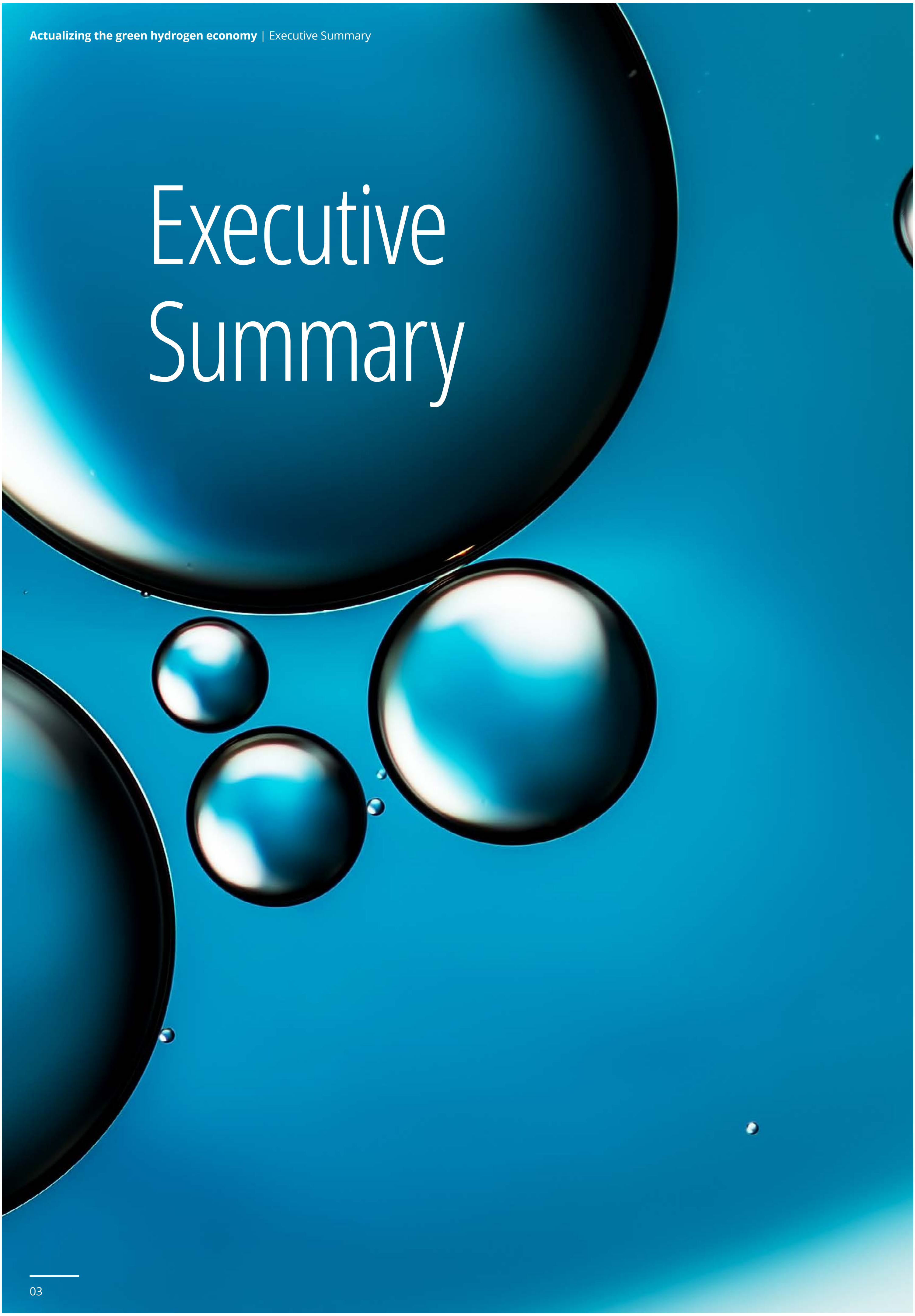
Deloitte.

Actualizing the green hydrogen economy

Legal and financial considerations to advance sustainable energy

MAKING AN
IMPACT THAT
MATTERS
since 1845

Executive Summary



Action on the global climate crisis front is wanting and far from sufficient. Findings of the Intergovernmental Panel on Climate Change's (IPCC) 6th Assessment Report (AR6) highlight that projected adverse impacts and related losses and damages intensify with every increment of global temperature rising. Limiting global warming requires deep decarbonization of the whole economy. Such a transition to net-zero greenhouse gas (GHG) emissions entails low carbon intensity at each sector of the economy and important changes in behaviors, regulations, and institutions. For hard-to-abate sectors such as heavy-duty transport and some industrial processes where electrification can be very difficult or impossible, mitigation options can include decarbonizing through abatement technologies and switching to new low- and zero-emitting energy carriers such as clean hydrogen and its derivative molecules, such as ammonia, methanol and other synthetic fuels.

This paper reviews the green hydrogen landscape providing insights on current and developing law and policy frameworks, finance, and bankability considerations, and provides recommendations to help advance the green hydrogen value chain considering key challenges and areas of opportunity.

Given the nascent nature of the clean hydrogen sector, alignment of the policy and regulatory architecture towards a Paris-aligned green hydrogen economy can provide important legal clarity, certainty and can create an enabling environment for stakeholder engagement across the value chain. The global policy environment on the development of a green hydrogen economy is shaping up, notably via the US Inflation Reduction Act (IRA), the German H2Global offtake platform, and other national and regional hydrogen strategies in areas such as the European Union, the United Arab Emirates and Australia. While the importance of finance and different cost-reduction support mechanisms (such as operational or investment support schemes) was underscored across these regions, the policy environment currently lacks sufficient region-specific tools to help kickstart the green hydrogen economy.

The physical and economic characteristics of green hydrogen make its production cost highly sensitive to the weather conditions and its financing structure. Moreover, the nascent nature of clean hydrogen market makes it highly dependent on policy and regulatory support. Initiation of a clean hydrogen economy, in line with sustainable development goals, requires:

1. Facilitating investments via unlocking funds and foreign investment initiatives,
2. Reducing financing costs via enabling access to low-cost finance,
3. Creating a level-playing field for green hydrogen via operational subsidies until at least late 2030s,
4. Creation of demand for green hydrogen via sectoral initiatives and obligations, and
5. Reduction of the permitting and construction periods via facilitated permitting processes.

Several mechanisms can be used to help make green hydrogen projects economically more competitive and to facilitate investments: investment support, financing support, operational support, Research and Development (R&D) support, market creation and permitting facilitation (Figure 1).

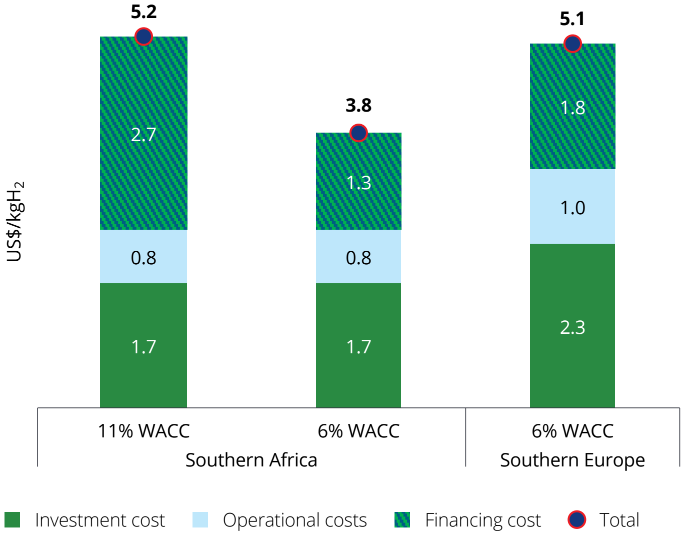
Figure 1. Summary of the policy support mechanisms to increase the bankability of green hydrogen projects

Investment support	Financing support	Operational support
Finance a part of the capital expenditure *e.g., Innovation fund (EU) Clean H2 Infra Fund (worldwide)*	**Reduce the cost of capital** *e.g., SDG Nambia One Fund (Nambia)*	**Premium proportional to hydrogen production** *e.g., SDE ++ (the Netherlands) IRA 45v (US)*
R&D support	**Market creation**	**Permit facilitation**
Develop a self-sustaining hydrogen value chain *e.g., Clean Hydrogen Joint Undertaking (EU)*	**Ensure that green hydrogen will be bought** *e.g., H2Global (Germany) European Hydrogen Bank (EU)*	**Facilitate the roll-out of projects by allowing quick commissioning** *e.g., Net-Zero Industry Act (EU)*

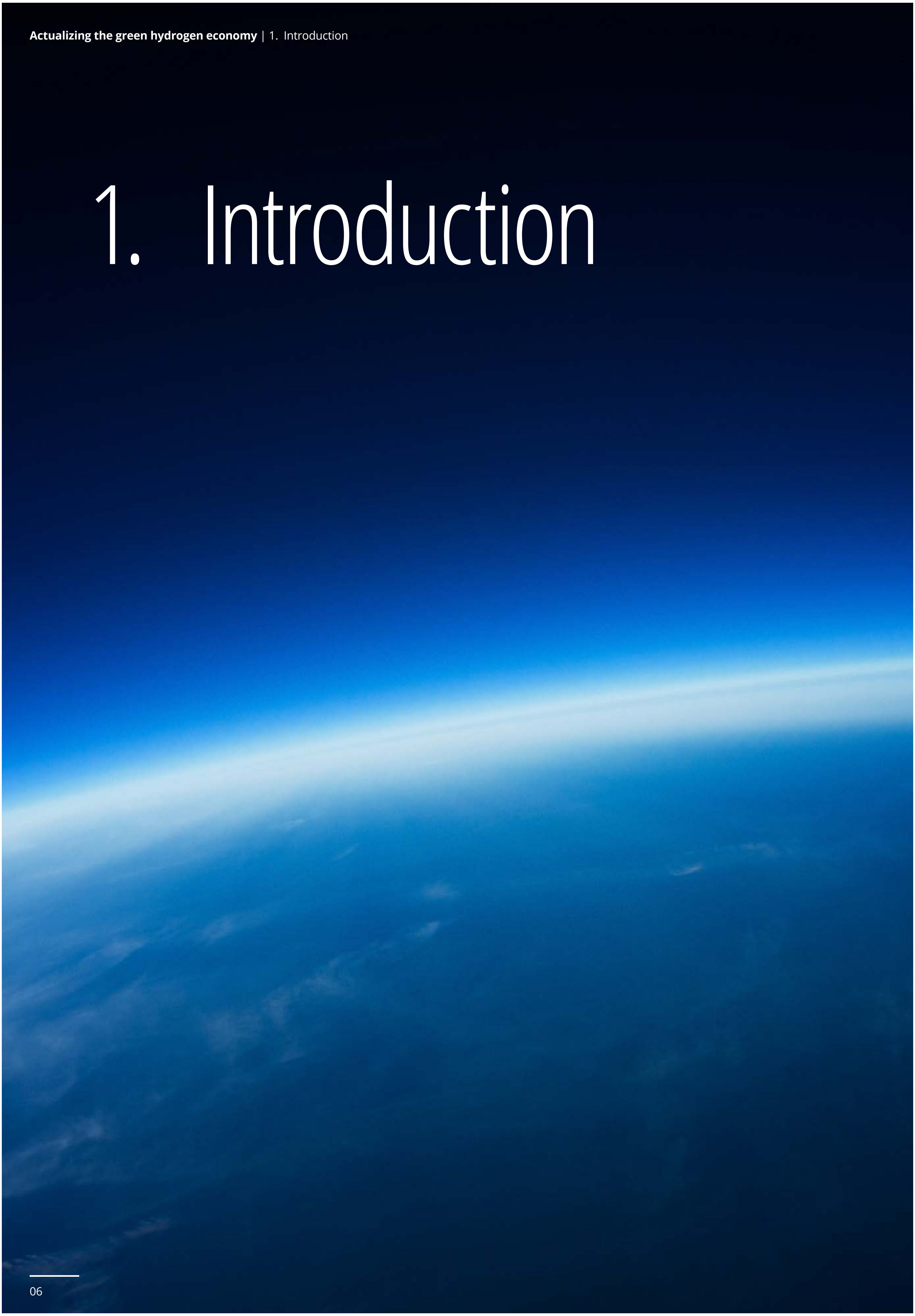
The analysis in the current paper showcases the importance of support mechanisms to help reduce the upfront costs of the projects that would bring both the needed investments and the associated financing costs down. Reducing risks associated with green hydrogen projects (regulatory risks, market risks, technology risks, etc.) especially in developing economies can bring significant cost reductions thanks to reduced cost of capital in these regions. Reducing the cost of capital in these regions to similar levels in the developed economies can reduce the project costs by more than 25% (Figure 2). Considering direct monetary support, investment support mechanisms are identified as one of the most efficient cost-reduction levers, reducing both the upfront investment needs and financing costs simultaneously.
Unlocking the decarbonization potential of green hydrogen requires important policy and regulatory action. The findings of the analysis reinforce the importance of actions activating different levers facilitating development of green hydrogen projects, notably in developing economies:

- **Facilitate deployment**: Given the current climate emergency, the action should be imminent. Reducing delays in project development via anchoring permitting processes with a central agency, accelerated environmental impact assessments (EIAs) and strategic environmental assessments (SEAs), and leveraging the existing infrastructure and retrofitting them to hydrogen infrastructures can reduce some of the risks associated with delayed actions.
- **Improve social acceptability**: Sustainability-linked actions in line with the UN Sustainable Development Goals (SDGs) should acquire full public support. Collaboration and empowering local communities, alignment of regulatory measures with Indigenous sustainability perspectives and grounded in free prior informed consent of the local population through effective participatory processes can be key for increased support of the local populations and social acceptability of green hydrogen development.
- **Create the market**: Green hydrogen for different end uses tends to be more expensive than its counterparts, and early adoption of this technology likely requires both creation of a market where there is a demand for such a product and bridging the cost gap between green hydrogen and the conventional fossil fuels. The projects need to be supported in their early stages, which can take several forms: direct investment or operational support, contracts for differences, offtake contracts, and other demand creation mechanisms such as guarantees of origin and green certificates.
- **Enhance the financing conditions**: Projects in developing and emerging economies with high renewable endowments need facilitated financing and liquidity through blended funding, international green finance and state guarantees to help reduce the cost of capital and consequently the financing costs of the projects.

