UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

BREAKTHROUGH AGENDA

GLOBAL PROGRAMME HYDROGEN IN INDUSTRY

Mapping of financial and technical assistance of clean hydrogen for developing countries

1. Background and objective

Clean hydrogen[1] provides a viable solution for countries to achieve net zero and fulfil their commitments under the Paris Agreement. It can significantly reduce the approximately 28% of the world's annual CO2 emissions stemming from hard-to-abate industrial sectors like chemicals, iron and steel, aluminium, cement, and heavy-duty transport. Furthermore, its widespread application can play a pivotal role in industrial and socio-economic growth, particularly in developing countries endowed with abundant renewable energy potential.

However, the funding committed to hydrogen projects in developing countries remains low - due to a number of barriers and uncertainties in regulatory, economic and financing aspects. It is essential to understand ongoing initiatives where public and private resources are allocated along the clean hydrogen value chain in developing countries.

UNIDO, in cooperation with the Breakthrough Agenda, and with early-stage inputs by the World Bank and IRENA, developed a mapping exercise of financial and technical initiatives on clean hydrogen for developing countries to shed light on ongoing financial and technical assistance initiatives. The mapping exercise was distributed to development finance institutions, international development agencies and governments to identify ongoing hydrogen assistance measures throughout its value chain.

Such assistance measures are crucial for scaling up hydrogen infrastructure, promoting innovation, lowering production costs, and accelerating clean hydrogen uptake in alignment with sustainable development goals and climate targets. With the aim of providing a a global overview, this policy brief reports on a mapping of financial and technical assistance for clean hydrogen initiatives in developing countries and transition economies.

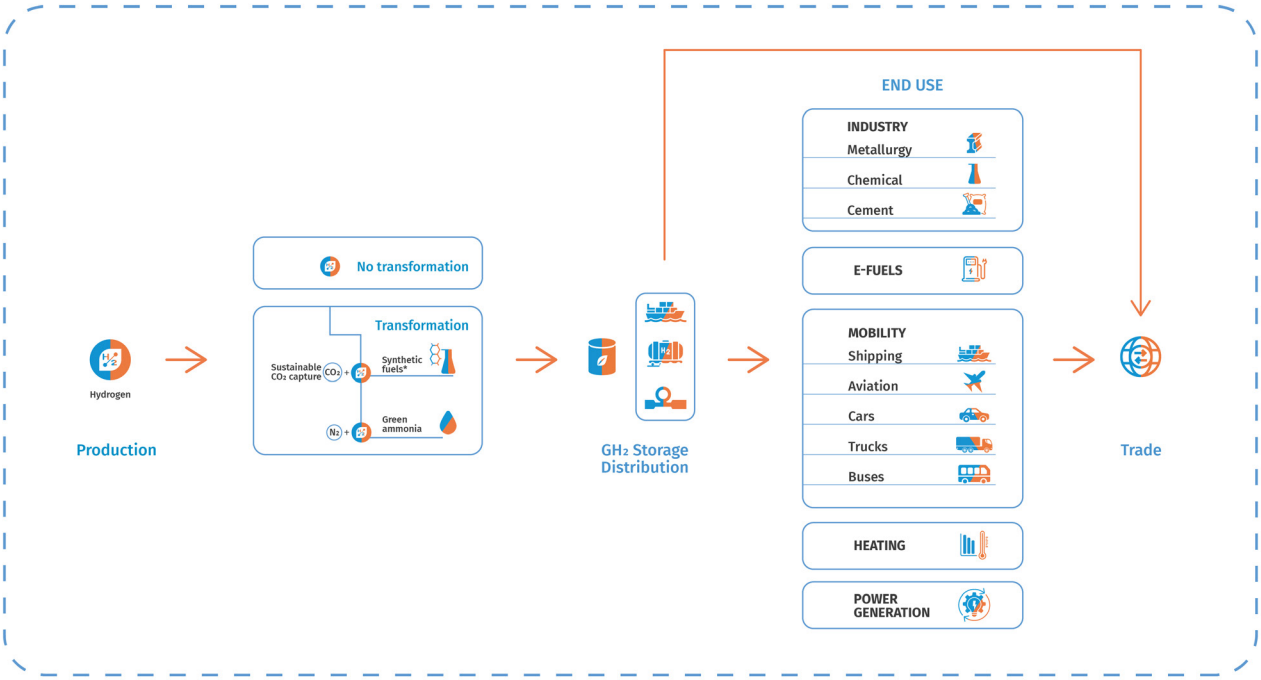
1. Clean, or low-carbon hydrogen refers to both hydrogen produced through electrolysis powered from renewable sources and hydrogen produced from natural gas reforming with carbon capture and storage.

