Supporting the

BREAKTHROUGH AGENDA

IRENA
International Renewable Energy Agency

INTERNATIONAL CO-OPERATION

TO ACCELERATE GREEN HYDROGEN DEPLOYMENT

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IRENA Collaborative Framework on Green Hydrogen

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About IRENA

The International Renewable Energy Agency (IRENA) serves as the principal platform for international co-operation; a centre of excellence; a repository of policy, technology, resource and financial knowledge; and a driver of action on the ground to advance the transformation of the global energy system. A global intergovernmental organisation established in 2011, IRENA promotes the widespread adoption and sustainable use of all forms of renewable energy, including bioenergy and geothermal, hydropower, ocean, solar and wind energy, in the pursuit of sustainable development, energy access, energy security, and low-carbon economic growth and prosperity. www.irena.org

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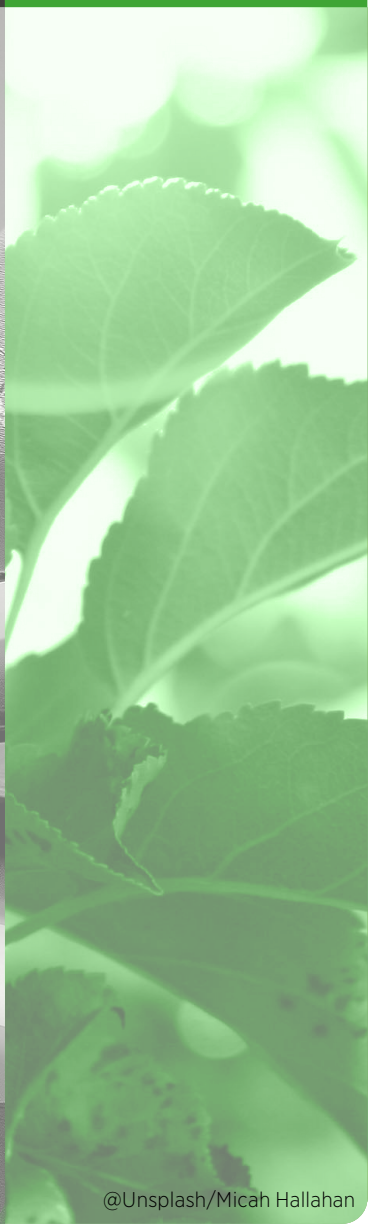

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Abbreviations

AGHA	Africa Green Hydrogen Alliance
CDR	Commission Delegated Regulations
CFGH	Collaborative Framework on Green Hydrogen
COP28	2023 United Nations Climate Change Conference
EHB	European Hydrogen Bank
EU	European Union
GHG	greenhouse gas
H2HUBS	Regional Clean Hydrogen Hubs Program
IRA	Inflation Reduction Act
IRENA	International Renewable Energy Agency
ISO	International Organization for Standardization
GO	guarantee of origin
GST	Global Stocktake
METI	Ministry of Economy, Trade and Industry (Japan)
MW	megawatt

EXECUTIVE SUMMARY

IRENA established the Collaborative Frameworks as platforms for dialogue and co-ordinated action to support the global energy transition. With its nearly universal global membership, IRENA has a unique mandate to bring the global community together to discuss and co-operate on topics of strategic importance.

In 2023, the Collaborative Framework on Green Hydrogen (CFGH) focused on taking stock of global hydrogen deployment after years of strategy development and project announcements, supporting the Global Stocktake process of the 2023 United Nations Climate Change Conference (COP28). The two meetings of the CFGH convened that year shed light on the following questions: *Where does the world stand in terms of translating plans into action, what challenges do member states face and what solutions can they benefit from?*

The first CFGH meeting held in 2023 concentrated on developing demand structures for green hydrogen, while the second focused on the supply side. This brief synthesises essential insights gathered from IRENA's member countries and the experts who participated in these meetings.

The Brief also serves as an input to the **Breakthrough Agenda** hydrogen sector Priority Action 5, 'Landscape Co-ordination', in that it provides an overview of initiatives underway at an international level. With its near-universal membership, the IRENA CFGH is uniquely positioned to enhance the coordination and transparency of international collaboration on green hydrogen.

Key insights from the CFGH meetings are displayed below.

Key insights include:

Overarching themes

Strategy launches and updates:
The momentum towards planning green hydrogen remains strong, and hydrogen strategy launches have surged in recent years. In 2023 trailblazers like Germany and Japan published initial strategy revisions and updates. Given the rapid evolution of the green hydrogen sector, updating strategies is crucial to address those developments.

Standards and certification:
Significant advancements in certification and standards include the unveiling of the International Organization for Standardization (ISO) methodology for assessing greenhouse gas emissions, and the Declaration of Intent for the mutual recognition of certification schemes announced at COP28. Despite the progress being made, however, challenges persist in trading hydrogen as derivates. In 2024, IRENA is leading efforts to map existing accounting methods, standards and certification schemes, focusing on green-hydrogen-based ammonia, methanol and steel produced by direct reduced iron.

Sustainability:
For truly sustainable green hydrogen value chains to be created, project planners must account for more than emissions. They must also consider local environmental impacts, including energy and water supply, as well as social factors like job creation and community involvement.

Key insights on the supply side

The global pipeline of hydrogen pilot projects is nascent and concentrated in Europe and Asia. China, Germany, Spain and Australia account for 50% of planned or installed capacity; 46% of the capacity is still in the announcement phase (567 megawatts [MW]), with only 396 MW under development and 268 MW operational.

High financing costs and access to finance remain key challenges in the many developing countries with significant renewable energy potential. Catalysing green hydrogen production in such countries would require de-risking, risk sharing and tailor-made financing mechanisms.

Fostering community involvement, and thus bolstering social acceptance, is critical in the implementation of new energy technologies. Especially for those that involve large-scale infrastructure development, such as that required to meet future demand for green hydrogen. Peer learning from best practices will prove to be beneficial in this regard.