Figure 2. Impact of weighted average cost of capital (WACC) on the levelized cost of green hydrogen production in Southern Africa and Southern Europe



1. Introduction



Global warming crisis requires decisive actions, but in their current levels, they are far from sufficient. Findings of the Intergovernmental Panel on Climate Change's (IPCC) 6th Assessment Report (AR6) highlight that projected adverse impacts and related losses and damages intensify with every increment of global warming.[1] The reports have consistently illustrated emission scenarios that are essential to assess impacts and analyze mitigation efforts needed to act on the climate crisis.[2] These scenarios are crucial to help formulate projections for systems, including energy systems, which in turn support national and international policymaking and the design of plausible sustainable development policy actions. In its recent AR6 synthesis report, the IPCC shows that scenarios and mitigation pathways consistent with limiting global warming to 1.5°C are very likely to rely heavily on renewables, efficiency measures and net-negative emissions, consistent with a rapid introduction of mitigation measures.[3] The United Nations Environment Programme (UNEP) Emissions Gap report corroborates this finding outlining, to get on track for limiting global warming to 1.5°C, global annual greenhouse gas (GHG) emissions must be reduced by 45% compared to emission projections under policies currently in place, and they must continue to decline rapidly after 2030, to avoid exhausting the limited remaining atmospheric carbon budget (below 400 $GtCO_{2eq}$ of cumulative emissions by 2050).[4]

Climate change has and is adversely impacting and exposing vulnerabilities of individual livelihoods and climate-sensitive sectors. AR6 highlights the very high likelihood of increase in compounding and cascading impacts making it more difficult to manage, resulting in an exacerbation of vulnerabilities of ecosystems and people to climate hazards.[5] The risks are bound to have a ripple effect across the food, energy and water sectors to mention a few.[6] In the past year, the Russia-Ukraine war pinpointed the vulnerability of the current global energy system, given its dependence on fossil fuels produced from a very small number of countries.[7] The IPCC underlines the importance of adaptation and mitigation actions, across scales, sectors and regions, that prioritizes equity, climate justice, rights-based approaches, social justice and inclusivity, leading to more sustainable outcomes, reducing trade-offs, supporting transformative changes and advancing climate resilient development.[8] These actions are needed for deep decarbonization that counters the scale and rate of climate change and its associated risks. Aligned to country-specific circumstances, carrying out the needed actions, requires political commitment with multi-level governance, regulation, laws, policies, and strategies that can help support deep emission reductions if scaled up and enhanced.[9]

Indeed, a deep decarbonization transition to net-zero carbon emissions entails low carbon intensity across each sector of the economy and radical changes in behaviors, regulations, and institutions.[10] In this regard, reducing energy and industry-related emissions requires electrification[11, 12] and an immediate shift towards renewables.[13, 14, 15] For hard-to-abate sectors such as heavy-duty transport and some industrial processes where electrification is very difficult or impossible, mitigation options can include decarbonizing through abatement technologies and switching to new low- and zero-emitting energy carriers such as clean hydrogen and its derivative molecules (e.g., ammonia, methanol and other synthetic fuels).[1] The Emissions Gap report also outlines some of the key actions needed to help advance transformation through avoiding lock-in of new fossil fuel-intensive infrastructure, further advancing and applying zero-carbon technologies and promoting behavioral shifts.[16]

Historically, hydrogen has been produced via reformation of natural gas (grey hydrogen) or gasification of coal (black/brown hydrogen), both being highly carbon intensive.[17] For hydrogen to be an effective emission reduction option, it should be produced using clean energy sources, or its CO_2 emissions should be abated via carbon capture and storage (CCS). Among different clean hydrogen production options, only electrolysis-based hydrogen using clean electricity has net-zero direct CO_2 emissions, as CCS-based solutions are associated with residual CO_2 emissions and upstream methane emissions of natural gas.[18] Green hydrogen can be produced via water electrolysis using renewable electricity, mostly wind and solar power. Because of lower technological maturity of other electrolysis-based clean hydrogen production routes and promising cost reduction of renewables and electrolyzers, green hydrogen is considered to become the key clean hydrogen supply option in the long run, being both economically viable and truly sustainable.[19] Development of a global green hydrogen market has the potential to play a critical enabling role in developing and emerging economies to help drive robust sustainable development outcomes.[20]

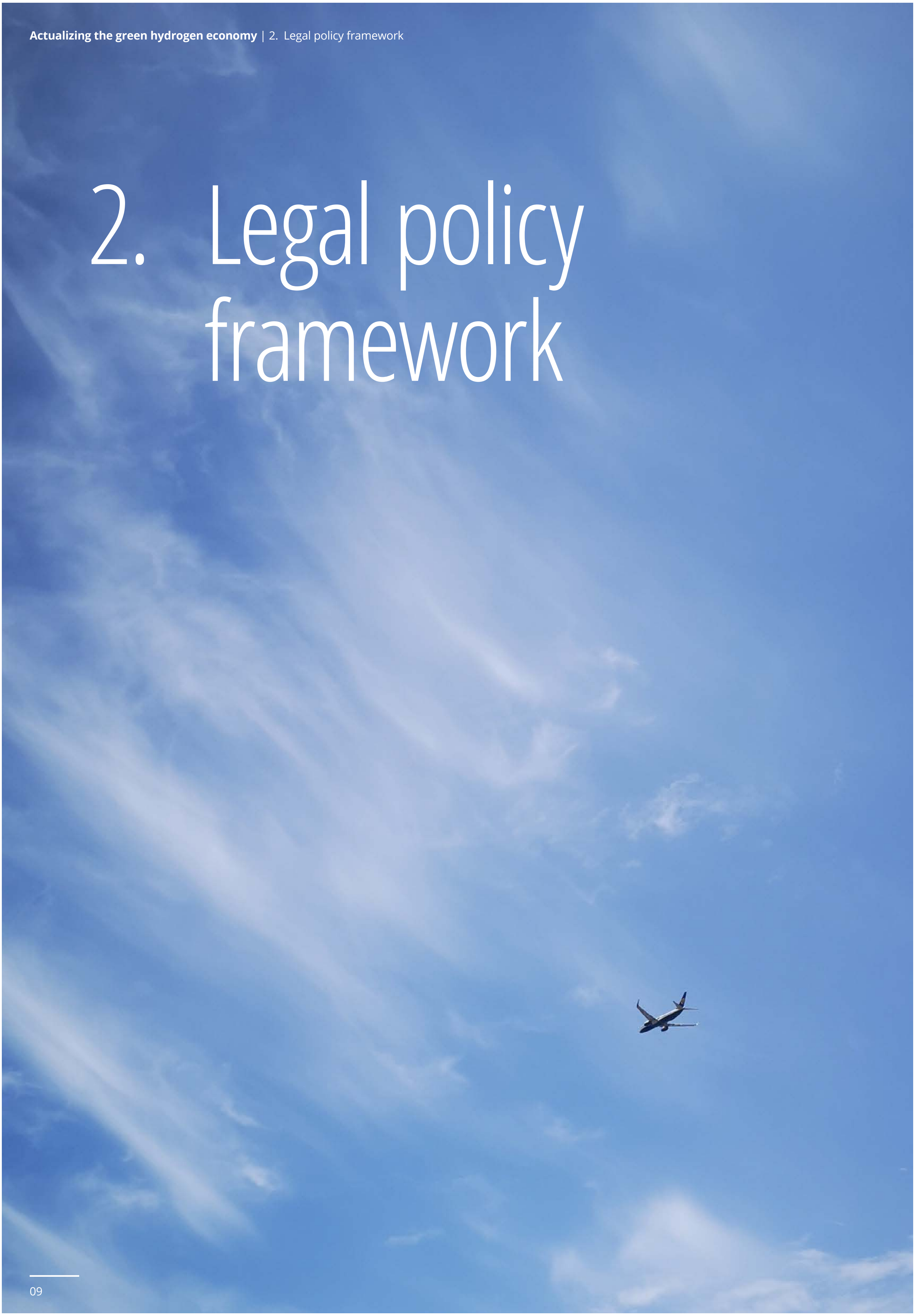
Green hydrogen can help decarbonize hard-to-abate sectors such as heavy-duty transport and some industrial processes where electrification is impossible or very costly.

From an industry perspective, as many industrial processes are already optimized for higher efficiency and some cannot only rely on electrification (such as steel production and chemicals), key transformations needed to help bring the industry sector to a Paris-compatible pathway include integration of green hydrogen production capacities.[21] Moreover, while there appears to be scientific consensus regarding the effectiveness of electrification to help decarbonize across many sectors, some sectors, such as maritime transport and aviation, require solutions beyond electrification. Synthetic fuels produced from clean hydrogen such as ammonia and methanol can bring needed emission reductions to the maritime transport sector.[22] Similarly, sustainable aviation fuels, seen as leading solutions for the decarbonization of aviation, can be produced either from hydrogen (synthetic kerosene via Fischer-Tropsch reaction) or biological feedstock (bio-kerosene).[23] Finally, hydrogen can be an important game changer for the integration of variable renewable energy sources (wind and solar power) to the power system, bringing the needed flexibility to the system by providing long-term energy storage and grid stability.[24, 25]

The global clean hydrogen (mostly green) economy can grow up to US$1.4 trillion annually by 2050. It can reduce GHG emissions by 85 $GtCO_{2eq}$ and contribute significantly to economies by supporting about 1.5 million new jobs per year between 2030-2050 in developing and emerging economies.[19] Therefore, an effective understanding of the regulatory and financing environment needed to help successfully scale-up the supply of green hydrogen is critical to actualizing intersections with the United Nations (UN) Sustainable Development Goals (SDGs).

To help unlock the decarbonization potential of green hydrogen, it should be widely affordable. With the right policies put in place now, it could soon become a cornerstone of the world's shift away from fossil fuels.[26] Furthermore, international cooperation and coordination is important to help develop a market for hydrogen from renewable sources, with coordinated targets, standards, and bilateral and multilateral cooperation agreements.[27]

2. Legal policy framework



A review of national law and governance frameworks explores the importance that forward-facing regulatory approaches play in advancing the green hydrogen economy. Advanced experiences are reviewed from the European Union (EU), Germany, United States (US), Namibia, Australia, United Arab Emirates (UAE) and Morocco providing perspectives on the progression of legislative drafting vis a vis green hydrogen and its derivatives. Green hydrogen has gained significant attention in the policy framework around the globe with varying approaches adopted to advance capacity. Table 1 provides an overview of the policy and regulatory approaches adopted across the jurisdictions.

Table 1. Policy and regulatory approaches to promote the development of green hydrogen across the selected jurisdictions

Geography	Existing legal and policy framework	Enablers
European Union (EU)	• **First Renewable Energy Directive (RED), 2001** (updated in 2009) promoted the deployment of renewable energy sources across key sectors of the EU economy.[28] • **RED II, 2018** updated framework agreement governing renewable energy generation and use within the EU.[29] • **RED III, 2023 (Provisional agreement)** raised renewable energy targets from 32% to 42.5% aiming for 45%. It will modify sectoral targets including specific targets for hydrogen based renewable fuels of non-biological origin (RFNBO's).[30] • **European Commission (EC)** proposed an encompassing legislative framework for the production, consumption, infrastructure development and market design for hydrogen (Also refer to **Renewable Energy Directive**).[31, 32] • **'Fit for 55' package** creates incentives for hydrogen use, including binding goals for industry and the transport sector.[33] • **Green Deal Industrial Plan** provides a conducive environment to scale up the manufacturing capacity for net zero.[34]	• A mutually supportive incentivization scheme which currently comprises of the Renewable Energy Directive and the Emission Trading System[35] • A plan to set up the European Hydrogen Bank, to invest more than US$3 billion (€3 billion) to kick start the European H_2 market[36] • Fixed-premium auctions for renewable hydrogen from 2023 will also be provided by the EU's Innovation Fund [37]
Germany	• **Renewable Energy Sources Act (EEG 2021) and Renewable Energies Ordinance (EEV, 2021)** contains support schemes for renewable energy sources, which directly affect the cost of electricity consumed for green hydrogen production.[38] • **Energy Industry Act (EnWG)** mentions the supply of hydrogen by providing the purpose of the act in the provision of grid-based supply based on renewables, drawing attention to hydrogen.[39] • **Koalitionsvertrag zwischen SPD, Bündnis 90/Die Grünen und FDP** formulates a 'national hydrogen strategy' as of 2022, and identifies the need to develop the Important Project of Common European Interest (IPCEI) to financially support investments in the development of a hydrogen network infrastructure.[40] • **National Hydrogen Strategy (NHS, 2020)** helps create the opportunity to play a key role in international competition for the development and export of hydrogen and Power-to-X technologies.[41] • **Federal Emission Control Act** provides an authorization procedure pursuant for the construction and operation of a hydrogen production facility such as a power-to-gas plant.[42] • **Environmental Impact Assessment Act** requires a preliminary audit keeping in mind fulfilment of requirements stipulated by the Hazardous Incident Ordinance.	• Federal Network Agency (BnetzA), responsible for the regulation of hydrogen projects as hydrogen currently falls under the regulation of gas and electricity markets[43] • Public funding guidelines for the financial support of international hydrogen projects • The funding guideline specifically supports projects for the production and further processing of green hydrogen and its derivatives as well as for the storage, transport, and use of hydrogen in countries outside the EU via an investment grant for the systems[44] • The aim of H2Global to purchase green hydrogen products cheaply on the world market and to sell them to the highest bidder in the EU

Geography	Existing legal and policy framework	Enablers
United States	• **Energy Policy Act, 2005** expanded large-scale hydrogen research and delved into development of hydrogen as an alternative source of fuel.[45] • **Inflation Reduction Act** provides clean energy incentives with provisions for clean hydrogen and fuel cell technologies, either extending existing federal tax credits, or creating new federal tax credits.[46] • **California specific initiatives** – **Low Carbon Fuel Standard** leverages federal investment from the Infrastructure Investment and Jobs Act establishing an environmentally and economically sustainable and expanding renewable hydrogen hub.[47] – **Alliance for Renewable Clean Hydrogen Energy Systems (ARCHES)** supports an H2 consortium to advance public-private partnerships that accelerate deployment of clean, renewable H2 projects and infrastructure.[48]	• Launch of The Hydrogen Shot to help accelerate breakthroughs in hydrogen technology and cut the cost of clean hydrogen by 80% to US$1 per kilogram (kg) in one decade[49] • Texas specific initiatives, 2022, including a new mega-scale green hydrogen facility[50]
Namibia	• **The National Energy Policy, 2017** aims to provide, energy security, enable cost-effective, reliable and consistent energy access, promotion of energy efficient technologies, and incentivize the effective development and use of domestic energy resources. The policy also aims to support expansion of renewable energy sources.[51] • **The Electricity Act, 2007** in which Electricity Control Board licenses only operations that involve electricity generation (solar and wind) and transmission, with approved projects including the establishment of networks for integration of power production and green hydrogen processing facilities.[52] • **The Electricity Bill, 2017 and the Namibia Energy Regulatory Authority Bill, 2017 (Under parliament's review)**, could significantly impact the procurement and licensing of power generation projects.[53] • **Harambee Prosperity Plan II** aims to foster development of renewable energy at scale, advancement of business models that promote local sustainable development grounded in renewable energy sources, and mobilization of finance to scale up infrastructure for renewable energy and green ammonia production.[54] • **Namibia Green Hydrogen Strategy** establishes the goal of positioning Namibia as a leading global hydrogen producer by 2025.[55] • **Synthetic Fuels Act (Yet to pass)** aims to provide transparent oversight towards organizing, acquiring, and overseeing future green hydrogen projects built on state-owned property and detail on incentives, corporate tax structures, royalties, and competition laws.[56]	• The Republic of Namibia exercises exclusive jurisdiction over natural resources and components of the natural environment within its national boundaries[57, 58] • Establishment of a special economic zone (SEZ) and expansion of the Walvis Bay Port currently being evaluated[59] • In May 2022, Namibia launched its first sovereign wealth fund called as the Welwitschia Fund[60]