2. Assistance needs in the clean hydrogen value chain

The clean hydrogen value chain (Fig. 1) is typically categorised into three fields: upstream (production), mid-stream (storage and distribution), and downstream (transformation and end uses, both as feedstock and as an energy carrier).

Developing countries require support to realise the opportunities clean hydrogen offers, financial support being a key one. The funding committed to clean hydrogen projects in developing countries remains low, mainly due to persisting barriers and uncertainties in regulatory, economic, and financing aspects. According to the International Renewable Energy Agency (IRENA), total investments of USD 4.6 trillion are needed for green hydrogen and its derivative fuels until 2050 to align the current energy system with a 1.5C pathway. Until 2030 alone, an investment gap (needed-planned) of roughly $460 billion remains across the hydrogen value chain (McKinsey Hydrogen Insights, 2022). A ramp-up in the deployment of financing and technical assistance across all sections of the hydrogen value chain is needed for developing countries to attain their full potential of socio-economic and industrial development.

Figure 1. Clean Hydrogen Value Chain



Assisting developing countries in identifying viable business models and obtaining investment is crucial and development finance institutions, development agencies and donors have a key role to play. With this mapping exercise, UNIDO is aiming to support DFIs and active players in financing by identifying missing gaps. Similarly, the survey reveals gaps where UNIDO and other agencies provide Technical Assistance (TA) complementary to the ongoing Financial Assistance (FA) measures. Initiatives include a cooperation with the World Bank on designing feasible financing instruments as well as the government perspective with various publications on policy measures, e.g. the report “Green Hydrogen for sustainable development: a policy toolkit for developing countries” [2].

2.https://www.unido.org/sites/default/files/files/2024-02/Green%20hydrogen%20for%20Sustainable%20Industrial%20Development%20A%20Policy%20Toolkit%20for%20Developing%20Countries.pdf

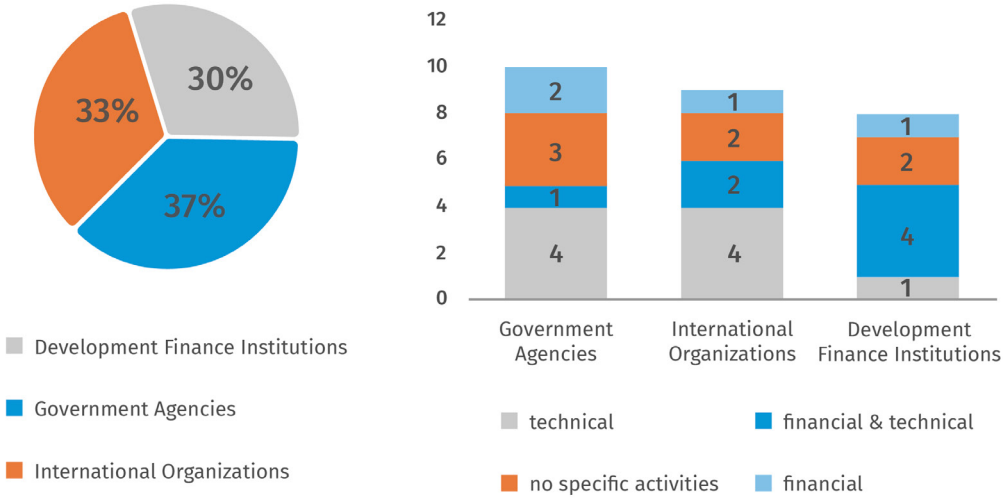
3. The questionnaire approach

The methodology involved the design of two distinct questionnaires—one for financial initiatives and one for technical assistance initiatives. The key focus of the questionnaires was to identify: a) the type of financing instruments or technical assistance being implemented, b) where the assistance is implemented or planned along the hydrogen value chain, and c) how the financing instrument or technical assistance is supporting to create an enabling environment for clean hydrogen.