Key insights on the demand side

Efforts to create demand need to be stepped up:

There has been modest progress in creating demand for green hydrogen. It is important that both governments and companies send stronger collective demand signals by moving from targets to policies and from commitments to contracts. Identifying pre-defined off-takers is crucial.

Regulatory support must be maintained, alongside bold policy making:

Long-awaited developments like the adoption of the Delegated Acts of the European Renewable Energy Directive made 2023 a pivotal year for bold policy making and decisions regarding public funding for green hydrogen. In a race to lead the green hydrogen sector, significant incentive schemes and policy mechanisms were introduced. Although diverse in design and approach, these aim to send robust demand signals while ensuring an ample and secure supply of green hydrogen. This is an important step in the process of setting plans in motion. Regulation and investment support are crucial pre-conditions to ramp up green hydrogen production and deployment.


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While there has been progress in building up supply and demand structures for green hydrogen and derivatives, a substantial deployment gap must be closed to achieve a net-zero future. Several key barriers to successful hydrogen deployment were addressed in 2023. Yet, the CFGH meeting also pinpointed blind spots and areas requiring more attention. IRENA will lead efforts to tackle these issues and maintain the CFGH as a central forum for global collaboration in 2024.

01
INTRODUCTION

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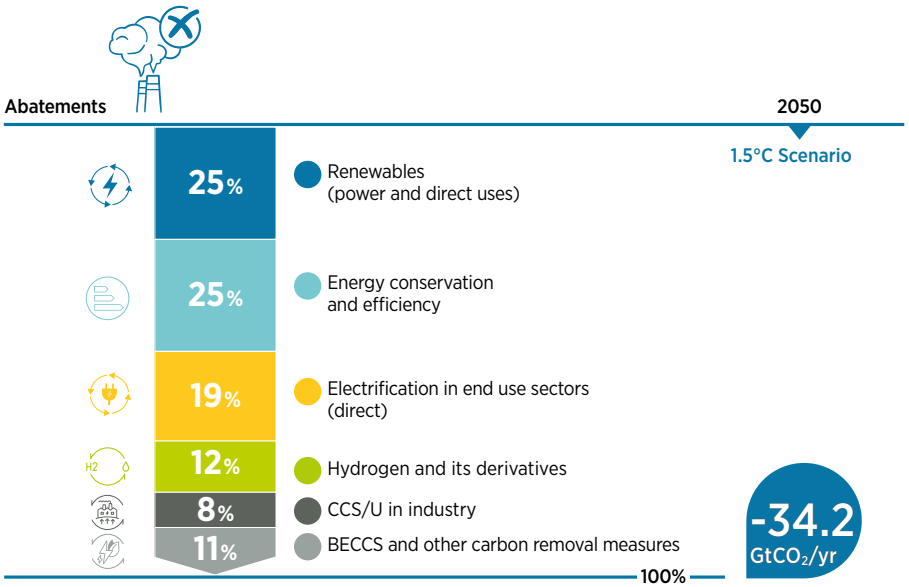
01 INTRODUCTION

Green hydrogen and its derivatives are key to the last mile of net-zero emissions reduction – which should be completed by mid-century at the latest. Achieving net-zero requires a comprehensive transformation of all sectors, including not just power but also end uses. A combination of energy efficiency and renewable energy can deliver the bulk of the emissions reductions needed to meet the goals of the Paris Agreement. For some applications where the direct use of renewable electricity is not technically viable or cost-effective, green hydrogen can help reduce the decarbonisation gap. According to IRENA's calculations, under the 1.5°C Scenario, by 2050, green hydrogen and its derivates may abate 12% of emissions and account for 14% of final energy consumption (**Figures 1** and **2**). That alone would require scaling up electrolyser capacity from negligible numbers today to 5 722 gigawatts in 2050 (IRENA, 2023a).

Green hydrogen and derivatives give highly industrialised countries opportunities to transform their industries so as to achieve net-zero emissions, while also presenting prospects for industrial development in developing countries rich in renewable energy resources. Achieving these goals requires a combination of strong demand signals, effective public policies and proactive private sector involvement. Green hydrogen deployment will also lead to the creation of new value chains, some of them spanning the globe, involving a wide range of stakeholders. International collaboration is needed to share best practices and also the lessons learnt along the way.

Figure 1. **Carbon dioxide emissions abatement in 2050 under the 1.5°C Scenario**