Geography	Existing legal and policy framework	Enablers
Australia	• **The Climate Change Act, 2022** embed the Paris Agreement and targets found in the nationally determined contribution (NDC) into the national framework, with subnational legislation leading the way on climate policy.[61, 62] • **The National Electricity Law**[63] **National Gas Law**[64] **and the National Energy Retail Law**[65] are three overarching laws which are relevant to the governance of energy markets and help regulate access to natural gas pipeline services (transmission and distribution). • **The Clean Energy Future package and the Renewable Energy target (RET)** policies have focused on materially reducing emissions in the electricity sector.[66] • **Amendment to the National Gas Law, 2022** regulations to further blending of hydrogen and derivatives under the national framework.[67] • **Australia's National Hydrogen Strategy, 2019** provides a national vision for advancement of a domestic clean hydrogen sector.[68] • **Native Title Legislation Amendment Bill 2021** provides indigenous title holders a strong position to insist best practice agreements are negotiated.[69] • **South Australia** – **The Principal Act** amended petroleum and geothermal regulations making hydrogen, and its compounds and by-products, regulated substances.[70] • **New South Wales** – **NSW's hydrogen strategy, 2021** supports green hydrogen, with a planned amendment Bill targeting blending of up to 10% hydrogen and biomethane into natural gas pipelines by 2030, and also provides specific exemptions for electricity used in the production of green hydrogen.[71]	• Need to ensure that the rights of Indigenous Australians are adequately addressed in the current frameworks for renewable energy and hydrogen development[72] • In NSW, green hydrogen producers are expected to be able to achieve over US$2 per kg in cost reductions by combining revenue from certificates generated under the state's Renewable Fuel Scheme and electricity charge concessions[73] • The Hydrogen Accord between Australia and Germany was signed in June 2021 to help facilitate strategic cooperation in this field[74]
United Arab Emirates (UAE)	• **National Energy Strategy** collectively positions a national drive to help achieve net-zero emissions by 2050.[75] • **Masdar initiative** focuses on the development and mobilization of innovative technologies releating to renewable energy, energy efficiency, carbon management and monetization, water management and desalination.[76] • **The National Hydrogen Strategy (in draft stage)** furthers the vision for hydrogen in UAE, provides inputs for policy development, prioritizes hydrogen in the domestic energy mix, and puts in place a diversification strategy and net-zero targets by 2050.[77] • **Energy Strategy 2050** aims to increase the share of clean energy in primary energy consumption to 25–50 per cent by 2050.[78]	• The UAE plans to invest around US$163 billion (nearly Dh600 billion) in clean energy to help support the goals of climate neutrality[79] • UAE has been drawing up a comprehensive road map to position itself as an exporter of the clean fuel and tap into its future potential[80]
Morocco	• **Roadmap on green hydrogen, 2021** three pillars (i) development of a domestic market and demand, including establishment of enhanced export and storage facilities, (ii) technology deployment aimed at cost reductions and local industrial integration, and (iii) mobilization of investment that identifies possible clusters and measure for its financing.[81] • **Germany-Morocco Hydrogen Agreement** was signed for the joint development of green hydrogen production pledging more than US$300 million (€300 million) investment to enable Germany to source green hydrogen from Morocco.[82]	• Development of the green hydrogen industry in Morocco is projected to require a total investment of between US$38 billion to US$272 billion (Dh140 billion to Dh1 trillion) between 2020 and 2050 to help meet potential demand by 2050[83]

The operational subsidy schemes introduced by the US Inflation Reduction Act (IRA), along with the Hydrogen Shot introduced by the US Department of Energy to help accelerate breakthroughs in hydrogen technology and reduce production costs, and State initiatives driven in California and Texas provide a strong support system for the American industry to help scale up production. The EU in contrast, has leveraged a facilitative approach against the backdrop of a robust regulatory architecture governing renewable energy generation and emissions trading, and a forward-facing strategy in the EU Green Deal. Through creation of the European Hydrogen Bank, and the German H2Global, a facilitative offtake approach is utilized –whereby green hydrogen products are secured cheaply and sold within the EU at market rates—to help secure supply, reduce risk, and increase utilization.

Among potential future hydrogen exporters, Australia utilized its national strategy to outline priorities, identify areas of competency, integrate an adaptive and nationally coordinated approach to help support industry development, using a 'review-revise-adapt' feedback loop, and continue to advance respect for Indigenous land rights.[84] A Hydrogen Accord between Australia and Germany was also signed in June 2021 to help advance strategic bilateral cooperation on green hydrogen. Similarly, Namibia utilized their national strategy to help inform and guide domestic legal reform processes related to energy, land use and taxation, and initiated the creation of a specialized framework through the draft Synthetic Fuels Act.

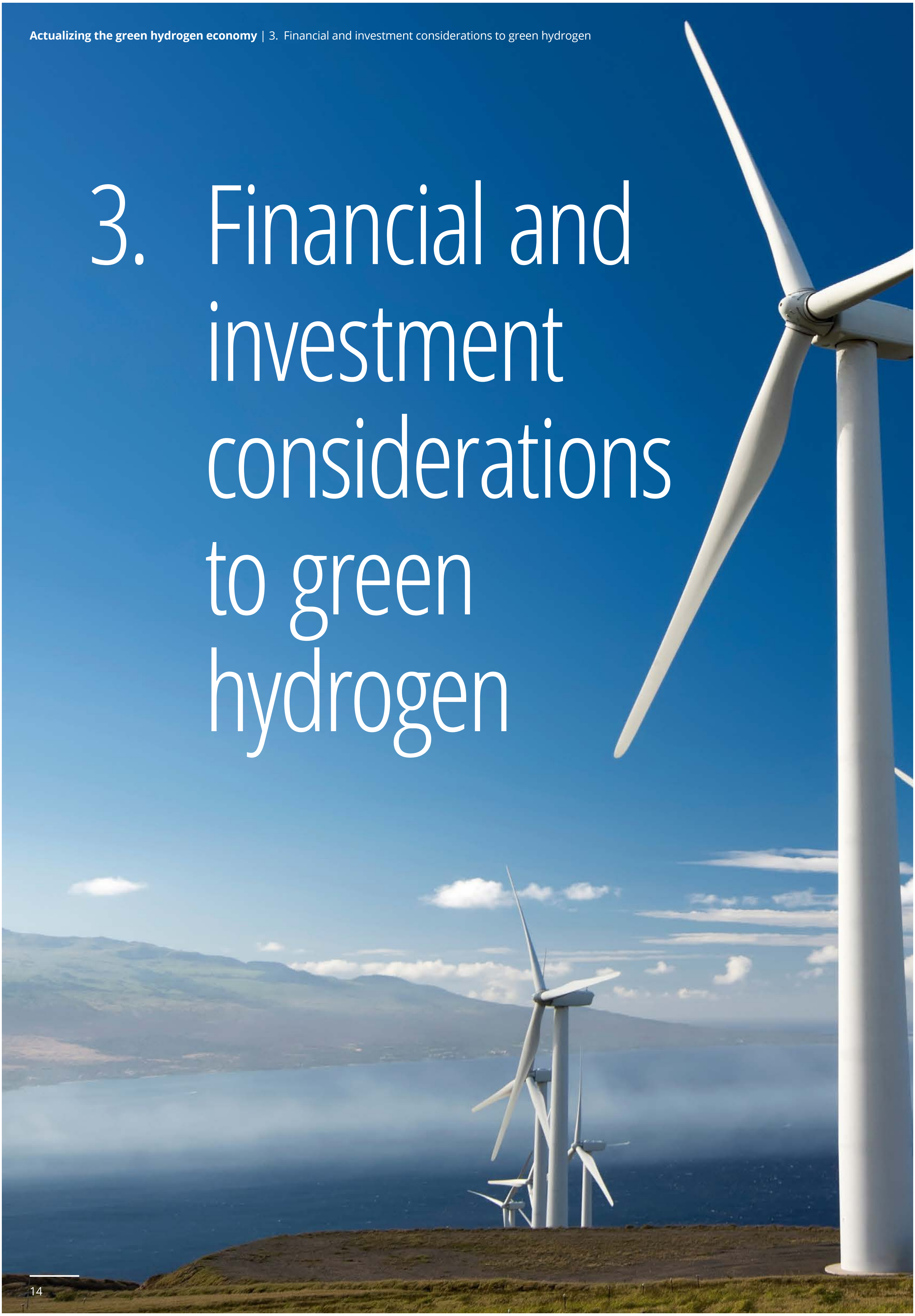
The UAE leveraged synergies across their National Energy Strategy 2050 and Net Zero by 2050 strategic initiative to help operationalize a coordinated approach through centralization of ministerial mechanisms in collaboration with key stakeholders. While the UAE's National Hydrogen Strategy remains under development, efforts led by the Masdar Initiative and partnerships with Australia's GHD Group Pty Ltd. and Germany-based Fraunhofer-Gesellschaft continue to advance innovation, mobilize investment, and develop frontier technology across the green hydrogen value chain. Similarly, Morocco developed a green hydrogen roadmap through their National Hydrogen Commission to help advance market demand, reduce technology costs and develop clusters to facilitate investments. The Germany-Morocco Hydrogen Agreement signed in 2020 provides a strong basis for bilateral energy cooperation.[85]

Establishment of a clear policy intention through formulation of national strategy instruments was observed to provide a direction of travel for legislative and ministerial bodies, while acting as a catalyst for stakeholder engagement and mobilization of investments. Alignment of the policy and regulatory architecture towards a Paris-aligned green hydrogen economy can provide important legal clarity, certainty and can create an enabling environment for stakeholder engagement across the value chain. Depending upon the jurisdiction, this process could include a stocktaking exercise to determine gaps and identify enabling elements, reform and enhancement of exciting instruments to help ensure they are fit for purpose was observed across each jurisdiction, and creation of specialized incentive or funding schemes such as those utilized in the EU and US, creation of sector specific legislation as seen in Namibia, or utilization of existing modalities while experience is developed as seen in UAE and Morocco.

Adoption of a value chain approach has also been observed across many jurisdictions. Actualization of the green hydrogen economy necessitates the creation of comprehensive pathways at the convergence of industrial, Indigenous, land, and sustainable development priorities.

Given the nascent nature of the sector, policy and regulatory support is needed in early experiences to help bridge the gaps and leverage cooperative approaches to actualize pilot schemes end-to-end. The importance of finance was underscored across each jurisdiction. Mobilization of low-cost finance and value creation was observed through a range of approaches, including creation of direct incentives, development of national support schemes, inclusion of sovereign wealth funds, and consideration of appropriate tax structures to effectively capture benefits for host jurisdictions.

3. Financial and investment considerations to green hydrogen



3.1. Economic and financial characteristics of green hydrogen

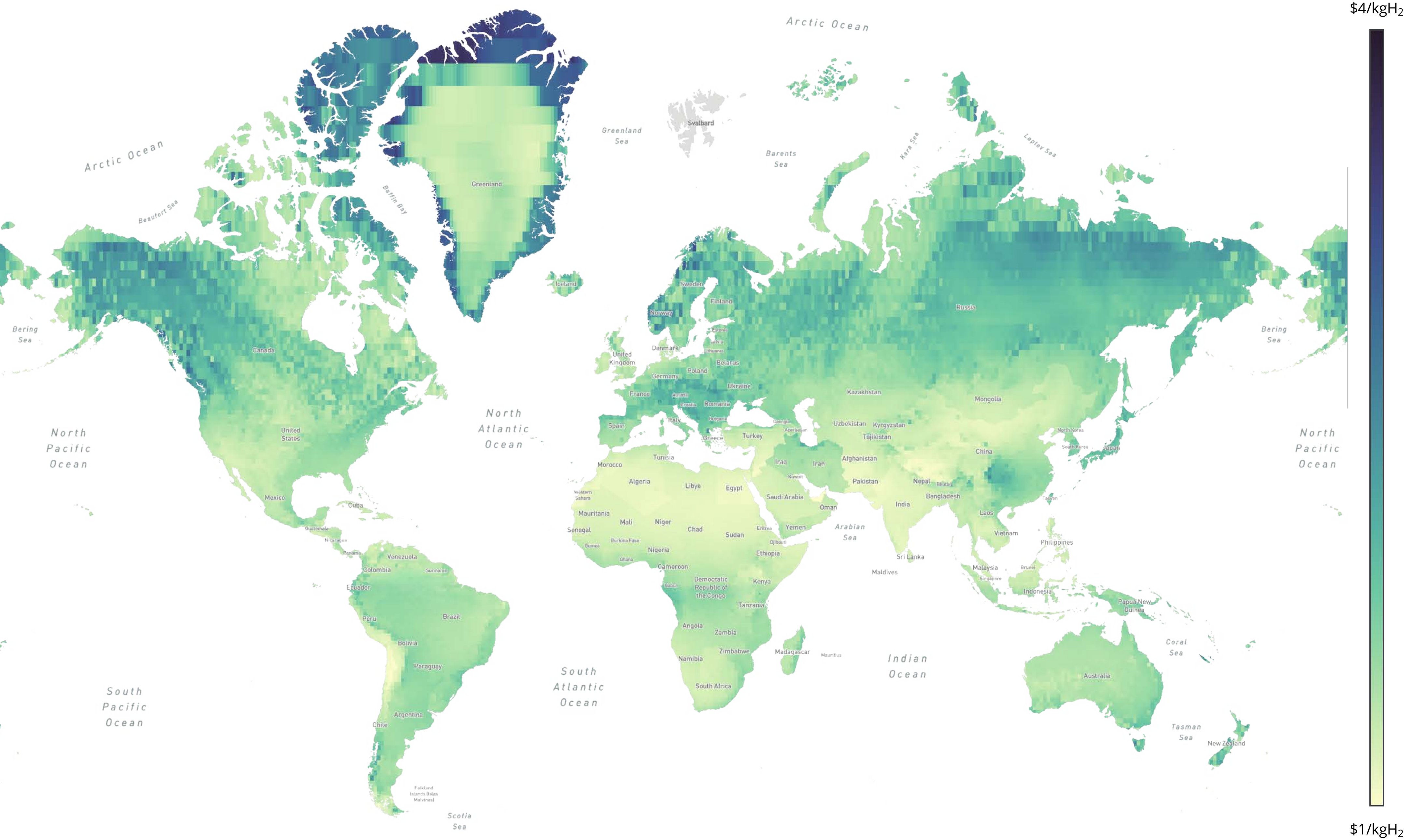
Green hydrogen can be produced via electrolysis of water using wind and solar electricity, therefore virtually everywhere. However, the cost of green hydrogen production can vary significantly across different geographies with a key element influencing the cost of green hydrogen being the production yields of the renewable power plants, stemming from solar irradiation and wind speed. As the plant yield of a renewable power source increases, the higher the plant production for a given installed capacity, which then drives down the cost of the electricity production. This, in turn, reduces the cost of the green hydrogen production. The average cost of hydrogen production (including the investment and operational costs) can be defined using the Levelized Cost of Hydrogen (LCOH) metric. LCOH accounts for all capital and operating production costs in the levelized manner over a unit of produced hydrogen and its derivative (US$/kg). Figure 3 Shows the LCOH of green hydrogen around the globe with the technology cost estimations for the year 2050.