Within this mapping exercise, the various assistance types were grouped into the three segments of the hydrogen value chain outlined above: upstream, midstream, and downstream. Outside of the value chain lies the trade category (see glossary in annex 3 for category details). The categorization of support measures, in particular the financial ones, was developed based on consultation with the World Bank. Technical assistance categories were defined based on UNIDO experience and the types of TA activities we aim to engage in with developing country counterparts[3]. The financial assistance questionnaire expanded on identifying risks associated with the bankability of clean hydrogen projects via a scoring table (rating from a scale of 1 – Low to 5- High).

Responses were obtained over the course of 9 months, from February to October 2023, which included the follow-up with respondents in the given period to verify and update their provided data. The questionnaire was distributed to 44 institutions across international organizations, government agencies, and development financial institutions between July and September 2023. Responses were received from 61% of the contacted organizations. Figure 2 showcases their classification and the type of assistance provided.

Figure 2. Distribution of responding organisations, including types of assistance programmes



3. Limitations include varying level of granularity in questionnaire sub-categories, which may not capture the full breath and detail of assistance available. This may have led to some respondents under- or misreporting some of their assistance programmes due to a lack of appropriate options, or perceived mismatch of categorizations. As such, the scope of the questionnaire only quantifies a number of specific assistance programmes, and inconsistencies in the results cannot be ruled out. Only the number of assistance initiatives is captured, not their monetary volume. The entire questionnaire aimed to be objective and included a glossary of terms (see annex 3) for the respondent's reference and common understanding.

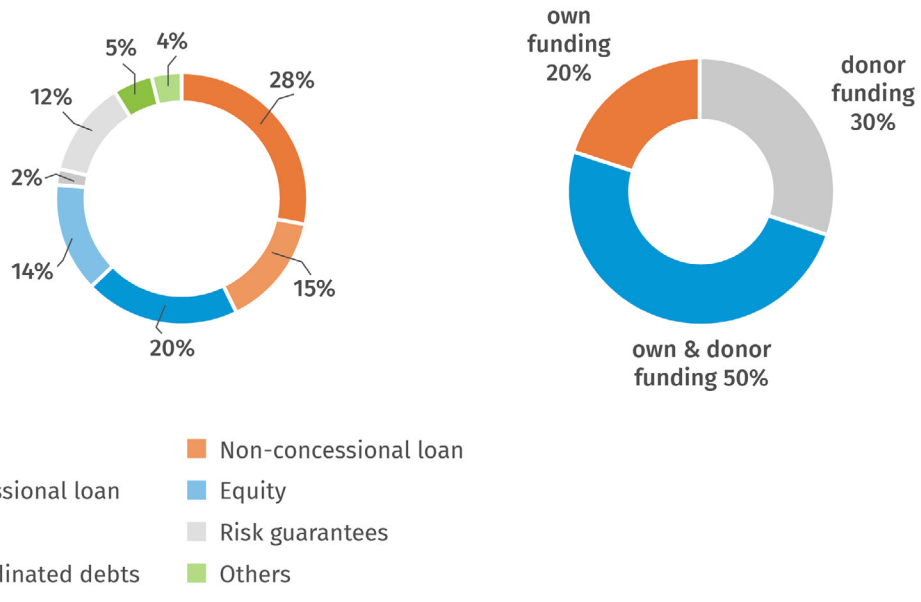
4. The mapping – overview of findings

The findings provide an overview of financial and technical assistance allocated along the value chain as follows:

- Within the current hydrogen landscape, the majority of assistance is directed towards downstream hydrogen applications (financial 65%, technical 58%).
  - » *Mobility* claimed the highest share of both financial (9%) and technical (11%) assistance within downstream applications.
  - » *This is followed by chemicals*, at 8% of financial and 10% of technical assistance.
- Storage and distribution, constituting the midstream segment of the value chain, accounted for 18% of financial and 21% of technical assistance.
- The upstream segment received the least number of assistance programmes, at 13% (both financial and technical).
- The remaining share of assistance (3% financial, 7% technical) does not fall under the value chain categorization, as it is dedicated to promoting trade activities.