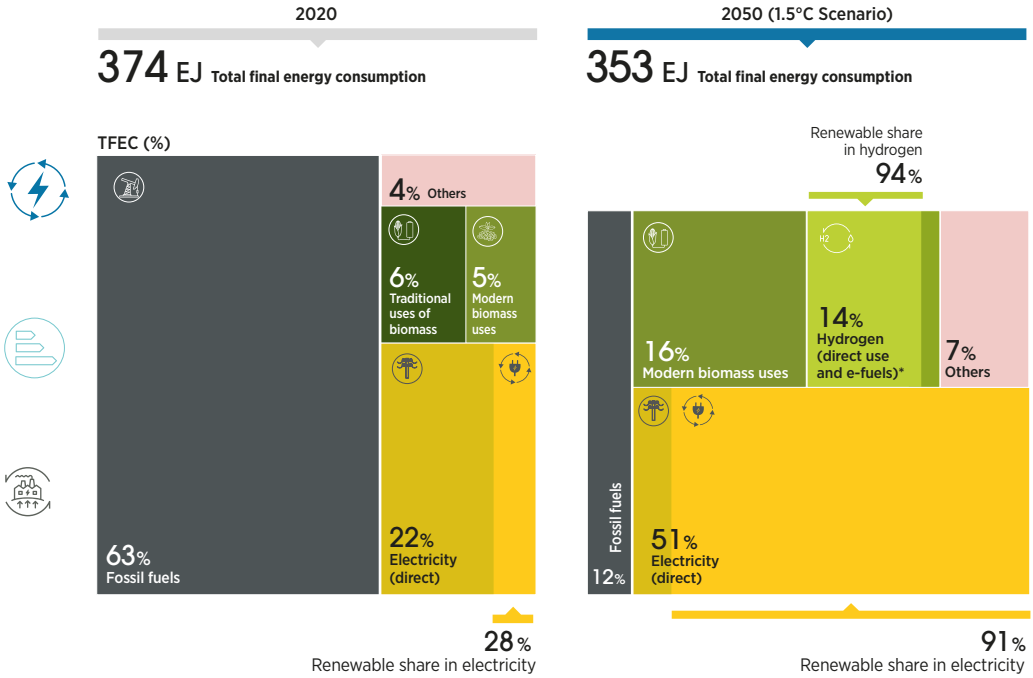


Source: (IRENA, 2023a).
Notes: BECCS = bioenergy with carbon capture and storage; CCS/U = carbon capture and storage/utilisation; $GtCO_2$/yr = gigatonne of carbon dioxide per year.

Implementation of green hydrogen strategies has increased rapidly in recent years, along with numerous project announcements and bi- and trilateral agreements. While Japan, the Republic of Korea and Australia have been front runners in hydrogen strategy development, since 2020, more and more countries have launched their strategies. Today, about 50 strategy documents and four strategy revisions exist (IRENA, forthcoming). However, it is challenging to evaluate how many of these initiatives have been translated into tangible actions and where the world stands in terms of green hydrogen deployment.

One approach to determine the progress being made was the first Global Stocktake (GST) process of the 2023 United Nations Climate Change Conference (COP28). The GST process was designed to take an inventory of where the world stands on climate action, and identify gaps. In 2023, IRENA's Collaborative Framework on Green Hydrogen (CFGH) was dedicated to supporting the GST process by taking a close look into recent developments within the green hydrogen sector. With IRENA's near-universal membership, the CFGH brought the global community together and shed light on the progress to date in building up green hydrogen and derivatives supply and demand structures. Participants, including governments and industry stakeholders, were invited to share their experiences regarding barriers encountered, and discuss potential solutions. Insights gained from these meetings were disseminated during COP28, providing valuable information about the progress and challenges in the global green hydrogen landscape.

Figure 2. **Breakdown of total final energy consumption by energy carrier over 2020-2050 under the 1.5°C Scenario**



Source: (IRENA, 2023a)

Note: The figures above include only energy consumption, excluding non-energy uses. For electricity use, 28% in 2020 and 91% in 2050 are from renewable sources; for district heating, the shares are 7% and 84%, respectively; for hydrogen (direct use and e-fuels), the renewable energy share (*i.e.* green hydrogen) would reach 94% by 2050. Hydrogen (direct use and e-fuels) accounts for total hydrogen consumption (green and blue) and other e-fuels (e-ammonia and e-methanol). Electricity (direct) includes the consumption of electricity that is provided by all sources of generation: renewable, nuclear and fossil fuel-based. Traditional uses of biomass refer to the residential TFEC of solid biofuels in non-OECD countries. Modern bioenergy uses include solid biomass, biogas and biomethane used in buildings and industry; and liquid biofuels used mainly in transport, but also in buildings, industry and other final consumption. Remaining fossil fuels in 2050 correspond to natural gas (mainly used in industry and transport, and to a lesser extent in buildings), oil (mainly in industry and transport, and to a lesser extent in buildings) and coal (corresponds to uses in industry - cement, chemicals, iron and steel). Others include district heat and other renewables consumption. EJ = exajoule; OECD = Organisation for Economic Co-operation and Development; TFEC = total final energy consumption.

Hydrogen played a crucial role at COP28 in Dubai: it was part of the first GST process, the final outcome paper and discussions within the COP28 Presidency's High-Level Roundtable on Hydrogen. A number of thematic sessions on the sidelines of COP28 focused on various aspects of hydrogen. The United Nations Framework Convention on Climate Change Secretariat shared insights into the GST's technical dialogue, a collaborative discussion involving countries, experts and stakeholders. The resulting report evaluates collective progress towards fulfilling the purpose and long-term goals of the Paris Agreement. It states that "achieving net-zero CO_2 and GHG emissions requires systems transformations across all sectors [...], rapid scaling up of renewable energy, widespread electrification of end uses, use of clean fuels, including low-carbon hydrogen and ammonia" (UNFCCC, 2023). The final outcome paper calls on Parties to contribute to accelerating zero- and low-emission technologies, including low-carbon hydrogen production (UNFCCC, 2023).

While the GST process clarified that hydrogen will play a role in fulfilling the Paris Agreement, COP28 itself was the stage for a number of further declarations and announcements. Some of the key outcomes are included in **Figure 3**.

Figure 3. **Key outcomes on hydrogen at COP28**

01	MUTUAL RECOGNITION OF CERTIFICATION SCHEMES	More than 30 countries launched the COP28 Declaration of Intent recognising the key role of clean hydrogen in global decarbonisation and meeting global energy needs, endorsers of the declaration seek to work toward mutual recognition of hydrogen certification schemes to help facilitate global market.
02	ISO METHODOLOGY	ISO Methodology for GHG emissions assessment for Hydrogen on a lifecycle assessment (LCA) basis has been revealed at COP28.
03	INTERNATIONAL HYDROGEN TRADE FORUM	Public-Private Action Statement signed by the International Hydrogen Trade Forum (IHTF) and the Hydrogen Council aims to advance implementation of cross-border trade corridors in hydrogen and its derivatives internationally.
04	UPTAKE AGREEMENT SHIPPING SECTOR	Shipping leaders and green hydrogen producers agreed on uptake targets for 2030 to enable a net zero maritime sector including an 11 tonne (Mt) 2030 production target for use by the shipping sector.
05	INDUSTRY DECARBONISATION AGREEMENT	Alliance for Industry Decarbonization (AFID) has adopted decarbonisation committments on increasing production of renewable energy and green hydrogen by 2020.