In 2050, producing solar PV-based green hydrogen in North Africa could cost one-quarter of European production. Benefiting from high renewable (especially solar) endowments, green hydrogen produced in Australia, Chile, Mexico, northern and sub-Saharan Africa, and Middle Eastern countries can be highly cost competitive. Moreover, the widespread availability of land in these regions for renewable installations, compared to those with limited land availability (such as Japan, Korea, and some parts of Europe[86]) makes these regions more adapted for development and exports of green hydrogen.

The cost competitiveness of green hydrogen does not only depend on wind and solar potentials. Green hydrogen is a highly capital-intensive technology, that requires significant investments. Production costs of green hydrogen consists of investments in renewable powerplants, electrolyzers, their connection equipment, the fixed operation and maintenance costs and the cost of water consumed for its production. Therefore, the bulk of the LCOH consists of investment costs, and its cost elements are largely fixed costs. Figure 4 shows an illustration of the breakdown of the costs of green hydrogen production in Morocco for the year 2021.

Green hydrogen is a highly capital-intensive technology, that requires significant investments. Production costs of green hydrogen consists of investments in renewable powerplants, electrolyzers, their connection equipment, the fixed operation and maintenance costs and the cost of water consumed for its production.

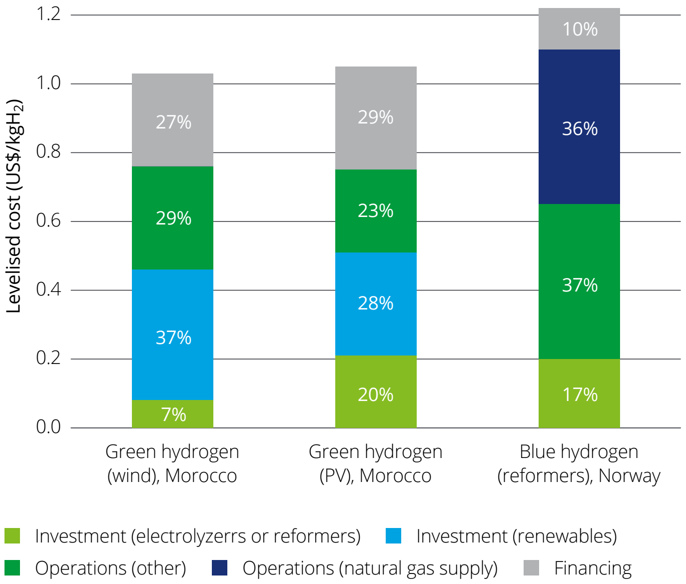
Figure 3. The levelized cost of hydrogen production over the globe, 2050



Source: Deloitte's 2023 global green hydrogen outlook[19]

A key challenge regarding the development of green hydrogen is the availability of liquidity. Many of the regions that have significantly high green hydrogen supply potential suffer from lower availability of financing options for the required investments. Therefore, access to investment funds in such regions can be identified as one of the critical measures needed to help solve the bottlenecks regarding the development of a global cost-competitive green hydrogen value chain.

Figure 4. Illustration of different cost components of green hydrogen produced in Morocco in 2021



Source: Deloitte's 2023 global green hydrogen outlook[19]

Highly capital intensive in nature, green hydrogen projects require raising significant amounts of debt and equity, which can adversely impact financing costs and competitiveness of investments. An important factor influencing financing costs is the country political risk level. Some of the most promising locations for green hydrogen projects may suffer from high country-related political risks. In practice, private investors and lenders expect higher rates of return to compensate for greater political risks. Such perceived risks are translated into a higher weighted average cost of capital (WACC) for the projects, which acts as an interest rate therefore, increasing the overall cost of the project via additional financing costs. Access to affordable finance can be a critical enabler for green hydrogen projects, and particularly those located in emerging markets with high political risks that may be otherwise prevented from tapping into their exceptional production potential. Moreover, the lack of projects and absence of a market in scale means that there is no or very limited reference for commercial due diligence. This in turn translates into a market risk for both lenders and investors that would increase the WACC by increasing the cost of both debt and equity.

Project development timelines can be a major bottleneck in scaling up the production of green hydrogen that consist of two major processes: permitting procedures and construction. Permitting schemes for renewable energy projects can bring significant delays to the operation of the power plants. After an investment decision, once the expenditure allocations are done, the permitting and validation procedures as well as the construction operations can bring not only delays, but also resulting financial losses due to the blocked liquidity and applied interest during the operation. Minimizing the delays and the financial costs of the projects will require accelerated and streamlined permitting processes and construction. Although permitting challenges are currently concerning more advanced economies such as Europe, the United States and Australia[89], this can be a relevant subject for developing countries as well with potentially complex regulatory landscapes as the project pipelines mature.

Like renewables, which have experienced significant cost reduction over the last decades, the manufacturing cost of green hydrogen equipment is projected to fall steeply in the coming decades.[90] The installation cost of solar panels and onshore wind is expected to drop by 45% and 18%, respectively, between 2020 and 2050, with electrolyzers also expected to experience significant cost reductions, decreasing by two-thirds over the same timeframe.[91] Therefore, green hydrogen is expected to become one of the most cost-competitive hydrogen production technologies in the long run. In 2050, levelized production costs could fall below US$1/kgH$_2$ in Chile, and below US$1.1/kgH$_2$ in north and sub-Saharan Africa, Mexico, China, Australia, and Indonesia.[3] Yet, currently green hydrogen is the most expensive one[92], and it is expected to remain generally more expensive than the carbon-intensive gray hydrogen at least until 2035 (Figure 5). Therefore, to help create a level playing field, green hydrogen projects need support through operational premiums until they are commercially competitive.

Development of a global green hydrogen value chain has a two-fold challenge: decarbonization of its current uses, and creation of new hydrogen uses. Currently, industry consumes about 95 million tons of hydrogen globally, nearly entirely produced from fossil sources (natural gas reformation or coal gasification)[19].In a climate-neutral world, clean hydrogen (including its derivative molecules such as ammonia and methanol) can become the second biggest final consumed energy carrier.[93] While some of these end-uses can consume hydrogen by simply replacing the initial commodity by it, in most of the cases a significant infrastructure and equipment shift is needed.[94] For instance, hydrogen for the road transport sector requires a complete change of the vehicle engines, from internal combustion engines to electric motors, including fuel cells.

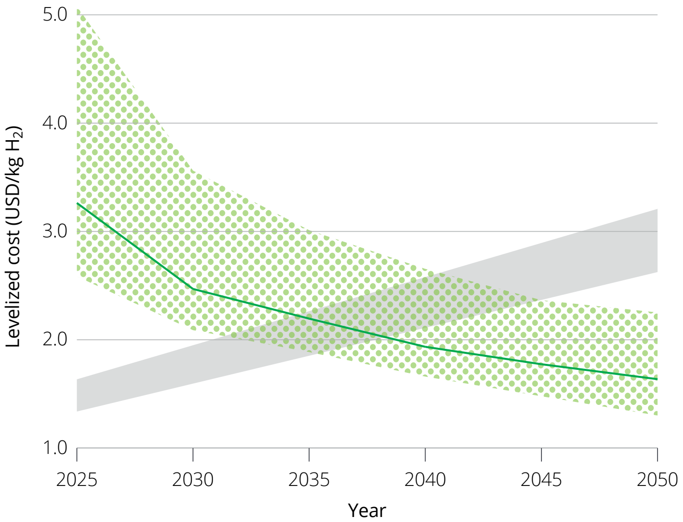
Economic and financial support to help produce green hydrogen should be complemented with the creation of demand signals for clean hydrogen and its derivative molecules in different sectors. Initiation of a clean hydrogen economy, in line with the Sustainable Development Goals, requires:

1. Facilitating investments via unlocking funds and foreign investment initiatives,
2. Reducing financing costs via enabling access to low-cost finance,
3. Creating a level-playing field for green hydrogen via operational subsidies until at least late 2030s,
4. Creation of demand for green hydrogen via sectoral initiatives and obligations, and
5. Reduction of the permitting and construction periods via facilitated permitting processes.

In the following section, different policy support mechanisms that can be used to help activate each of the identified action points are explained.

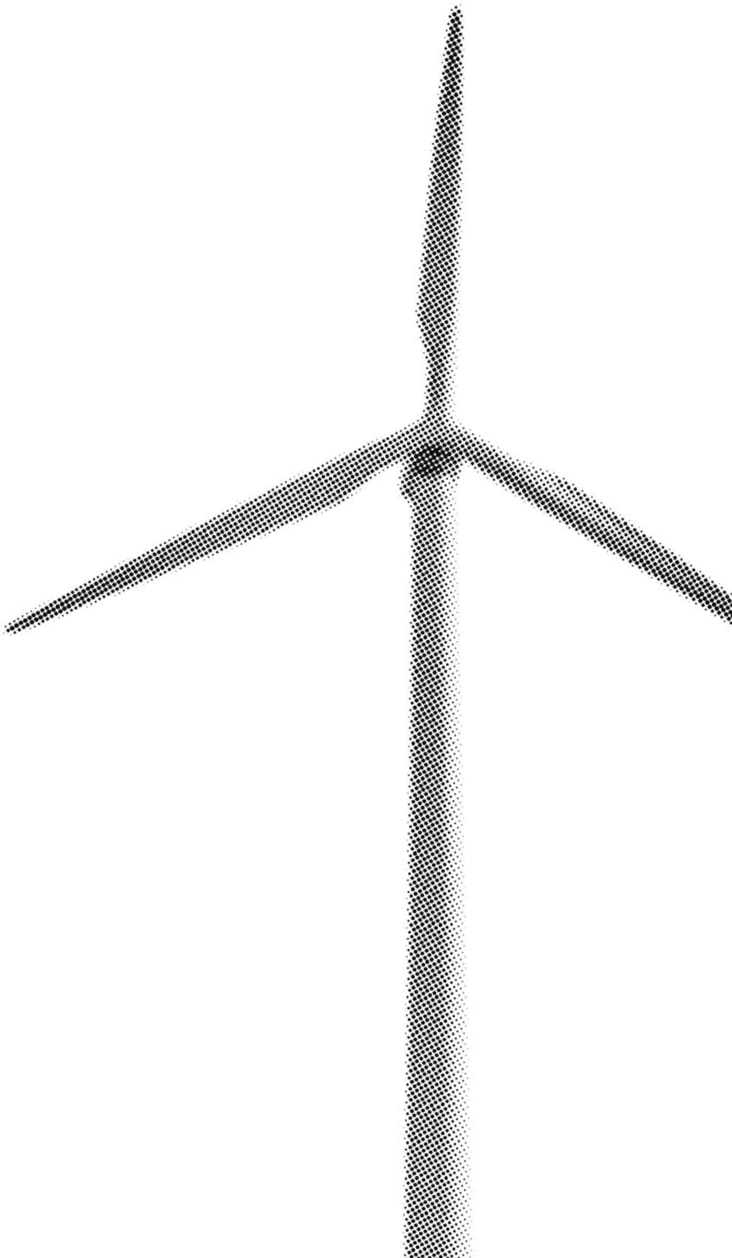
Green hydrogen is highly capital intensive and currently more expensive than its fossil counterpart, making it highly sensitive to financing conditions and policy support.

Figure 5. Outlook on production costs of green hydrogen and grey hydrogen between 2025 and 2050



Note: Green line represents the median of the green hydrogen LCOH, and the spectrum shows the variation between maximum and minimum values. Grey area shows the evolution of the cost spectrum of grey hydrogen during this period.

Source: Deloitte's 2023 global green hydrogen outlook[19]



3.2. Overview of some of the main financial and economic instruments to help increase bankability of green hydrogen projects

Several mechanisms can be used to help make green hydrogen projects economically more competitive and to facilitate investments. Potential policy support schemes can be grouped as follows: investment support, financing support, operational support, R&D support, market creation and permitting facilitation. Figure 6 shows these support mechanisms with associated examples.

Investment support mechanisms can reduce the amount of money required to build production capacities. There are many funds that support green hydrogen projects by financing a part of their capital expenditure (CAPEX). In Europe, the Innovation Fund supports up to 60% of a project's CAPEX and a variable fraction of its operational expenditures (OPEX) incurred in the first 10 years of operation.[95] The Connecting Europe Facility for Energy (CEF – E) is an EU funding instrument for targeted infrastructure investment at European level.[96] CEF-E deploys more than US$6 billion (€5.84 billion) to help fund up to 50% of the CAPEX of hydrogen infrastructure and grid-connected electrolyzer projects of 100 MW or above. In the private sector, Hy24 provides equity for infrastructure projects worldwide through its currently operational more than US$2 billion (€2 billion) 'Clean H_2 Infra Fund'.[97] Such funds inject liquidity into projects and help reduce the required investments.

The International Energy Agency (IEA) states that 65% of the funding required to reach net-zero emissions must come from the private sector.[98] However, in developing countries where renewable hydrogen production is more promising, private investors and lenders expect higher rates of return to compensate for greater political and operational risks resulting in higher WACC levels. Financial support mechanisms, such as guarantees can help to reduce country risk premium and thus the cost of capital, making the projects more bankable. The European Investment Bank (EIB) offers solutions in the form of guaranteed instruments in markets where there is a lack of investment.[99] EIB also at times guarantees potential losses from a project. Blended finance mechanism is another financial support mechanism that can mobilize private investments alongside sustainable development outcomes to help increase the bankability of the projects. The 'SDG Namibia One Fund', launched in 2022, is a case in point with a first US$43 million (€40 million) grant from Invest International, and aiming to collect more than US$1 billion (€1 billion).[100] Currently, green hydrogen projects suffer from a lack of financial support mechanisms, entailing lower bankability for such projects.

Operational subsidies are often designed as a premium that varies with hydrogen production functioning as a subsidy to compensate for the difference between the production cost (LCOH) and the revenues. In the Netherlands through the Sustainable Energy Transition (SDE++) scheme, electrolytic hydrogen producers are eligible to receive up to US$3.4/kg$H_2$ for 12 to 15 years, but only for a limited number of full load hours per year. For instance, in 2023, eligible production is capped at 1,490 full load hours and in 2026, that limit is 2,330 full load hours.[101] Tax credits are tax exemptions for producers that also work as operational subsidies. The US Inflation Reduction Act offers a clean hydrogen production tax credit.[102] Effectively, it is a 10-year incentive for clean hydrogen production with a tax reduction of up to US$3/kg$H_2$ when the carbon intensity is below 0.45 kgCO_{2eq}/kgH_2.[103]. Crucially, the IRA legislation allows the federal government to pay out this subsidy directly.

