutz-und-energiewende-in-deutschland/wie-klimaneutral-ist-co2-als-rohstoff/

Recommendation 3: In addition to economic criteria, comprehensive climate, environmental and social sustainability criteria must also be applied to the production of hydrogen.

Germany is and will continue to be an energy-importing country. In the future, a significant share of PtX demand will have to be met by imports. International trade in PtX products plays a key role in the decarbonisation and defossilisation of various sectors in industry and transport and is therefore highly relevant for reaching the climate targets and making the energy transition a success. Standardisation of the production of hydrogen and its derivatives, e.g. in the form of certification, is the basis for ensuring the quality of the hydrogen that is produced, imported or used. It is therefore crucial for the success of the hydrogen economy in terms of climate policy to establish a definition of green hydrogen that is as internationally accepted as possible, or at least EU wide.

One milestone is the long-negotiated Renewables Directive II (RED II) on RFNBOs (Renewable Fuels of Non-Biological Origin, i.e. renewable hydrogen and its derivatives), which establishes sustainability criteria for the transport sector to meet the targets for renewable fuels.[14] Under RED II, the European Commission officially recognises certification schemes to prove compliance with the targets (known as voluntary schemes). The revision of RED II also extends the requirements to other sectors. It contains the criteria for electricity procurement and GHG emissions in two delegated acts:[15]

- Renewable electricity criteria for RFNBOs (Delegated Act on Art. 27 RED II): This is where the criteria for electricity from renewable energy sources for RFNBOs are stipulated.

- Methodology for calculating GHG emissions from RFNBOs (Delegated Act on Art. 28 RED II): This delegated act sets out the methodology for calculating GHG emission reductions for RFNBOs. It also defines the eligible carbon sources for hydrogen derivatives.

The delegated acts establish important basic guidelines for the additionality of renewables for procuring electricity for the production of hydrogen. These guidelines now need to be transposed into national law.

However, RED II does not regulate sustainability criteria above and beyond this. Especially for hydrogen imports, in addition to economic criteria, comprehensive climate, environmental and social sustainability criteria must also be applied. Sustainability criteria are crucial for the ramp-up of the green PtX and hydrogen economy, as hydrogen will only be a viable long-term alternative to fossil fuels if it is produced and used in a way that takes environmental, social and governance aspects into account.

National and international hydrogen projects, particularly in countries of the Global South, must have a positive impact on local development and on the following Sustainable Development Goals (SDGs) from the United Nations' 2030 Agenda: these include SDG 6 (Clean Water), SDG 7 (Affordable and Clean Energy), SDG 8 (Decent Work and Economic Growth; this also includes education goals), SDG 9 (Industry,

[14] EUR-Lex - 52021PC0557 - EN - EUR-Lex (europa.eu)
[15] A detailed assessment of RED II is not the subject of this paper.

Innovation and Infrastructure), SDG 12 (Responsible Consumption and Production), SDG 13 (Climate Action) and SDG 14 (Life Below Water).

Particularly in international cooperation, it is therefore necessary to look beyond the definition of electricity procurement and GHG reduction. **WWF calls for the development and enforcement of comprehensive sustainability criteria for trade in hydrogen products.** These should be codified in particular in the import strategy of the German government, which has yet to be developed, and in the voluntary schemes of the European Commission.

Deep dive into necessary sustainability criteria:

The following aspects of sustainability are crucial for international trade in hydrogen and its derivatives from WWF's perspective:

Climate change mitigation

- *Use of renewable energy/power procurement:* The hydrogen economy also necessarily means transforming the energy mix (energy transition) – away from fossil fuels towards renewable energy. To ensure this shift, the use of renewable energy sources, i.e. the origin of the electricity, is crucial. In addition, the criteria of location, simultaneity and additionality are relevant for hydrogen production to ensure system security and grid stability and compensate for, rather than encourage, bottlenecks in the grid.
- *Preserving and expanding national climate action strategies:* The development of the international hydrogen economy also represents a major opportunity for all partner countries, as they can increase their share of renewable energy as well as hydrogen. However, this presupposes that no negative effects arise in the process, for example the use of renewable electricity to export hydrogen, which is removed from the country's own electricity mix. Renewable energy must be additionally developed or surplus electricity used.
- *Meeting local energy needs and local hydrogen demand:* Hydrogen projects must demonstrate that they contribute to meeting local demand and local decarbonisation, either with the aim of grid stability in the electricity sector or for use in other industrial and transport applications. The development of the hydrogen economy must go hand in hand with meeting local energy needs as well as local hydrogen demand.
- *Use of a sustainable CO_2 source:* The CO_2 required for the production of hydrogen derivatives such as e-fuels should be captured exclusively from the air or from waste gas streams generated by the use of sustainable biomass. The CO_2 cycle must ultimately be closed so that no additional emissions are produced.