Sources: (AFID, 2023; COP28 UAE, 2023; Hydrogen Council, 2023; ISO, 2023; UNFCCC Climate Champions, 2023).
Note: COP28 = 2023 United Nations Climate Change Conference; GHG = greenhouse gas; ISO = International Organization for Standardization.

These developments reflect the sustained political attention and support for hydrogen. However, the question remains, how can individual countries effectively leverage the potential of green hydrogen and derivatives – whether to transition their industries to net zero or to embark on large-scale production projects. The path forward remains critical.

This brief provides key insights gained during the 2023 CFGH meetings. It also provides updates on the developments in countries that are aspiring to become major green hydrogen consumers and those that hold substantial renewable energy potential, and could also act as green hydrogen exporters. It further contains insights into how challenges can be addressed and what tools have recently been made available.

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02
COUNTRY INSIGHTS

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02 COUNTRY INSIGHTS

As IRENA's CFGH serves as a global platform for dialogue and co-operation, member countries were invited to share updates on recent green-hydrogen-related developments in their respective nations. These updates included discussions on policy priorities, incentive schemes for demand and supply creation, challenges faced and ongoing projects. This brief presents the key insights from all the country interventions shared at the 2023 CFGH meetings, encompassing nations across the world (**Figure 4**).[1] Germany and the United Arab Emirates co-facilitated the CFGH meetings.

Figure 4. **Country interventions at IRENA's 2023 CFGH meetings**

Note: CFGH = Collaborative Framework on Green Hydrogen.
Disclaimer: This map is provided for illustration purposes only. Boundaries and names shown on this map do not imply the expression of any opinion on the part of IRENA concerning the status of any region, country, territory, city or area, or of its authorities, or concerning the delimitation of frontiers or boundaries.

[1] This section is based on the interventions and priorities shared by members of the CFGH meetings. It is not a comprehensive reflection of all sector developments in those member countries, and does not cover all the countries that may assume an important role.

Australia

Australia has focused primarily on green hydrogen, demand for which is on the rise in the country's economy. Australia has set ambitious targets, including achieving net-zero emissions by 2050 and reducing emissions by 43% by 2030, with an 80% reduction through renewables. To support these goals, Australia has launched an AUD 2 billion programme (about USD 1.34 billion) to subsidise green hydrogen production (Hydrogen Headstart program). In February 2023, the Energy and Climate Change Ministerial Council approved a review of the 2019 National Hydrogen Strategy. The purpose of this review is to ensure Australia is on track to not only becoming a leading global player in hydrogen production and export by 2030, but also using hydrogen to decarbonise domestic industries.

Further, the Australian government has been actively developing a Guarantee of Origin (GO) scheme over the past three years. The scheme is designed to measure, track and verify carbon emissions and other attributes of Australian clean energy products, including hydrogen and renewable electricity. The voluntary GO scheme serves as a foundational policy to support the growth of clean energy markets and international trade in low-emission products. It enables tracking renewable electricity claims and quantifying emissions and other attributes of hydrogen and hydrogen energy carriers, with potential for expansion to other clean energy products in the future. The GO scheme aims to stimulate market creation, incentivise innovation in clean energy products and accelerate their adoption, and assist new projects in securing financing. It thus contributes to wider efforts to scale up renewables and the hydrogen industry (Commonwealth of Australia, 2023). The public consultation process was closed by the end of 2023.

Austria

Austria published its national hydrogen strategy in June 2022, which details how it intends to use hydrogen to decarbonise its economy and energy system. The measures included in the strategy are designed to support hydrogen along the entire value chain. Austria emphasised the important role played by hydrogen in selected industrial applications, for example, iron and steel, and chemicals, as well as in certain areas of mobility, mostly heavy-duty transport and aviation, where electrification is not a viable option. Austria foresees that, despite the targeted use of hydrogen, domestic production capacities alone cannot cover the quantities required to decarbonise hard-to-abate sectors, and imports will play an important role in the future. Austria intends to boost the demand for renewable hydrogen and build the required infrastructure. Investments in renewable hydrogen production will be stimulated, and sustainable business models will be promoted. Through domestic environmental funding, EUR 3 billion (roughly USD 3.3 billion) has been made available until 2030 to promote demand for hydrogen in hard-to-abate sectors.

Canada

Canada has progressed in key areas since launching its hydrogen strategy in 2020. The Canadian Federal Government has established several working groups. One of it is a codes and standards group, which is co-chaired by the Standards Council of Canada. It is considering the identification of standard gaps as a key focus area. Canada has also announced several investment tax credits since 2022 that will encourage clean hydrogen production; carbon capture, use and sequestration; clean electricity and clean technology manufacturing. The Canada Growth Fund has allocated CAD 15 billion (about USD 11.25 billion) to incentivise private sector investments in the deployment of key technologies such as hydrogen, and CAD 20 billion (about USD 15 billion) was allocated through the Canada Infrastructure Bank to incentivise major clean electricity and clean growth infrastructure projects.

Canada is set to release a progress report to the 2020 hydrogen strategy in 2024, outlining potential hydrogen applications across various sectors, including hard-to-abate sectors. This report is expected to provide insights into suitable incentives for these sectors and identify potential challenges. Canada is witnessing a continuous stream of new hydrogen project plans at various stages of development across the country, including domestic-use projects and more than ten large-scale projects with export potential. With ambitions to become a net hydrogen exporter, Canada is keeping hydrogen production as a primary focus.