Figure 6. Summary of the policy support mechanisms to help increase the bankability of green hydrogen projects

Investment support

Finance a part of the capital expenditure

e.g., Innovation fund (EU)
Clean H2 Infra Fund (worldwide)

Financing support

Reduce the cost of capital

e.g., SDG Nambia One Fund (Nambia)

Operational support

Premium proportional to hydrogen production

e.g., SDE ++ (the Netherlands)
IRA 45v (US)

R&D support

Develop a self-sustaining hydrogen value chain

e.g., Clean Hydrogen Joint Undertaking (EU)

Market creation

Ensure that green hydrogen will be bought

e.g., H2Global (Germany)
European Hydrogen Bank (EU)

Permit facilitation

Facilitate the roll-out of projects by allowing quick commissioning

e.g., Net-Zero Industry Act (EU)

Source: Deloitte analysis

R&D subsidies have a dual social and financial function. First, grants can help accelerate innovation and development of a self-standing hydrogen value chain by bringing down costs and thereby allowing for the scale up of emerging technologies, such as green hydrogen production technologies, while also building up a strong workforce with specialized skills. In Europe, the Clean Hydrogen Joint Undertaking (CH-JU) supports research and innovation in hydrogen technologies, with the scope including renewable hydrogen production, distribution, storage, and use for transport and energy-intensive industries.[104] Targeting establishment of new knowledge (early-stage research action), exploration of the feasibility of a new technology, support actions for standardization and the development of prototypes, demonstrations, or pilots, the CH-JU provides economic support mainly through grants and is endowed with about US$1 billion (€978 million) funding completed with more than US$1 billion (€1 billion) from private sources.[40] The CAPEX of projects that are expected to have a significant impact in accelerating the transition to a hydrogen economy may also be considered as an eligible cost.

Another reason for underinvestment is the lack of a proper market for green hydrogen. It is necessary to develop the potential market and to use offtake agreements or compensation mechanisms to help ensure that the hydrogen produced will be bought. This is the purpose of German H2Global instrument, a competitive double auction platform which aims to secure revenues for hydrogen producers and ramp-up the green hydrogen market on an industrial scale. H2Global acts as an intermediary providing 10-year purchase contracts on the supply side and short-term contracts on the demand side.[105] As with contracts for difference (CfD), the difference between suppliers' lowest bids and buyers' highest bids is compensated by grants from a public or philanthropic funding body. The revenues are secured for the producers, which is attractive for investment, and importers gain access to green derivatives. At the European level, the Commission is designing the first pilot auctions on renewable hydrogen production, named the 'European Hydrogen Bank' (EHB). The first US$860 million (€800 million) auctions will be launched under the Innovation Fund by autumn 2023[106] This auction can help create the EU's domestic market for hydrogen, provide transparency and coordination as well as assesses demand, infrastructure needs and hydrogen flows. The Commission is also exploring how to design an auction to include renewable hydrogen imports from countries outside the EU. CfDs can be considered at a later stage when a reference clean hydrogen price is determined.

Carbon quotas, carbon taxes and green certificates/guarantees of origin can increase the demand for green hydrogen, facilitating the creation of its market. The EU Emissions Trading System both raises money for the Innovation Fund and helps create demand for clean hydrogen. Some countries like France or South Africa already have carbon pricing schemes in place.[107] These schemes help increase the cost of carbon-intensive grey hydrogen and thus make green hydrogen more competitive. Additionally, green hydrogen certification is an important step in creating markets. With certificates, downstream industries like ammonia or steel production can market their items as environmentally friendly. A few institutions already deliver green hydrogen certifications, such as CertifHy in the EU, TÜV SÜD in Germany, the Aichi Prefecture in Japan, or the China Hydrogen Alliance.[108] In the same way, the EU taxonomy creates a frame of reference for investors and companies. Certification works to signal credible green projects for investors to invest in. Even if it is not linked to any financial benefits, the taxonomy works as an incentive to help scale up investment in green projects. For example, the Climate Bond Standard and Certification Scheme proposes the Hydrogen Production Criteria to certify hydrogen production as a Certified Climate Bond.[109] This certification helps to prioritize financial investments.

Finally, non-monetary support mechanisms to help accelerate permitting processes and reduce construction delays can be an important facilitator to roll-out of green hydrogen projects. Reducing permitting times and ensuring the timely availability of materials can attract investments by reducing project risks. For the EU, the Net-Zero Industry Act sets a 12-month permitting time limit for projects with a yearly manufacturing capacity of less than 1 GW in an EU Member State.[110] In practice, this should be done by lowering administrative burden. However, this Act only provides time goals and not guidelines which might not make it an efficient incentive. The EU's Critical Raw Materials Act sets targets for the extraction, processing, and recycling of platinum group metals (which are used in electrolyzers) and others.[111] The goal is to help avoid shortages and to keep prices low and steady. The Minerals Security Partnership (MSP) is an international coalition[112] of the US and 10 partners which aims to safeguard the supply of critical minerals for developing countries with limited geological endowments.[113] Leveraging close collaborations is a first step to help increase materials supply security, but more measures are needed to help reduce project risks further.

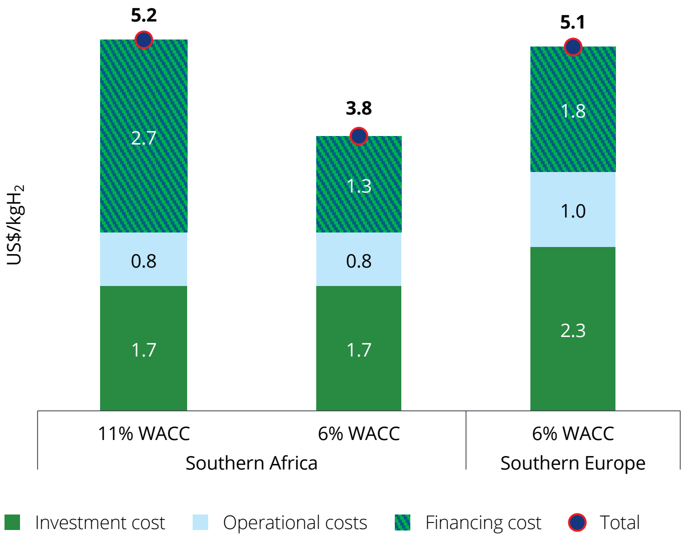
3.3. Effectiveness of the main financial and economic instruments

A case study is utilized to help illustrate how various support mechanisms presented in the previous section impact the economic and financial viability of green hydrogen projects. Analysis considers the cost and financial indicators of a green hydrogen production project via electrolysis using solar power in Southern Africa.

3.3.1. Financing support

Today, with current financing conditions, the WACC in countries in Southern Africa is higher than that of European countries. This is, at least partially, due to its higher country risk that stems from political, institutional, and regulatory risks. Compared to a European country, the investments bring much higher financial costs. Deloitte chose Southern Europe (as the region with the highest solar potential, and therefore, lowest LCOH in Europe) as a comparison reference. Figure 7 shows the impact of reduced WACC on the levelized cost of hydrogen produced in Southern Africa and Southern Europe.

Figure 7. Impact of WACC on the levelized cost of green hydrogen production in Southern Africa and Southern Europe



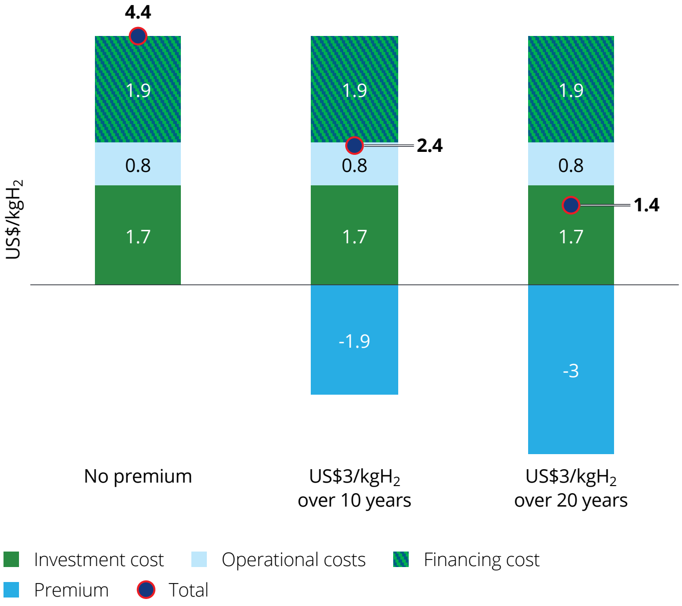
Source: Deloitte analysis based on the renewable endowments from the reanalysis of Copernicus - ERA 5 hourly solar PV capacity factors database, current technology costs for renewables and electrolyzers from IRENA[87] and IEA cost data[88] respectively and country-specific capital costs aligned with IRENA's lower and upper bond estimations.[87]

In current financial conditions, the cost of green hydrogen produced in Southern Africa is slightly higher than the cost of the one produced in Southern Europe, although Southern Africa holds better renewable potential than Southern Europe. Each year, more hydrogen can be produced with fewer electrolyzer and solar panel capacities in Southern Africa. Even if financing costs are higher in Southern Africa due to its higher WACC, investment costs are lower. While financing costs represent 35% of the LCOH in Southern Europe, it accounts for more than 50% of it in Southern Africa. The relative share of the financing costs showcase the effectiveness of bringing down the WACC. When the WACC in Southern Africa decreases by 45% (reaching 6%, its current levels in Europe), the LCOH in Southern Africa falls by 26%. Without additional cash support, it increases Net Present Value[114] (NPV) of the project by 5%. The solar-based green hydrogen in Southern Africa with a WACC of 6% costs 25% less than the same in Southern Europe. This illustration shows that financing conditions have an impact on reducing LCOH, and ease of financing in the high solar potential emerging countries such as Southern Africa would bring mutual benefits of development in the producing country and the availability of cheaper green hydrogen for the global market.

3.3.2. Operational and investment support

Considering the same case study (solar-based green hydrogen production in Southern Africa), Deloitte analyzes the effect of an operational premium-type support, similar to the US Inflation Reduction Act. With a premium of US$3/kg$H_2$ for 10 years, the green hydrogen LCOH is decreased by 45% (Figure 8). This accounts for an overall support of US$1.3 million for the considered project over 10 years. The same premium of US$3/kg$H_2$ over 20 years brings the LCOH down to US$1.36/kg$H_2$, in turn making green hydrogen cost competitive with grey hydrogen. However, it should be noted that such a subsidy does not necessarily amount for twice the same subsidy over 10 years. This is due to the discount rate, which also adds the

Figure 8. Impact of operational support on the levelized cost of hydrogen today



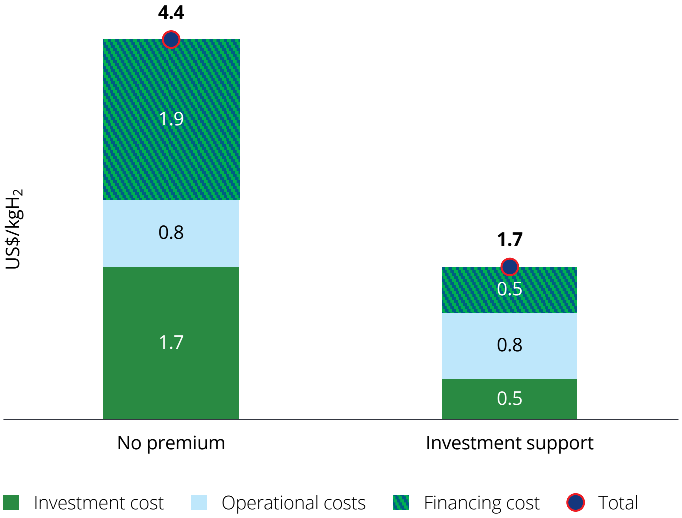
Source: Deloitte analysis based on the renewable endowments from the reanalysis of Copernicus - ERA 5 hourly solar PV capacity factors database, current technology costs for renewables and electrolyzers from IRENA[87] and IEA cost data[88] respectively and country-specific capital costs aligned with IRENA's lower and upper bond estimations.[87] The WACC is assumed to reduce from current 11% to 6% in the long run.

annual interest rates to the equation. Such a support entails a 69% reduction of the LCOH. The second decade of operational support thus only leads to a 24% decrease, as opposed to the 45% decrease in the first 10 years. From the producer's point of view, it could be more interesting to benefit from bigger premiums in fewer years than a smaller one that will be distributed over the entire lifetime of the production facilities.

To help assess the effectiveness of operational premiums and investment support mechanisms comparatively, this analysis assumes an investment support equivalent to operational premium over the support period. It assumes that operational premium comes from developed countries (this is consistent with current European cooperation with developing countries such as Namibia for future green hydrogen imports). Therefore, a discount rate of 3%[115] is used to calculate the real cost of operational support for supporting state. An investment support equivalent to the same overall support as operational premium in the previous example decreases the green hydrogen LCOH in Southern Africa by 60% (Figure 9). Investment support can reduce both financing costs and investment costs as it can reduce the liquidity requirements at the beginning of the project. The green hydrogen LCOH with investment support is 28% lower than with operational support considering the same support expenses for the funding state. This results from the asymmetry between public interest rates and the weighted average cost of capital, and injection of the whole amount of support at the beginning of the project which helps reduce both investment and financing significantly. Investment support (e.g., Hy24 Clean H_2 Infra Fund) is suggested to be more beneficial both from a hydrogen producer's point of view due to its predictability, and as it is bifurcated from the output levels of the production facilities, which can also be translated to less exposure to production risks.

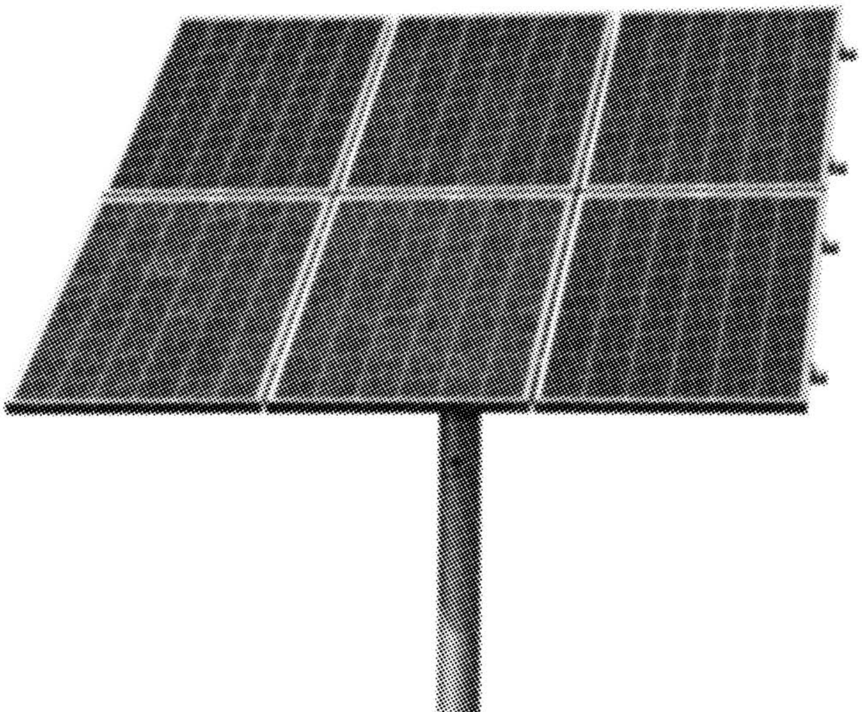
With equal spendings, the investment support entails higher cost reductions than the IRA-like operational premium. For a US$1.3 million of investment support, this LCOH is reduced by US$2.61/kg$H_2$ as opposed to a reduction of only US$1.94/kg$H_2$ for the case with operational support.