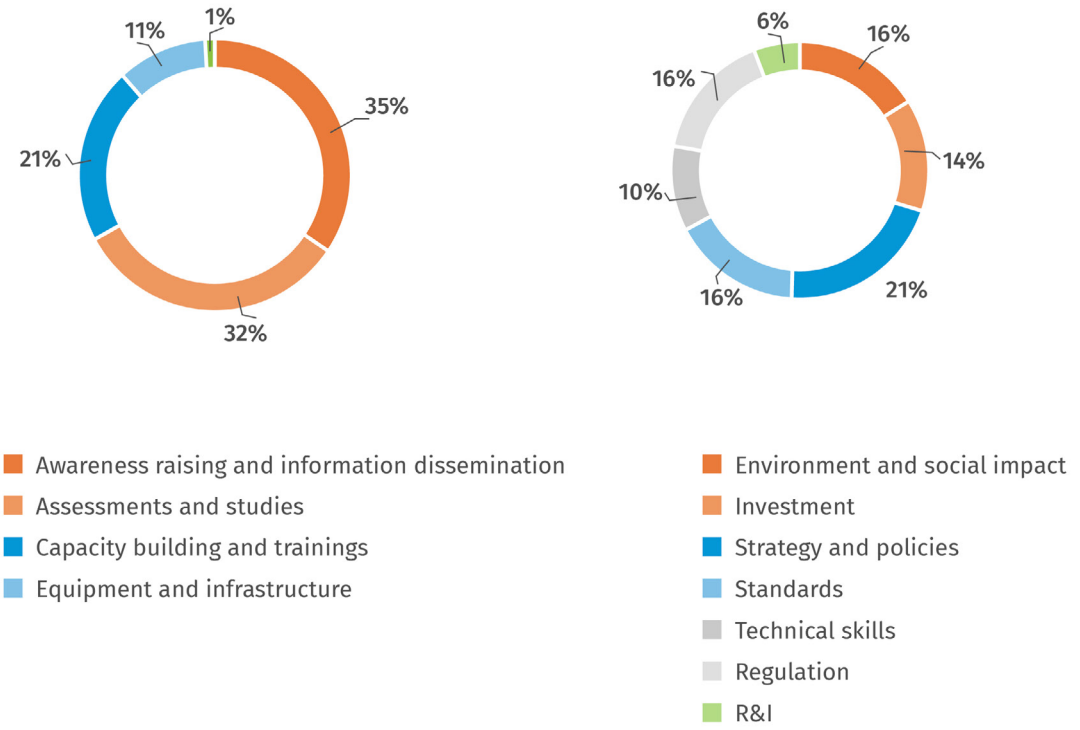
Examining financial assistance in specific, grants emerged as the predominant instrument accounting for 28% (see Figure 3). 10 respondents indicated providing grants to financially support hydrogen production. Concessional loans are the second most used financial instrument, at 20%. Both of these are rather traditional types of financial assistance. Equity can be regarded as a more innovative solution and accounts for 14% of financial assistance programmes. Bonds and subordinated debts were only used by 1 organization at almost all stages of the value chain (see annex 1). As for the source of funding, they are primarily represented through a combination of the respective institution's own sources & donor funding (50%), see Figure 3 below.

Figure 3. Overview of financial assistance types (left) and funding sources (right)



As for technical assistance, awareness raising and information dissemination has been the most prevalent support amongst the questionnaire respondents at 35% (see Figure 4 below), with 15 institutions conducting them in the area of strategies and policies and 14 for hydrogen production or upstream. Assessment and studies is the second most reported type of assistance, at 32%. On the other hand, only 1 organization conducted work on equipment and infrastructure (11% of all technical assistance, see annex 2). In the areas in which technical assistance is granted (right side of Figure 4), the distribution is more even. Strategy and policies received the most assistance at 21%, while technical skills (10%) and research & innovation (6%) received the least.

Figure 4. Overview of technical assistance (per area on the right)



5. Key messages and implications

The responses highlight a need for enhanced distribution and coordination of financial and technical assistance along the clean hydrogen value chain. Of all value chain segments, downstream hydrogen applications (58-65%) received by far the most overall assistance whilst the upstream (13%) and midstream (18-21%) segments are comparatively under-assisted in both types of assistance. Possible explanations include the existence of industrial end-users of fossil-based hydrogen, which are obvious targets for industrial greening assistance.