China

China is the world's largest hydrogen producer - primarily generated using unabated fossil fuels. China's annual hydrogen demand hovers around 35 Mt. A pivotal policy is the "Medium- and Long-Term Plan for the Development of the Hydrogen Energy Industry (2021-2035)", which aims to support hydrogen-related developments and the implementation of fuel cell vehicles in urban areas through the establishment of hydrogen refuelling stations and the promotion of fuel cell vehicle deployment. In doing so, China positions the transportation sector as a key driver of its hydrogen development.

China's Hydrogen Alliance has taken a significant step by introducing the "Standard and Assessment for Low-carbon Hydrogen, Clean Hydrogen, and Renewable Hydrogen Energy", which is now being expanded to encompass green ammonia, green methanol and other related products.

Nonetheless, a major challenge in China lies in transitioning green hydrogen from a demonstration phase to industrial-scale operation. To address this challenge, China is exploring integrated hydrogen deployment approaches; the transportation sector is offering a higher price tolerance option, whereas the industry sector is being more cost sensitive. This two-pronged strategy reflects China's multi-faceted approach to achieving its hydrogen goals.

Chile

Chile's excellent renewable electricity potential, positions it well to becoming a major green hydrogen producer. Chile aims to accelerate investment in domestic applications to then become a relevant player in export markets (Ministerio de Energia, 2020). Even though Chile is relatively distant from major import markets, it is confident to be able to supply cost-competitive green hydrogen and derivatives in the future. Chile is developing an action plan on how to address issues such as engaging communities and indigenous peoples, besides further social aspects, to make green hydrogen truly sustainable.

Kenya

Kenya has an electricity grid that is currently powered by about 90% renewable energy, although it has set a target to reach 100% renewable energy share by 2030. This renewable energy abundance is a significant factor attracting investors. Kenya's agriculture sector is the cornerstone of the economy. This is why it aims to locally produce ammonia for fertilisers, reducing the need for fertiliser imports. Kenya's vision focuses on leveraging green hydrogen for sustainable socio-economic development, specifically ensuring food security. By 2027, Kenya aims to develop its domestic market; it focuses on green ammonia production, followed by the next phase of exporting hydrogen and its derivatives (from 2032 onwards) (Ministry of Energy and Petroleum, 2023).

Kenya's public sector is actively planning to engage private sector players to participate in the domestic production of hydrogen using the grid or direct renewable power sources. Incentives such as special economic zones, climate funds and other investment plans, including investments from development finance institutions, have already been secured.

Kenya has made substantial progress in the hydrogen sector, having launched its green hydrogen strategy and roadmap in September 2023. It is developing guidelines for hydrogen production and hopes to launch them soon. With these efforts – and supported by agreements with foreign direct investors that are ready to utilise hydrogen as an energy source – Kenya aims to be a leading player in green hydrogen production within the next two years.

Mauritania

Mauritania seeks to become a key player in the green hydrogen economy, through the development of strategies and roadmaps. With its abundant coastline, spanning around 700 kilometres, Mauritania has the potential to harness solar and wind energy. The country aims to export hydrogen and use its vast iron ore resources to produce green steel. But despite its ambitions, Mauritania has expressed concerns about being left behind in the race towards a sustainable future. To address these concerns, the Government of Mauritania, in collaboration with the Africa Green Hydrogen Alliance, organised the Africa Green Hydrogen Finance Accelerator Forum in April 2023, which was supported by various organisations such as the UN Climate Change High-Level Champions, World Bank and European Investment Bank. A November 2022 McKinsey study found that six countries of the Africa Green Hydrogen Alliance, including Mauritania, will require potential investment of USD 55 billion by 2030 to achieve their green hydrogen ambitions; by 2050, this figure could rise to USD 900 billion.

The Netherlands

The Netherlands is transitioning from being a significant hub for natural gas today, to a hub for green hydrogen. It has initiated construction of a national hydrogen pipeline network, which will connect ports and major industrial clusters in Germany, Belgium and the Netherlands by 2030. Given the anticipated high demand, the establishment of international shipping corridors is essential for the Netherlands, as national production alone will not suffice. The Port of Rotterdam will play a central role in these corridors. Country representatives emphasised the importance of certification and standardisation. While they see the potential of ammonia as a leading energy carrier in the near future, they drew attention to the need to accelerate the development of markets for other hydrogen-related carriers beyond ammonia.

Panama

In July 2023, Panama approved its National Hydrogen Strategy, which targets the production of 2 Mt of green hydrogen by 2040 (Republica de Panama, 2023). A critical aspect of Panama's strategy is ensuring social acceptance of green hydrogen projects, which have the potential to create high-value jobs, and thus foster the development of a skilled workforce.

Recognising the importance of involving local communities, Panama's strategy ensures that discussions with communities take place before project implementation. It prioritises engaging with communities that are likely to be neighbours to green hydrogen facilities. This essential acknowledgement of the importance of dialogue and community involvement might also be extended to international collaboration, with a focus on the involvement of regional organisations and agencies dedicated to green hydrogen.

Fostering communication among communities, including those with experience with green hydrogen projects, is crucial. Sharing information, knowledge and experiences will facilitate the achievement of decarbonisation goals in the clean energy sector.

Portugal

Portugal is revising its Energy and Climate Plan 2030 to include a 55% reduction in greenhouse gas (GHG) emissions. Portugal is committed to accelerating the transition to green hydrogen, scaling renewables, and increasing and anticipating its targets for renewables and carbon neutrality. In the electricity production sector, the share of renewables is expected to reach 80% by 2026, four years earlier than the initial target. Portugal has an advantageous position as a green hydrogen producer and exporter given its green, reliable and cost-competitive electricity. Industry is a priority target sector, notably fertilisers and green steel production. Additional projects involve the glass and ceramic sectors, cement and synthetic fuels. To jump-start the creation of a hydrogen market, Portugal will launch a national competitive auction for the centralised purchase of renewable gases for blending in the natural gas network.