Figure 9. Effect of investment support on green hydrogen LCOH in Southern Africa



Note: The total of investment support is the same as for the operational support of US$3/kg$H_2$ over 10 years to compare their effectiveness. This support amounts to US$1.3 million. Like the previous example, this analysis assumes that the WACC is being reduced from current 11% levels to 6% in the long run.

Source: Deloitte analysis based on the renewable endowments from the reanalysis of Copernicus - ERA 5 hourly solar PV capacity factors database, current technology costs for renewables and electrolyzers from IRENA[87] and IEA cost data[88] respectively and country-specific capital costs aligned with IRENA's lower and upper bond estimations.[87]
An investment support equivalent to US$3/kg$H_2$ of LCOH reduction over 10 years is assumed as the investment subsidy (US$1.3 million).



3.3.3. Facilitating permitting processes

Ambiguities in permitting approval time and material availability can entail delays before the projects' operation. Construction time of green hydrogen production facilities can vary from 1 year to 3 years.[116] Delays in the commissioning can delay the first revenues of the production plant. These revenue delays can have an impact on the project's Net Present Value (NPV) and LCOH. LCOH is increased by 5% with a delay of 1 year and 14% for 2 years (Table 2).

Table 2. Net Present Value and LCOH of a green hydrogen project in Southern Africa for different support mechanisms and different construction times

Case	LCOH (US$/kg$H_2$)	NPV (US$/kW)	NPV Variation (%)
Reference case	4.36	- 1,406	NA
Operational support over 10 years	2.42	- 450	68%
1-year construction delay	4.60	- 1,426	-1%
2-year construction delay	4.97	- 1,443	-3%

Note: This analysis assumes a market price of US$1.5/kg$H_2$. The NPV is calculated per kW installed electrolyzer capacity.

Source: Deloitte analysis based on the renewable endowments from the reanalysis of Copernicus - ERA 5 hourly solar PV capacity factors database,[31] current technology costs for renewables and electrolyzers from IRENA[87] and IEA cost data[88] respectively and country-specific capital costs aligned with IRENA's lower and upper bond estimations.[87] The analysis assumes a US$1.5/kg$H_2$ of hydrogen market price, and the NPV is calculated over kW installed electrolyzer capacity.

As summarized in Table 2, support mechanisms can impact the economic and financial viability of green hydrogen projects differently. Operational and investment support mechanisms can increase the bankability of green hydrogen projects. Nevertheless, in the current grounds where the environmental impacts of grey hydrogen are not reflected in its market value, increasing competitiveness of green hydrogen projects requires not only supply-side subsidies but also ambitious carbon taxing and other mechanisms to help create a level playing field for green hydrogen projects. Deloitte's analysis shows that one of the main enablers of competitiveness of green hydrogen in developing economies is enabling suitable financing conditions. Reduced WACC to the similar levels as the developed economies can bring the financing costs down and render green hydrogen projects bankable in the developing economies. This stems from high capital intensiveness of green hydrogen projects. In addition, this analysis suggests that investment support can be more efficient than operational support such as IRA, thanks to their higher effect on the LCOH of green hydrogen. This can also bring a significant increase in the NPV of the projects.

> Deloitte's analysis shows that one of the main enablers of competitiveness of green hydrogen in developing economies is enabling suitable financing conditions.

4. Recommendations

Unlocking decarbonization potential of green hydrogen requires important policy and regulatory action. The findings of the analysis underline the importance of actions activating four different levers of facilitating development of green hydrogen projects, notably in developing economies:

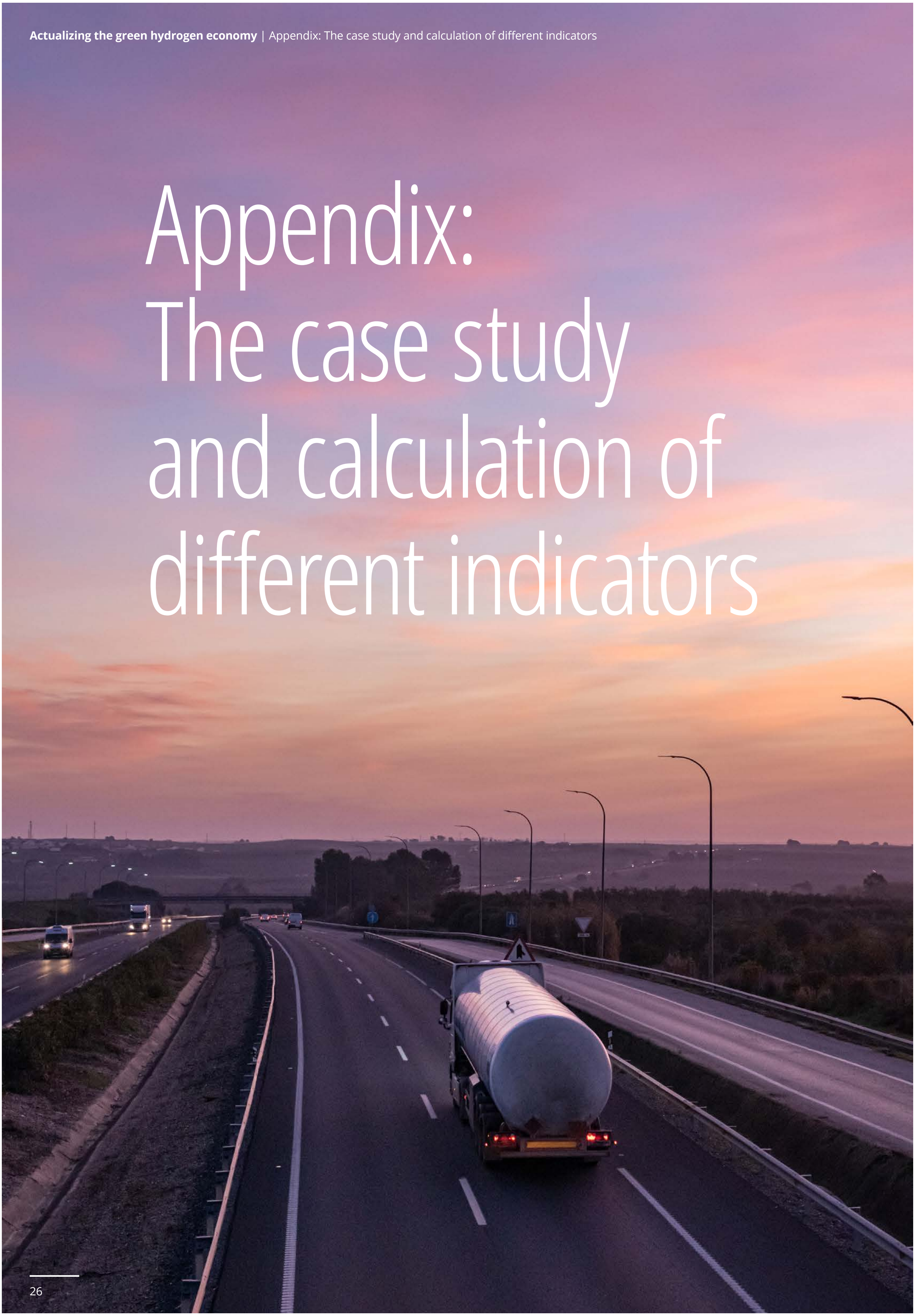
- **Facilitate deployment:** Given the current climate emergency, action should be imminent. Reducing delays in project development via anchoring permitting processes with a central agency, accelerated environmental impact assessments and strategic environmental assessments, and leveraging the existing infrastructure and retrofitting them to hydrogen infrastructures can help reduce the risks associated with delayed actions.

- **Improve social acceptability:** Sustainability-linked actions in line with the SDGs should acquire public support. Collaboration and empowering local communities, alignment of regulatory measures with Indigenous sustainability perspectives and informed and free consent of the local population through effective participatory processes are key for increased support of the local populations and social acceptability of green hydrogen development.

- **Create the market:** Green hydrogen for different end uses is generally more expensive than its counterparts, and an early adoption of this technology requires both creation of a market where there is a demand for such a product and bridging the cost gap between green hydrogen and the conventional fossil fuels. The projects need to be supported in their early stages, which can take several forms: direct investment or operational support, contracts for differences, offtake contracts, and other demand creation mechanisms such as guarantees of origin and green certificates.

- **Enhance the financing conditions:** Projects in developing and emerging economies with high renewable endowments need facilitated financing and liquidity through blended finance, international green finance and state guarantees to help reduce the cost of capital and consequently the financing costs of the projects.

Appendix: The case study and calculation of different indicators



In the following, the levelized cost of hydrogen (LCOH) and net present value (NPV) calculations and the associated assumptions are presented. They are applied to a case study that corresponds to a green hydrogen production project via electrolysis using solar power in Southern Africa, with investment taking place currently.

Hydrogen production

The available wind and solar potential for green hydrogen production is calculated first by mapping considered regions (Southern Africa and Southern Europe) over an adjustable grid with spatial granularity varying from 1° to 2.5° cells. For each cell, both an annual wind speed time series and an annual solar irradiation time series from the Copernicus - ERA5 dataset[117] were used to help calculate the solar capacity factors at the centroid location of that cell. As such, hourly hydrogen yields are derived from the weather data for the year 2016. Fixed ground-mounted PV systems with optimized tilt angles (as a function of the cell latitude) were considered to represent solar power plants in the model.

The maximum available land on each cell for solar installations lays the groundwork for identifying the PV-based green hydrogen supply potential at that cell. Hydrogen production is then calculated with a Python script for each cell within the regions to get the optimal electrolyzer capacity over PV capacity ratio and annual green hydrogen production per MW of electrolyzer installed capacity.

In the reference case, a 1-year construction period for PV-based green hydrogen production facility is assumed.[118] Therefore, the first kg of hydrogen is produced in the beginning of year 2 and the maintenance and operational expenditures start from that date on. The operational lifetime of the PV-electrolyzer plant is assumed to be 20 years.[60] When construction is delayed, mechanically, the hydrogen production is postponed.

Calculation of levelized cost of hydrogen

The calculation of LCOH is based on economic characteristics of the production facility: equipment investment costs, annual fixed operation and maintenance costs and variable operational costs. Moreover, to reflect the impact of the location on the LCOH, local factors of each cell are added to the investment equations to calculate the levelized cost of the fixed expenditures over a unit of green hydrogen produced. Equation 1 shows the LCOH of green hydrogen production:

$$LCOH = \frac{CAPEX + \sum_{t=1}^{lf} \frac{OPEX_{fixed,t} + OPEX_{var,t} \times E_t}{(1+WACC_t)^t}}{\sum_{t=1}^{lf} \frac{E_t}{(1+WACC_t)^t}} \qquad \textbf{(Eq. 1)}$$

Where CAPEX is the initial investment costs, $OPEX_{fixed,t}$ is the annual fixed operation and maintenance cost in year t, $OPEX_{var,t}$ is the variable operation and maintenance cost that depends on the production level, E_t is the annual hydrogen production output, $WACC_t$ is the weighted average cost of capital in year t and lt is the lifetime of the production facility.

Table 3 shows the used input data in the calculation of the PV-based green hydrogen LCOH.

Table 3. Hydrogen production technologies cost data

Technology	Efficiency	Lifetime	Over-night cost ($\text{US\$}_{2017}$ / MW_e)	Variable O&M costs ($\text{US\$}_{2017}$ / MWh_e)			Fixed O&M cost ($\text{US\$}_{2017}$ / MW_e)		
Year	2020	2025	2020	2020	2030	2040	2020	2030	2040
PV	100%	25	649	0	0	0	14	12	1
Alkaline Electrolysis	62.5%	20	793	0.53	0.53	0.53	11.9	5.8	5.8

Source: Deloitte calculations, based on IEA (2019),[119] Bolat and Thiel (2014)[120]

A premium on the production is normally constant over time, without any indexation to inflation or discounting effect. The premium is included in LCOH calculation to show its direct effect on the overall LCOH reduction (Equation 2).

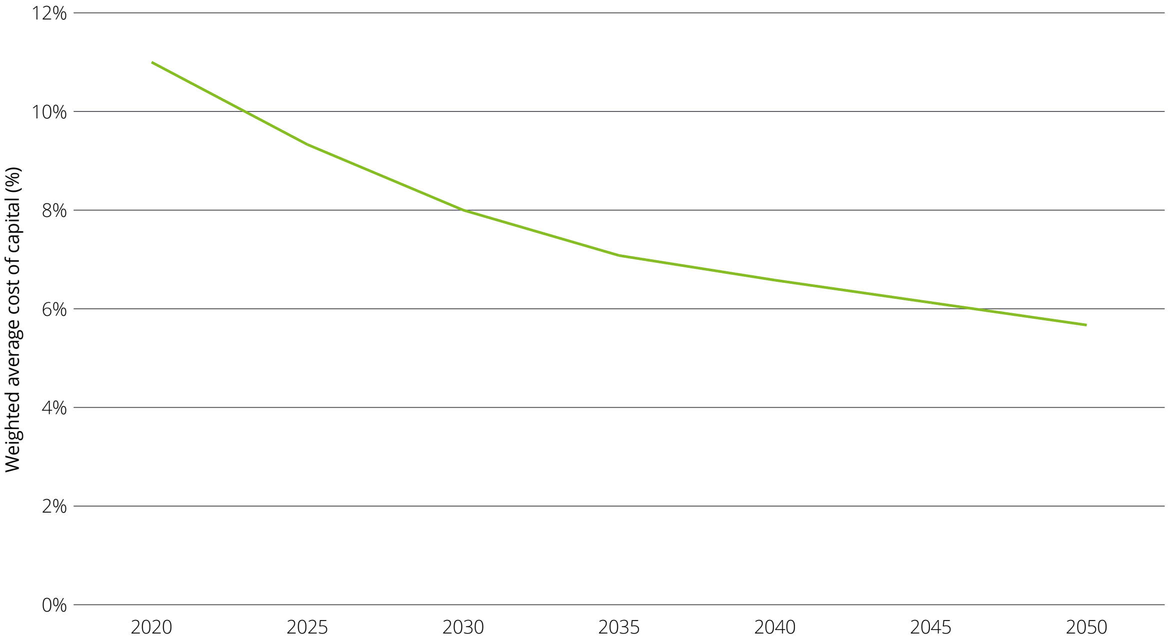
$$LCOH = \frac{CAPEX + \sum_{t=1}^{lf} \frac{OPEX_{fixed,t} + OPEX_{var,t} \times E_t - H_2premium \times E_t}{(1+WACC_t)^t}}{\sum_{t=1}^{lf} \frac{E_t}{(1+WACC_t)^t}} \qquad \textbf{(Eq. 2)}$$

On the contrary, the investment support is given at year 0, which has no depreciation impact because of the interest rates. Including this support in the LCOH formula is shown in Equation 3.

$$LCOH = \frac{CAPEX - Investment\_support + \sum_{t=1}^{lf} \frac{OPEX_{fixed,t} + OPEX_{var,t} \times E_t}{(1+WACC_t)^t}}{\sum_{t=1}^{lf} \frac{E_t}{(1+WACC_t)^t}} \qquad \textbf{(Eq. 3)}$$

The cost of capital consists of regulatory risks, political risks, off-taker risks, currency risks and other land, resource, and technical risks. Among these elements, regulatory and political risks can account for up to half of the weight of the risk elements.[121] Values of current WACC were derived from IRENA's 2022 World Energy Transitions Outlook: 1.5°C Pathway report,[122] while future WACC values are based on extrapolation. This methodology allows the approximation of a country-dependent risk-adjusted WACC for the LCOH calculation over the plant's lifetime. WACC values are assumed to be decreasing thanks to reduced risks via progressive adoption of hydrogen technologies and uptake in demand. The WACC values are converging across different countries following the assumption of growing financial risk transfer mechanism or resort to international finance. This assumption leads to bringing the WACC of the countries with high political and regulatory risks to the same levels as more stable regions such as Europe (6% by 2050). Figure 10 shows the evolution of the WACC considered in this study for Southern Africa.