Environment

- *Water availability:* Many of the countries or regions predestined for hydrogen production are very sunny and often also experience water shortages. Although electrolysis does not require a very large amount of water (approx. 9 l per kg of H_2), water resources that would have to be available to the public for other purposes, e.g. as drinking water, for households, other industry and agriculture, may not be used. Additional water resources are also needed in cooling and other processes. Electrolysis today is based on the use of highly purified freshwater.[16] Desalination of seawater is also an option. However, strict environmental regulations must be met, as harmful chemicals are also used in the desalination process and brine can be deposited in the sea, which in turn negatively impacts ecosystems.

- *Land requirements:* The development of hydrogen projects will require a large amount of land, as areas are needed for the expansion of renewable energy, the transport of electricity, water and hydrogen, the installation of electrolysers and the additional infrastructure required (digital and mobility). These areas may compete with other uses, e.g. buildings for local residents, land for agriculture or other economic purposes or protected ecosystems. The development of capacities for the hydrogen economy must not have a negative impact on the needs of the population or ecosystems. Areas subject to nature conservation should be excluded. Land rights must not be violated.

- *Preserving biodiversity:* The expansion of renewable capacities as well as the construction of additional infrastructure and power plants can negatively impact ecosystems. Projects and plants must be planned and built with nature conservation in mind. Proof must be provided that the land use has no significant residual impacts on biodiversity and agricultural land.

Social aspects

- *Human rights and fair working conditions* Top priority must be given to the socially responsible design of hydrogen projects, i.e. respect for human rights and fair working conditions. This includes health aspects, fair wages, safety and respect for human rights. It is essential that the UN Charter on Human Rights is respected.

- *Participation and local value creation* To foster acceptance of hydrogen projects in society, transparent communication and participation of the local community are necessary. In addition to adequate feedback mechanisms on the consequences for the local community, involving local residents can also contribute to capacity-building. The expansion of infrastructure must not only

[16] National Hydrogen Council (2021): Nachhaltigkeitskriterien für Importprojekte von erneuerbarem Wasserstoff und PtX-Produkten, p. 5; https://www.wasserstoffrat.de/fileadmin/wasserstoffrat/media/Dokumente/NWR_Positionspapier_Nachhaltigkeitskriterien.pdf.

be in the interest of the project, it also has to be in the interest of the local community, e.g. by creating jobs and providing better access to electricity.

- *Indigenous tribes and resettlement:* As described above, a lot of land is required for the production of renewable energy and the allocation of electrolysers. In most cases, land is used that is sparsely populated, often by indigenous tribes. The development of hydrogen projects must involve the local community throughout the entire process (keyword Free, Prior and Informed Consent) and must not result in involuntary resettlement. In the case of voluntary resettlement, fair compensation and improvement of living conditions must be guaranteed.

Governance is also crucial for implementation. Sustainable projects and regulations must be based on structures and procedures that are independent and enable transparency and participation and prevent corruption. Access to information is particularly important.

Based on these factors, suitable instruments should be developed by various stakeholders (policymakers, academia, business, civil society) that can be used internationally. The involvement of local stakeholders is key. Many of these factors, as well as certification projects, are currently being discussed in some places, but comprehensive certification and a practical roadmap for implementation are still lacking.

Recommendation 4: Hydrogen purchase agreements should be introduced at national, European and international level to ensure long-term supply and price stability.