Sweden

Sweden is focused on green hydrogen and e-fuels production for the decarbonisation of various sectors such as mining, steel, heavy-duty trucking, shipping and aviation. Industry and government initiatives, along with European Union (EU) support, drive these projects. Export products include fossil-free steel and e-fuels like e-methanol, with industries finding willing customers. Sweden aims for local production and consumption, and to avoid imports as much as possible. This is likely possible given the country's high green hydrogen potential and relatively low local production costs. To attract business developers, Sweden leverages its surplus low-carbon electricity, low electricity costs and high renewable energy potential. It also invests in education to build a skilled workforce. Challenges include increasing green hydrogen demand, safety measures, certification, standardisation and system efficiency improvements.

In terms of financing, Sweden benefits from national support programs and EU initiatives like the Important Projects of Common European Interest and Hydrogen Bank pilot auction, which help de-risk projects and bridge cost gaps, promoting renewable hydrogen markets.

United States

The United States has built its clean energy strategy, released in September 2022, around three principles: focus on hard-to-decarbonise sectors for the use of clean hydrogen, reduce the cost of hydrogen production and focus on regional networks. Today, the country's hydrogen production is about 10 Mt/year, with opportunities for clean hydrogen to meet a similar level of demand by 2030. A network of clean hydrogen producers, potential consumers and connective infrastructure will be developed through regional hydrogen hubs to eliminate key barriers. The United States is also focused on training a hydrogen workforce to help meet demand projections. One of the key policy drivers for clean hydrogen in the United States is the Inflation Reduction Act, which introduced a producer tax credit for clean hydrogen, grants and loans for fuel cell electric vehicles, a tax credit for producing sustainable aviation fuels, as well as grants to reduce emissions from ports and port infrastructure (see **subsection 3.1**). A key focus area is co-ordinating the development of international certification standards.

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03

RAMPING UP GREEN HYDROGEN SUPPLY AND DEMAND: KEY CHALLENGES AND SOLUTIONS

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03 RAMPING UP GREEN HYDROGEN SUPPLY AND DEMAND: KEY CHALLENGES AND SOLUTIONS

Despite some progress, building and scaling up green hydrogen and derivatives supply and demand structures remains challenging. While the deployment of green hydrogen has steadily increased since 2020, it needs to be accelerated if the 2030 goals of 60-70 Mt/year are to be achieved. Most pilot projects are in Europe and Asia, and only in the announcement phase. Most projects have not yet reached a final investment decision. In this context, there is a pressing need for governments and companies to reinforce demand signals, and shift from targets to policies and from commitments to contracts (IEA *et al.*, 2023). Key challenges outlined in the CFGH meetings, as well as solutions presented by experts, are summarised below.

3.1. REGULATIONS AND INCENTIVE SCHEMES TRIGGERING DEMAND AND SUPPLY CREATION

As green hydrogen production and use are still not competitive on a large scale, various incentive schemes have been implemented to accelerate uptake. Many of these schemes are likely to have implications beyond the countries that introduced them and may influence international market dynamics. The incentive schemes introduced vary in their design and approach, yet share a common goal: sending strong demand signals and securing sufficient supply at the same time. This subsection presents an overview of the latest incentive schemes and examines their potential impact on the global adoption of hydrogen technologies.

European Union: The Renewable Energy Directive and the European Hydrogen Bank

With the adoption of two Commission Delegated Regulations (CDRs), commonly known as delegated acts, a long-awaited regulation for green hydrogen and its derivatives has finally taken effect. This marks the end of a period of uncertainty for future green hydrogen and derivative producers within the European Union, as well as for project developers in other countries looking to export to the European Union. To be eligible for support schemes, products must adhere to the regulations outlined in the delegated acts. The first delegated act (CDR 2023/1184) establishes rules for determining the conditions under which electricity used in hydrogen production may be classified as fully renewable. The Act clarifies the principle of "additionality" for hydrogen production under the EU's Renewable Energy Directive. This principle requires electrolysers used to produce hydrogen to be connected to new renewable electricity production, incentivising an increase in renewable energy available to the grid. The delegated act outlines ways to

demonstrate compliance with additionality rules and introduces criteria to ensure renewable hydrogen is produced only when and where sufficient renewable energy is available (temporal and geographical correlation). The second delegated act (CDR 2023/1185) outlines the methodology for assessing GHG emissions savings from renewable fuels based on hydrogen (EC, 2023a, 2023b). Both domestic and international producers exporting renewable hydrogen to the European Union will be subject to the regulations specified in the delegated acts.

Another new core component launched by the European Union to fulfil its green hydrogen goals is the European Hydrogen Bank (EHB). The European Commission has designed the EHB to promote the use of clean energy sources and reduce carbon emissions by providing financial incentives to businesses and consumers who adopt green hydrogen technologies. The EHB aims to facilitate investments in green hydrogen production, aligning with the REPowerEU[2] targets. The EHB is built around four core pillars: creating an EU domestic market, facilitating international imports to the European Union, promoting transparency and co-ordination, and streamlining existing financing instruments. The EHB's primary objective is to bridge the cost differential between renewable hydrogen and fossil fuels, especially for early projects.

In November 2023, the EHB launched its first pilot auction for renewable hydrogen production within the European Union with a budget of EUR 800 million, coming from the Innovation Fund. This pilot auction will select projects to receive a subsidy as a fixed premium (EC, 2023c). Germany became the first member state to participate in a new "auction as a service" scheme. Germany will make EUR 350 million available from its national budget for domestic hydrogen production (EC, 2023d).

Japan: New subsidy scheme envisioned

Japan's updated Basic Hydrogen Strategy, published in June 2023, outlines a strategic goal to not only develop the domestic market but also expand into overseas markets (ANRE, 2023). The Japanese Ministry of Economy, Trade and Industry (METI) Comprehensive Resources and Energy Investigation Committee released a report outlining its intentions to implement a subsidy programme aimed at bridging the cost gap between low-carbon hydrogen and its derivatives and their fossil equivalents in 2024. The subsidy programme is envisioned as a form of Contracts for Difference and is intended to cover both domestically produced and imported hydrogen.