Figure 10. The considered WACC value evolution in Southern Africa



Source: Current values based on IRENA's 2022 World Energy Transitions Outlook: 1.5°C Pathway[12] report and the future projections extrapolated assuming reaching 6% in the long run

Financing costs refer to the depreciation of the investments. In other words, financing costs are the additional costs stemming from the early spent money and its potential interests. These costs are directly related to weighted average cost of capital. In case of considering a WACC value of zero, the financial costs are zero. Therefore, to identify the part of the financing costs from the overall costs, LCOH with a 0% WACC value should be subtracted from the LCOH with the real WACC.

Calculation of net present value

The NPV of each scenario of the case study is determined by calculating the costs (negative cash flows) and revenues (positive cash flows) for each year over the facility's lifetime. The future cash flows are discounted to represent the real time value of money (Equation 4), where B_t are the benefits or cash inflows, and C_t are the costs or cash outflows.

$$NPV = \sum_{t=0}^{lf} \frac{B_t}{(1+WACC)^t} - \sum_{t=0}^{lf} \frac{C_t}{(1+WACC)^t} \qquad \textbf{(Eq. 4)}$$

The benefits are calculated by multiplying the sold quantity by the reference market price, while the costs are the sum of capital and fixed and variable operational and maintenance costs, the loan payments, and the tax payments. Table 4 summarizes the financial assumptions for the NPV calculation.

Table 4. Financial and economic data of the case study

Parameter	Value
Debt share	20%
Debt tenor	10 years
Corporate tax rate	28%
Depreciation schedule	Base: 100% of CAPEX / Year 1: 50% / Year 2: 30% / Year 3: 20%
Hydrogen sell price	US$1.5/kgH2

Source: Deloitte calculations, based on IEA [123,124]

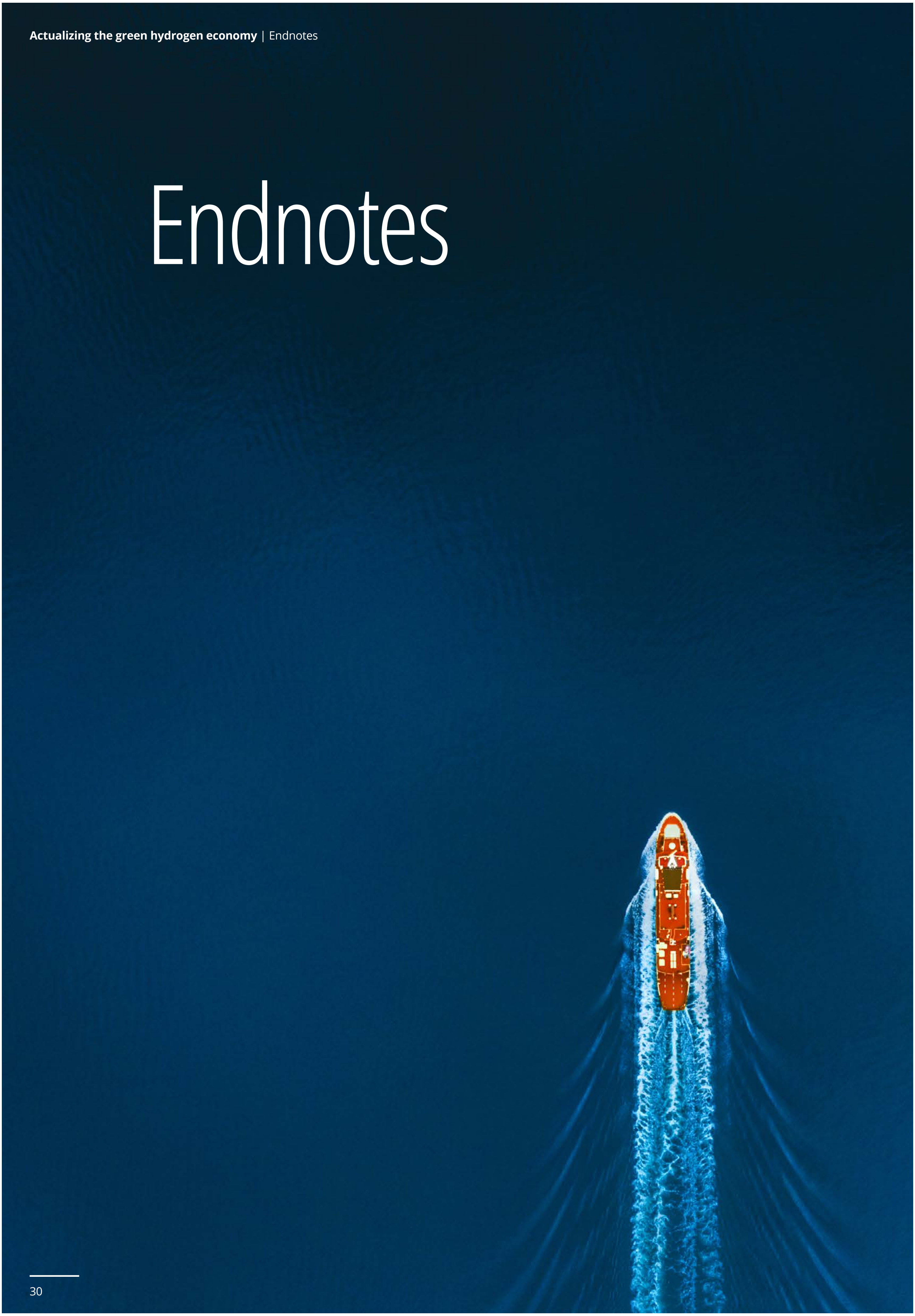
Overall support from public entities

The case study assesses the impact of different support mechanisms on the LCOH reduction. To be able to compare the cost-reduction effect of both types of support, the same overall amount of monetary support is considered. For operational support, similar to the US Inflation Reduction Act (IRA), a US\$1.5/kgH_2 premium over 10 years is considered. The calculations assume that hydrogen production premium support would, in the first few years, come from developed countries. This is consistent with current European cooperation with developing countries such as Namibia for future green hydrogen imports. Therefore, the interest rate taken to represent the time value of money for operational support is chosen based on European countries' public interest rate.[41] Total support is equal to the sum of operational support for each year discounted based on a 3% public interest rate (Equation 5). The same total is then used for investment support, in the beginning of the project investment.

$$Total\_support = \sum_{t=0}^{lf} \frac{E_t \times H_2premium}{(1+r)^t} \qquad \textbf{(Eq. 5)}$$

Where r is the public interest rate and H_2premium is the hydrogen production premium support in US\$/kgH_2 unit.

Endnotes



1. Intergovernmental Panel on Climate Change, Synthesis Report of the IPCC Sixth Assessment Report (AR6), 2023.
2. Jiesper Tristan Strandsbjerg Pedersen and others, 'IPCC Emission Scenarios: How Did Critiques Affect Their Quality and Relevance 1990–2022?' 75 Global Environmental Change 102538 (2022).
3. Intergovernmental Panel on Climate Change, Synthesis Report of the IPCC Sixth Assessment Report (AR6), 2023. P.58
4. United Nations Environment Programme, "The Closing Window, Emissions Gap Report" UNEP, 2022.
5. Intergovernmental Panel on Climate Change, Synthesis Report of the IPCC Sixth Assessment Report (AR6), 2023 p.62.
6. Intergovernmental Panel on Climate Change, Synthesis Report of the IPCC Sixth Assessment Report (AR6), 2023 p. 63.
7. United Nations Environment Programme, "The Closing Window, Emissions Gap Report" UNEP, 2022. p.38.
8. Intergovernmental Panel on Climate Change, Synthesis Report of the IPCC Sixth Assessment Report (AR6), 2023 p. 66.
9. Intergovernmental Panel on Climate Change, Synthesis Report of the IPCC Sixth Assessment Report (AR6), 2023 p. 79.
10. Stammer, Detlef and others, "Hamburg Climate Futures Outlook: Assessing the Plausibility of Deep Decarbonization by 2050," Universität Hamburg, 9 June 2021.
11. Oytun Babacan et al., "Assessing the feasibility of carbon dioxide mitigation options in terms of energy usage," Nature Energy Vol. 5(9), 2020.
12. Behrang Shirizadeh and Philippe Quirion. "The importance of renewable gas in achieving carbon-neutrality: Insights from an energy system optimization model," Energy Vol. 255, 2022.
13. Henri Waisman et al., "Key technological enablers for ambitious climate goals: insights from the IPCC special report on global warming of 1.5° C," Environmental Research Letters Vol. 14(11), 2019.
14. Julianne DeAngelo et al., "Energy systems in scenarios at net-zero CO2 emissions," Nature communications Vol. 12(1), 2021.
15. Behrang Shirizadeh and Philippe Quirion, "Low-carbon options for the French power sector: What role for renewables, nuclear energy and carbon capture and storage?," Energy Economics Vol. 95, 2021.
16. United Nations Environment Programme, "The Closing Window, Emissions Gap Report" UNEP, 2022, p. XXII.
17. International Energy Agency, "Hydrogen – Analysis," 2022.
18. Parkinson, B., Balcombe, P., Speirs, J. F., Hawkes, A. D., & Hellgardt, K. (2019) 'Levelized cost of CO2 mitigation from hydrogen production routes' Energy & environmental science, 12(1), p.19-40.
19. Deloitte, "Green hydrogen: Energyzing the path to net zero – Deloitte's 2023 global green hydrogen outlook,", June 2023.
20. Johannes Trüby et al., "How green hydrogen conquers the world – an outlook on the global clean hydrogen market," 8th Multi-stakeholder Forum on Science, Technology and Innovation for the Sustainable Development Goals, May 2023.
21. United Nations Environment Programme, "The Closing Window, Emissions Gap Report" UNEP, 2022 p. 43.
22. Inal, O. B., Zincir, B., & Dere, C. (2021) 'Hydrogen as Maritime Transportation Fuel: A Pathway for Decarbonization' In Greener and Scalable E-fuels for Decarbonization of Transport (pp. 67-110). Singapore: Springer Singapore.
23. Timmons, D., & Terwel, R, "Economics of aviation fuel decarbonization: A preliminary assessment," Journal of Cleaner Production, 369, 133097, (2022).
24. Stöckl, F., Schill, W. P., & Zerrahn, A, "Optimal supply chains and power sector benefits of green hydrogen," Scientific reports, 11(1), 14191 (2021).
25. Behrang Shirizadeh and Philippe Quirion, "Long-term optimization of the hydrogen-electricity nexus in France: Green, blue, or pink hydrogen?," Energy Policy Vol. 181, 2023.
26. International Renewable Energy Agency, "Making the Breakthrough; Green Hydrogen Policies and Technology Costs," 2020.
27. United Nations Environment Programme, "The Closing Window, Emissions Gap Report" UNEP, 2022 p.45.
28. Directive 2001/77/EC i f the European Parliament and of the Council of 27 September 2001 on the promotion of electricity produced from renewable energy sources in the internal electricity market [2001] OJ L 283/33 27 October 2001.
29. Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC [2009] OJ L 140/16, 5 June 2009.
30. Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources [2018] OJ L 328, 21 December 2018.
31. Communication of February 2023 from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions a Green Deal Industrial Plan for the Net-Zero Age [2023] COM (2023) 62 final
32. Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources [2018] PE/48/2018/REV/1.
33. European Council, Fit for 55 package 2021.
34. European Commission, "The Green Deal Industrial Plan: Putting Europe's Net-Zero Industry in the Lead," Press Release, 2023.
35. Communication of July 2020 from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions Powering a Climate-Neutral Economy: An EU Strategy for Energy System Integration [2020] COM/2020/299 final.