Long-term power purchase agreements (PPAs) are becoming increasingly popular in the renewable energy sector as a means of long-term financing and risk minimisation for both plant operators and large industrial consumers. These long-term contracts – called hydrogen purchase agreements (HPAs) – are just as suitable for the hydrogen economy. They guarantee plant operators the advantage of securing long-term financing of the investment through a guaranteed purchase quantity over a long period of time (more than 10 years). This is particularly relevant in the ramp-up of hydrogen and the transformation phase of industry. For the industrial customer, the advantage is that the long-term supply of green hydrogen is ensured on the one hand and protected against price fluctuations in the market on the other.

The H2Global project has been offering hydrogen power agreements since 2022 with a funding volume of 900 million euros and compensates the difference between the supply and purchase prices with subsidies (double auction model). The project aims to promote the market launch of renewable hydrogen.[17] Currently, H2Global only promotes hydrogen production in third countries outside the EU. The European Commission is currently developing more auctions based on the H2Global model. To also harness the hydrogen potential in Germany and Europe and minimise transport

[17] H2Global Foundation (2023): Objective of the H2Global instrument; The H2Global Instrument (h2-global.de)

routes, a proposal should also be made that goes beyond this. **Hydrogen purchase agreements should also be introduced for national and European production with the aim of a rapid and climate-friendly hydrogen ramp-up.** In this context, support must be limited to the import of green hydrogen.

Recommendation 5: Public funds may not be channelled into subsidising fossil structures and blue hydrogen, as otherwise lock-in effects could arise until well beyond 2030.

Germany issued a joint declaration with Norway on 16 March 2022, stating that it would import blue hydrogen from Norway for a transitional period, the duration of which is not further defined. Promoting imports of blue hydrogen jeopardises the achievement of the Paris climate targets in the long term. Public funding of blue hydrogen is a misallocation of financial resources that poses the danger of a fossil lock-in, because it encourages more natural gas production and creates infrastructure that is no longer needed in a climate-neutral energy system. The National Hydrogen Strategy, which has already been announced several times, should contain a dedicated roadmap to accelerate the development of a green hydrogen economy that ensures the achievement of climate targets.

Importing or even promoting blue hydrogen hinders this ramp-up, because scarce resources are channelled into supporting fossil technologies. Only green hydrogen produced with additional or otherwise derived renewable energy makes the necessary contribution to climate change mitigation. Since, like green hydrogen, blue hydrogen would only be available in relevant quantities in a few years' time, it cannot function as a transitional solution, but would instead intensify fossil lock-in effects.

Carbon Contracts for Difference must also not promote blue hydrogen in the long term, as this can lead to longer-term lock-in effects.

The Federal Ministry for Economic Affairs and Climate Action has adopted the funding guideline on Carbon Contracts for Difference (CCfDs). Interested companies can already submit their requirements. CCfDs provide industry with the necessary investment and planning security and support basic industries in decarbonising their very energy- and emission-intensive processes and procedures and in boosting investments in climate-friendly technologies. In this case, CCfDs ensure that climate-friendly technologies can compete with conventional technologies. The transformation will require significant investments in the coming years. To avoid an investment backlog, industry must start investing now. There is momentum for action, because the need for modernisation in the industry is very high: industry has a reinvestment need of approx. 50% of industrial plants by 2030.[18]

Currently, the funding programme still includes a subsidy for blue hydrogen. **In the long term, however, Carbon Contracts for Difference may only be used for the promotion of green hydrogen, as only this will pay for significant**

[18] Agora Verkehrswende (2021): Klimaneutrales Deutschland 2045. Wie Deutschland seine Klimaziele schon vor 2050 erreichen kann, p.12; https://www.agora-energiewende.de/veroeffentlichungen/klimaneutrales-deutschland-2045.

emission reductions. Technologies that are based on fossil fuels should not be financed from public funds.

Furthermore, the widely used term "H2 readiness" for gas-fired power plants, import terminals, pipelines and other infrastructure must be precisely defined. This term is mentioned in the National Hydrogen Strategy, the coalition agreement, the LNG Acceleration Act, the EU taxonomy and in state aid legislation, among others, but is not clearly stipulated anywhere. It can make sense to build H2-ready infrastructure and power plants, provided that no better alternatives are available and they contribute to the climate targets. However, this requires specifications and guidelines with regard to the technical requirements for subsequent retrofitting, for the retrofitting costs and an actual and controllable roadmap for retrofitting, including the phase-out for fossil energy sources. **The term "H2 readiness" needs to be defined swiftly and unambiguously so that the right course can be set for climate change mitigation.**

Recommendation 6: Comprehensive climate criteria in green public procurement should be introduced to increase the demand for green hydrogen.