Under this scheme, recipients will either receive a top-up payment above a pre-determined reference price or be required to reimburse the government for any difference if production and transport costs turn out to be lower at any point. Projects may be eligible for support over a 15-year period. According to the report, Japan intends to set an emissions intensity threshold of 3.4 kilogrammes of carbon dioxide equivalent per kilogramme of hydrogen as the upper limit to be eligible for the subsidy (METI, 2023).

United States: The Inflation Reduction Act and Regional Clean Hydrogen Hubs programme

The Inflation Reduction Act was passed by the US Congress in 2022, bringing together multiple clean energy tax incentives into a single bill. This new law aims to allocate USD 369 billion over the next ten years to address energy security and climate change. A vital component of the Inflation Reduction Act is a set of lucrative tax credits promoting the rapid adoption of clean energy technologies like green hydrogen. In December 2023, the US government published proposed regulations that include criteria

[2] EU plan aimed at reducing Europe's dependence on fossil fuels and accelerating the transition to green energy.

of incrementality (clean power generators that began commercial operations within three years of a hydrogen facility being placed into service are considered new sources of clean power), geographical correlation of electricity production and electrolyser facility, and time matching. To qualify for the tax credit, electricity production must be matched hourly with hydrogen production. There will be a transition phase until 2028 that permits annual matching. Starting from 2028, hourly matching will be mandatory (IRS, 2023a, 2023b). While the rules are only proposed and are expected to undergo some specifications and changes, they seem to generally align with the EU Renewable Energy Directive.

In October 2023, the US Department of Energy (DoE) announced the seven finalists of the Regional Clean Hydrogen Hubs (H2Hubs) programme. The H2Hubs are intended to form the foundation of a clean hydrogen network in the United States receiving a total of USD 7 billion. USD 1 billion is planned to be allocated to the Regional Clean Hydrogen Hubs Demand-Side Support Initiative (DoE, 2023).

3.2. CLOSING THE COST GAP AND FINANCING LARGE-SCALE PROJECTS

One obstacle to scaling up green hydrogen is its relatively high production costs, especially when compared to grey hydrogen. In order to ramp up green hydrogen production, it is crucial to drive down production costs and close the gap between green and grey hydrogen (IRENA, 2020). The primary cost factors are renewable electricity and electrolyser facilities (IRENA, 2020).

Access to finance and high financing costs pose additional challenges, especially in developing countries. Green hydrogen production is capital intensive and requires large investments. Investments in renewable energies in general, including end uses, totalled USD 0.5 trillion in 2022, representing only about one-third of the average annual investment required to stay aligned with the 1.5°C Scenario. Furthermore, these investments are geographically concentrated in a few countries (IRENA, 2023a). A similar pattern can be observed in the emerging green hydrogen sector. According to calculations from the World Bank and the Organisation for Economic Co-operation and Development (OECD), emerging markets and developing countries, excluding China, require approximately USD 100 billion in investment annually from now until 2030. The external financial support is estimated to be between USD 10 billion and USD 40 billion per year between now and 2030 (World Bank, 2023).

While many developing countries have abundant renewable energy potential and are often perceived as potential green hydrogen and derivatives exporters, accessing finance for those projects - despite the aforementioned incentive schemes - remains challenging. Large green hydrogen projects in emerging markets and developing countries typically face high financing costs due to actual and perceived risks, deterring investors from entering this emerging sector. The top risk category mentioned by project developers is offtake risks, followed by political, regulatory and infrastructure risks (World Bank, 2023). Strong demand signals are required to secure investments into green hydrogen production projects (EC, 2023e).

De-risking and risk sharing will play a crucial role in catalysing green hydrogen production in emerging markets and developing countries. Political support, multilateral development banks and other finance institutions are required to design and implement more suitable instruments to enable low-cost finance access and create an enabling environment for green hydrogen production (GH2, 2022; IRENA, 2023b; World Bank, 2023).

3.3. TOWARDS COMPREHENSIVE SUSTAINABILITY

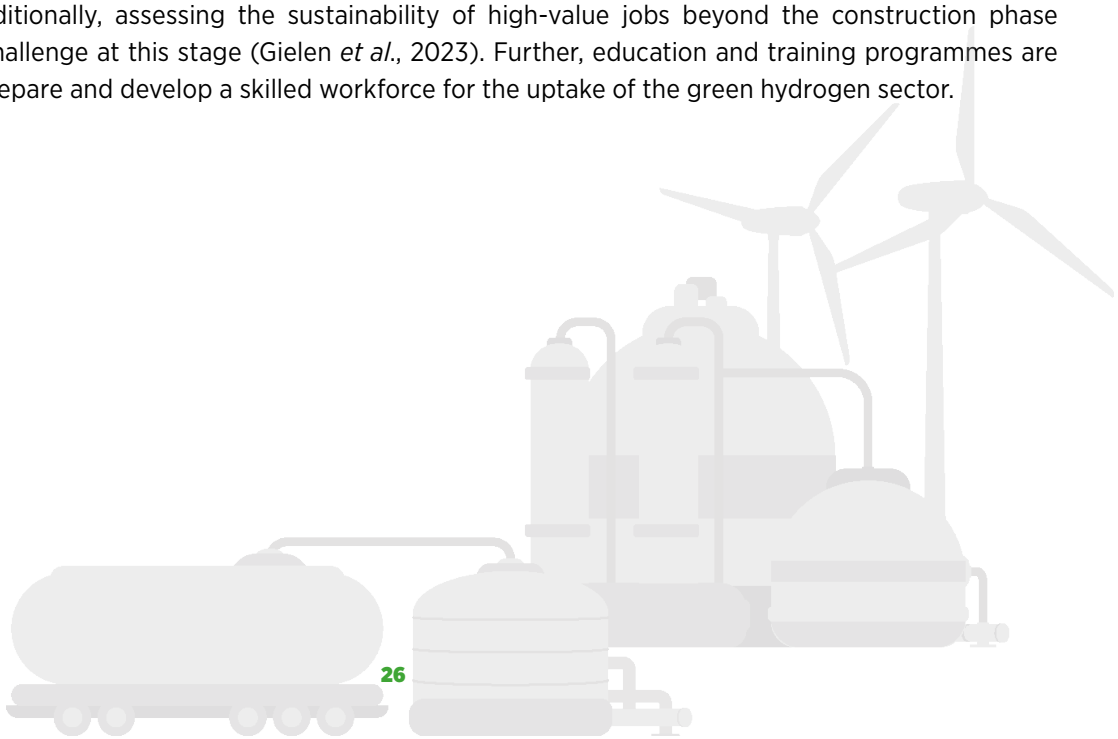
The launch of the ISO standard as a harmonised methodology to account for greenhouse gas (GHG) emissions from hydrogen production and transport has been a pivotal step forward in the hydrogen sector (ISO, 2023). It will be the foundation for harmonisation, safety and interoperability across the hydrogen value chain. However, to create truly sustainable green hydrogen and derivatives value chains, project planners must account for more than emissions.