36. Communication From the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions on the European Hydrogen Bank [2023] COM/2023/156 final
37. Directorate-General for Energy, "Commission Outlines European Hydrogen Bank to Boost Renewable Hydrogen," 16 March 2023.
38. Lena Maria Ringsgwandl and others, 'Current Legislative Framework for Green Hydrogen Production by Electrolysis Plants in Germany', 15 Energies (2022).
39. Federal Ministry for Economic Affairs and Climate Protection, Ordinance of the German Federal Government on the Implementation of the Renewable Energy Sources Act 2021 and on the Amendment of Other Energy Regulations 2021 (DE).
40. The IPCEI as a joint investment effort by cooperating European companies, flanked by state funding, provide an important impetus in the European internal market, and thus strengthen growth, employment, innovative ability, and global competitiveness throughout Europe. This instrument is intended to promote integrated projects along the entire hydrogen value chain. See more at Frequently asked questions about the Important Project of Common European Interest (IPCEI)
41. The National Hydrogen Strategy 2020 (DE).
42. Act on the Prevention of Harmful Effects on the Environment Caused by Air Pollution, Noise, Vibration and Similar Phenomena (Bundes-Immisionsschutzgesetz, BImSchG) 2002 (DE).
43. Electricity and Gas Supply Act (EnWG) 2005 amended in 2023 (DE)
44. Federal Ministry of Education and Research, Announcement of funding guidelines for international hydrogen projects under the National Hydrogen Strategy and the Economic Stimulus Package: Combating Corona Consequences, Safeguarding Prosperity, Strengthening Future Capability 2021.
45. Kim Talus and Maxwell Martin, 'A Guide to Hydrogen Legislation in the USA: A Renewed Effort', 15 The Journal of World Energy Law & Business (2022) .
46. Office of Energy Efficiency & Renewable Energy and Hydrogen and Fuel Cell Technologies Office, "Financial Incentives for Hydrogen and Fuel Cell Projects," accessed May 2023.
47. James M. Berger and Deanne Barrow, "Financing California Hydrogen Projects Using LCFS Credits," Norton Rose Fullbright, 8 December 2020.
48. State of California, "California Launches State-wide Alliance to Establish Federally Co-Funded Hydrogen Hub," Press Release, October 2022.
49. U.S Department of Energy, "DOE Establishes Bipartisan Infrastructure Law's US$9.5 Billion Clean Hydrogen Initiatives," 15 February 2022.
50. Office of the Texas Governor, "Governor Abbott Celebrates Construction Of Nation's Largest Green Hydrogen Facility In Texas," Press Release, December 2022.
51. Government of the Republic of Namibia, National Energy Policy 2017 (NM).
52. Government of the Republic of Namibia, Electricity Act 2007, Section 17 (NM).
53. Namibia Investment Promotion and Development Board, "Namibia Energy Sector Overview," 2023.
54. Office of the Prime Minister, Government of Namibia, The Harambee Prosperity Plan 2021-2025 (NM).
55. Ministry of Mines and Energy Namibia, "Namibia Green Hydrogen & Derivatives Strategy," 2022
56. Sowmya Sundar, "Namibia to Sign Implementation Agreement for US$10bln Green Hydrogen Project in Q2," Zwaya Projects , 9 March 2023.
57. Republic of Namibia, Constitution of the Republic of Namibia,1990, Article 100 (NM).
58. Republic of Namibia, Constitution of the Republic of Namibia,1990, Article 16(2) (NM).
59. Ministry of Mines and Energy Namibia, "Namibia Green Hydrogen & Derivatives Strategy," 2022
60. Bank of Namibia, "Welwitschia Fund," accessed May 2023.
61. Lee Godden, "Energy Law and Regulation in Australia," Handbook of Energy Law in the Low-Carbon Transition (De Gruyter, 2023), accessed 17 May 2023.
62. Peter Christoff and Robyn Eckersley, 'Convergent Evolution: Framework Climate Legislation in Australia' 21 Climate Policy, (2021).
63. Government of South Australia, National Electricity (South Australia) Act 1996, (AUS).
64. Government of South Australia , National Gas (South Australia) Act 2008, (AUS).
65. Government of South Australia, National Energy Retail Law (South Australia) Act, 2011(AUS).
66. Tim Nelson, Tahlia Nolan and Joel Gilmore, 'What's next for the Renewable Energy Target – Resolving Australia's Integration of Energy and Climate Change Policy?,' 66, Australian Journal of Agricultural and Resource Economics (2022) .
67. Department of Climate Change, Energy, the Environment and Water, "Extending the National Gas Regulatory Framework to Hydrogen Blends and Renewable Gases," Commonwealth of Australia, 2022.
68. Australia's National Hydrogen Strategy, 2019.
69. Commonwealth of Australia, Native Title Amendment Bill, 1997 (AUS).
70. Government of South Australia, Hydrogen and Renewable Energy Act – Draft Regulatory Impact Statement, 2023 (AUS).
71. Department of Planning, Industry and Environment, New South Wales, NSW Hydrogen Strategy, October 2021.
72. Government of South Australia, Hydrogen and Renewable Energy Act – Draft Regulatory Impact Statement, 2023 (AUS).
73. Department of Climate Change, Energy, the Environment and Water, "State of Hydrogen," Commonwealth of Australia, 2022

74. The Australia-Germany Hydrogen Accord, Governments of Australia and Germany.
75. United Arab Emirates, "Climate Change and the UAE's Response: The UAE's response to climate change," accessed June 2023.
76. Masdar, About Masdar, accessed June 2023.
77. Deena Kamel, "UAE in Deal to Develop National Hydrogen Strategy," Business, 25 September 2022.
78. Dawud Ansari, "The Hydrogen Ambitions of the Gulf States: Achieving Economic Diversification While Maintaining Power," SWP Comment, 2022, accessed 29 May 2023.
79. Waheed Abbas, "UAE Plans to Invest Nearly Dh600 Billion in Clean Energy," khaleej times, 23 November 2022.
80. United Arab Emirates, Ministry of Energy and Infrastructure, "UAE Hydrogen Leadership Roadmap," 4 November 2021.
81. Kingdom of Morocco, Feuille de Route de l'Hydrogène Vert 2021.
82. Camilla Froehlich and Kristina Laewen, "Germany's Green Hydrogen Revolution: Key Partnerships in the Making," Hogan Lovells, 10 December 2021.
83. Kingdom of Morocco, Feuille de Route de l'Hydrogène Vert 2021.
84. See also, Dr Thomas Longden, 'Analysis of the Australian Hydrogen Strategy' (Konrad Adenauer Stiftung 2020).
85. Camilla Froehlich and Kristina Laewen, "Germany's Green Hydrogen Revolution: Key Partnerships in the Making," Hogan Lovells, 10 December 2021.
86. Deloitte analysis based on open-source land-use data, using the Geofabrik and Monte-Carlo methods
87. International Renewable Energy Agency, "Renewable Power Generation Costs," 2022.
88. International Energy Agency, "Electrolyzers – Analysis," 2022.
89. Paul Bledsoe and Elan Sykes, "America's clean energy transition requires permitting reform," Progressive Policy Institute, September 2022.
90. Intergovernmental Panel on Climate Change, "Synthesis Report of the IPCC Sixth Assessment Report (AR6)," 2023.
91. Deloitte, "Transform to react: Climate policy in the new world order," 7 June 2022.
92. International Energy Agency, "Global hydrogen review 2021" 2021.
93. Hydrogen 4EU, "Charting pathways to enable net zero – 2022 edition," December 2022.
94. International Renewable Energy Agency, "Green hydrogen: A guide for policymaking," November 2020.
95. European Commission, "EU funding programmes and funds 2021-2027: Innovation Fund," May 2023.
96. European Commission, "EU funding programmes and funds 2021-2027: Connecting Europe Facility – Energy," May 2023.
97. Hy24, "Hy24 website," accessed May 2023.
98. International Energy Agency, "World Energy Investment 2023," 2023.
99. European Investment Bank, "Guarantees," accessed May 2023.
100. Environmental Investment Fund of Namibia, "SDG Namibia One," Press Release, 20 June 2023.
101. Ministy of Economic Affairs and Climate Policy, "SDE ++ 2022: Stimulation of Sustainable Energy Production and Climate Transition", accessed May 2023.
102. US Office of Energy Efficiency & Renewable Energy, "Financial Incentives for Hydrogen and Fuel Cell Projects," accessed May 2023.
103. Carbon dioxide equivalent (CO2eq) is a metric measure used to compare the emissions from various greenhouse gases based on their global-warming potential (GWP), by converting amounts of other gases to the equivalent amount of carbon dioxide with the same global warming potential.
104. Clean Hydrogen Partnership, "Who we are," accessed May 2023.
105. H2Global Stiftung, "The H2 Global Instrument," accessed May 2023.
106. European Commission, "Commission outlines European Hydrogen Bank to boost renewable hydrogen," March 2023.
107. Our World in Data, "Which countries have a carbon tax?," 14 October 2022, accessed May 2023.
108. International Renewable Energy Agency, "Low-cost Finance for the Energy Transition," 2023.
109. Climate Bonds Initiative, "Hydrogen Production Criteria", accessed May 2023.
110. European Commission "Proposal for a regulation of the European Parliament and of the council on establishing a framework of measures for strengthening Europe's net-zero technology products manufacturing ecosystem (Net Zero Industry Act)," (2023), Article 6.
111. European Commission, "Critical Raw Materials: ensuring secure and sustainable supply chains for EU's green and digital future," March 2023.
112. Australia, Canada, the EU, Finland, France, Germany, Japan, South Korea, Sweden, and the UK.
113. U.S. Department of State, "Minerals Security Partnership," accessed May 2023.
114. NPV is the difference between the present value of cash inflows and the present value of cash outflows over a period of time. Positive NPV means that a project is interesting from a financial point of view, while negative NPV means that the expenses cannot be recovered during the commissioning of it.
115. MTS Markets, "RepoFunds Rate ("RFR") in Europe," 31 May 2023.
116. International Energy Agency, "Energy Technology Perspectives 2023 – Analysis", January 2023.

117. Hersbach, H., Bell, B., Berrisford, P., Biavati, G., Horányi, A., Muñoz Sabater, J., Nicolas, J., Peubey, C., Radu, R., Rozum, I., Schepers, D., Simmons, A., Soci, C., Dee, D., Thépaut, J-N. (2023): ERA5 hourly data on single levels from 1940 to present. Copernicus Climate Change Service (C3S) Climate Data Store (CDS), DOI: 10.24381/cds.adbb2d47 (Accessed on 20-06-2023).
118. International Energy Agency, "Energy Technology Perspectives 2023," 12 January 2023.
119. International Energy Agency, "Innovation Gaps,“ May 2019.
120. Bolat, P., & Thiel, C. " Hydrogen supply chain architecture for bottom-up energy systems models. Part 2: Techno-economic inputs for hydrogen production pathways. International journal of hydrogen energy," 39(17), 8898-8925 (2014).
121. International Energy Agency, "Cost of Capital Observatory," 2022.
122. International Renewable Energy Agency, "World Energy Transitions Outlook: 1.5°C Pathway," March 2022.
123. International Energy Agency, "The cost of capital in clean energy transitions," 17 December 2021.
124. International Energy Agency, "Global Hydrogen Review 2021," October 2021.

Authors and Contacts

Authors

Prof. Dr. Bernhard Lorentz
Deloitte Center for Sustainable Progress (DCSP) Founding Chair
Managing Partner | Deloitte Germany
+49 15114881437
blorentz@deloitte.de

Dr. Johannes Trüby
Deloitte Economics Institute
Partner | Deloitte France
+33 155616211
jtruby@deloitte.fr

Dr. Pradeep Philip
Deloitte Economics Institute
Partner | Deloitte Australia
+61 416214760
pphilip@deloitte.com.au

Dr. Freedom-Kai Phillips
Deloitte Center for Sustainable Progress (DCSP)
Director | Deloitte Canada
+1 6475296621
fphillips@deloitte.ca

Dr. Behrang Shirizadeh
Deloitte Financial Advisory
Manager | Deloitte France
+33 670268419
bshirizadeh@deloitte.fr

Clément Cartry
Deloitte Financial Advisory
Senior Consultant | Deloitte France
+33 140882817
ccartry@deloitte.fr

Clémence Leveque
Deloitte Financial Advisory
Consultant | Deloitte France
+33 140882800
cleveque@deloitte.fr

Tatenda L. Wangui
Sustainability & Climate
Consultant | Deloitte Germany
+49 15140678924
luwangui@deloitte.de

Deloitte Global Contacts

Jennifer Steinmann
Sustainability & Climate leader,
Deloitte Global
jsteinmann@deloitte.com

Prof. Dr. Bernhard Lorentz
Deloitte Center for Sustainable Progress (DCSP) Founding Chair
Partner | Deloitte Germany
blorentz@deloitte.de

Dr. Pradeep Philip
Deloitte Economics Institute
Partner | Deloitte Australia
pphilip@deloitte.com.au

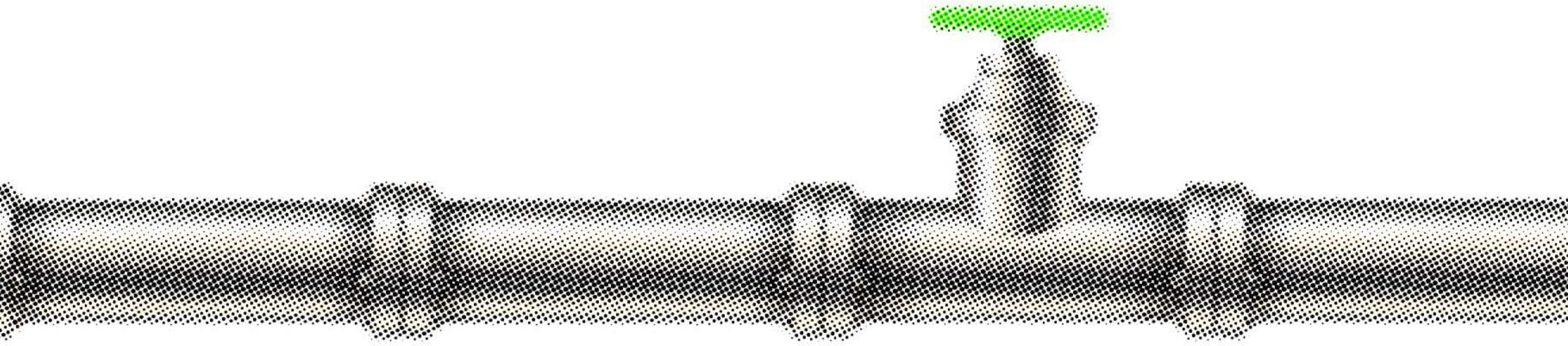
A special thanks to the following individuals who provided their support to help make this report possible:

Ashish Gupta
Barbara Jinks
Blythe Aronowitz
Chaanah Crichton
Dr. Felix Chr. Matthes
Dr. Jan Frederik Braun
Michelle Varney
Moustafa Bayoumi
Peter Bednall
Rebekah Susan Thomas
Richard J Bailey
Stefanie Busch

Deloitte Center for Sustainable Progress

The Deloitte Center for Sustainable Progress (DCSP) is focused on addressing challenges and identifying opportunities in line with reaching the goals of the Paris Agreement, by driving adaptation and mitigation activities, fostering resilience, and informing decarbonization pathways. By assembling eminent leaders and innovating thinkers, the Deloitte Center for Sustainable Progress explores effective and ground-breaking solutions—and collaborates to enable action on the crucial global challenges facing humanity.

To know more about Deloitte Center for Sustainable Progress (DCSP) click here



Deloitte.

About this Publication
This communication contains general information only, and none of Deloitte Touche Tohmatsu Limited (“DTTL”), its global network of member firms or their related entities (collectively, the “Deloitte organization”) is, by means of this communication, rendering professional advice or services. Before making any decision or taking any action that may affect your finances or your business, you should consult a qualified professional adviser.

No representations, warranties, or undertakings (express or implied) are given as to the accuracy or completeness of the information in this communication, and none of DTTL, its member firms, related entities, employees, or agents shall be liable or responsible for any loss or damage whatsoever arising directly or indirectly in connection with any person relying on this communication. DTTL and each of its member firms, and their related entities, are legally separate and independent entities.

About Deloitte
Deloitte refers to one or more of Deloitte Touche Tohmatsu Limited (DTTL), its global network of member firms, and their related entities (collectively, the “Deloitte organization”). DTTL (also referred to as “Deloitte Global”) and each of its member firms and related entities are legally separate and independent entities, which cannot obligate or bind each other in respect of third parties. DTTL and each DTTL member firm and related entity is liable only for its own acts and omissions, and not those of each other. DTTL does not provide services to clients. Please see www.deloitte.com/about to learn more.

© 2023. For information, contact Deloitte Touche Tohmatsu Limited.