A sustainable transformation of public procurement can provide powerful leverage for climate change mitigation and support the creation of green lead markets. Public procurement in Germany alone has an annual investment volume of 500 billion euros.[19] So far, however, the criterion of cost-effectiveness is still the primary factor when awarding contracts, and decisions are not made based on climate benefits. This needs to change.

The introduction of clear requirements in public procurement (green public procurement - GPP), as well as the introduction of quotas and standards, can stimulate demand for low-emission products like green steel. The design of GPP can take different forms. For example, governments can impose minimum requirements or preferential purchasing requirements for zero-emission steel that is subject to a certain greenhouse gas (GHG) emissions benchmark. A CO_2 limit could be introduced as a requirement or standard for certain products or materials that may be used for public procurement. Another possible model would be the introduction of mandatory CO_2 life cycle criteria to assess new projects. It would be conceivable to apply these criteria at national and European level. Combining both instruments would certainly be advisable.

Under the general administrative regulation (Allgemeine Verwaltungsvorschrift, AVV) on the procurement of climate-friendly services (AVV Klima), which came into force on 1 January 2022, a step in the right direction has already been taken at federal level: among other things, a "negative list" of services not to be procured was integrated, which covers particularly climate-relevant products. In addition, the German government has announced that it will introduce minimum quotas for climate-friendly products for public procurement.

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[19] Fischer, Andreas/Küper, Malte (2021): Green Public Procurement. Potenziale einer nachhaltigen Beschaffung, IW-Policy Paper, No. 23; https://www.iwkoeln.de/fileadmin/user_upload/Studien/policy_papers/PDF/2021/IW-Policy-Paper_2021-Green-Public-Procurement.pdf.

This means that the legal framework is in place. However, rigorous implementation is yet to come and must now follow. WWF advocates for the introduction of quotas as well as criteria in public procurement with the aim of making public procurement demand more sustainable. This is intended to create market incentives for CO_2-free materials with a view to establishing a market for green products in the long term. The government must play a pioneering role in these efforts. **Climate criteria must be comprehensively applied when awarding public construction contracts so that green public procurement is rigorously implemented.**

Recommendation 7: Grid and infrastructure planning must be geared towards climate-friendly investments in infrastructure and preventing stranded assets.

Hydrogen and its derivatives can be transported in different ways: as gas via pipelines, as liquid hydrogen (under very high pressure) in tanks by trucks or ships, with liquid hydrogen organic carriers (LOHC) or also as ammonia or other hydrocarbons (e.g. methanol or other synthetic fuels).

Each form of transport has advantages and disadvantages. Pipelines are the lowest-cost option, but are only suitable up to a length of a few thousand kilometres due to diffusion and costs.[20] In addition, it must be taken into account whether, for example, the electrolyser for offshore plants is situated near the plants or on land. Liquid hydrogen can be transported over longer distances, but storage is cost-intensive due to high pressure and very low temperatures.[21] LOHC, i.e. organic compounds that can absorb and release hydrogen through chemical reaction with a catalyst, are promising, but still in development and relatively cost-intensive as a result.

Investments in infrastructure must always be aligned with the goal of climate neutrality. Stranded assets, i.e. assets that lose value before the end of their (planned) useful life or lead to new liabilities, must be prevented. For example, pipeline infrastructure that will probably no longer be useful in 20-30 years must not be built today to avoid creating misguided incentives or sunk costs, i.e. irreversible costs. Infrastructure must be considered in terms of the goal, not the status quo.

To coordinate infrastructure development, planning for decades of investment is essential. Structured national and European hydrogen network planning is still in its early stages. Electricity, natural gas and hydrogen infrastructure must be planned in tandem. It is important that the planning process is transparent and easy to understand, and that it is designed, implemented and monitored by an independent body in order to avoid any special interests and to take climate targets fully into account in the planning process.

Integrated and independent planning of the electricity and gas grid infrastructure must be implemented in such a way that the hydrogen infrastructure is aligned with the actual needs of producers and consumers.

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