Environmental, social and governance aspects of green hydrogen production will impact the long-term viability and success of green hydrogen value chains. Looking into environmental aspects, local water scarcity risks and land availability can pose challenges to individual projects (IRENA and Bluerisk, 2023). There are further insights needed into how local communities can benefit from green hydrogen projects. Some green hydrogen strategies – like the Panama Green Hydrogen Strategy – already address social acceptance (Republica de Panama, 2023). One crucial action item involves designing and implementing a programme aimed at sharing best practices and disseminating information to the public regarding green hydrogen and sector developments. Additionally, Panama's intervention in IRENA's Collaborative Framework emphasises prioritising local community engagement, underscoring the necessity of involving regional entities in international collaboration and sharing knowledge and best practices (see **section 2**).

3.4. CAPACITY BUILDING, SKILLS AND JOBS

The emerging green hydrogen sector will create jobs and require a trained workforce. Approaches how to calculate the job potential of the sector differ. The European Commission estimates that every billion dollars invested in green hydrogen will generate 20 000 jobs across the entire supply chain, encompassing production, transmission, storage and utilisation. In sum, the green hydrogen economy has the potential to generate up to 1 million jobs by 2030 in the European Union, and 5.4 million upstream jobs by 2050. This is three times the number of people currently employed by the EU chemical industry (EC JRC, 2019).

Job creation is frequently cited as a socio-economic benefit for developing countries seeking to produce green hydrogen and derivatives. However, quantifying the potential socio-economic impact of green hydrogen in developing countries remains challenging, with only a handful of such projects implemented thus far. Additionally, assessing the sustainability of high-value jobs beyond the construction phase presents a challenge at this stage (Gielen *et al.*, 2023). Further, education and training programmes are needed to prepare and develop a skilled workforce for the uptake of the green hydrogen sector.



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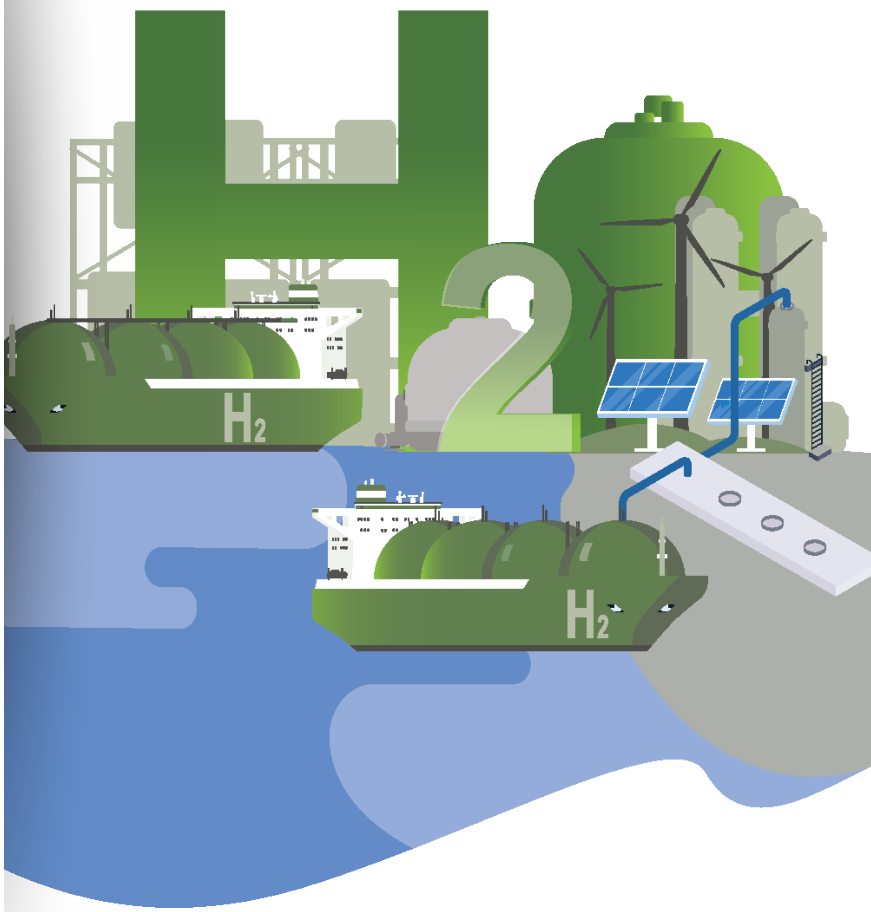

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