We should also bear in mind that the responses present a quantification of support initiatives, rather than their monetary volume, which may be distributed differently. Nonetheless, these findings imply a certain imbalance in the current clean hydrogen assistance landscape in terms of distribution along the value chain. Clean hydrogen production and infrastructure will need to be established besides the necessary enabling market uptake to ensure upstream, midstream and downstream operations are interlinked. Particularly midstream transport and distribution solutions are a vital missing link for the clean hydrogen value chain and currently suffer from a less technological readiness level than up- and downstream technologies, thus necessitating enhanced assistance.

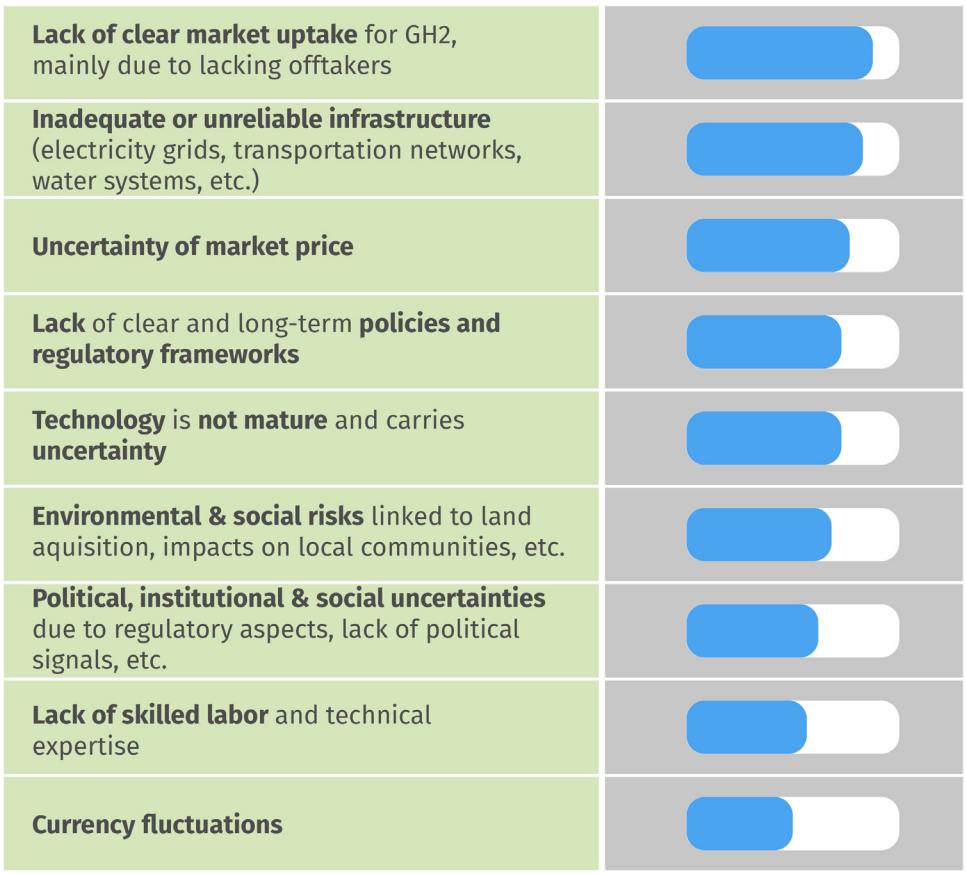
As such, more efforts are required to balance out the assistance portfolios for clean hydrogen development, and support needs to address both the supply and demand side of the equation, plus the connecting distribution network.

Financial Assistance

The questionnaire respondents reported **almost no financial assistance in the form of bonds** (only 5 in total, 2% of all reported assistance initiatives, by one single institution). Green bonds, issued by governments, private entities, and development banks, are designed to fund environmentally sustainable projects such as clean hydrogen initiatives and offer a favourable risk ratio. Bonds constitute an enormous financing potential, with the global bonds market valued at around USD 100 trillion, double the volume of the equity market (equity accounts for 14% of financial assistance among respondents). Accordingly, bonds can redirect significant capital to sustainable projects, but this potential remains largely untapped.

The questionnaire further identified financial risk perceptions towards clean hydrogen projects. The primary concern is centred on the **lack of a clear market and off-take commitment**. This is mainly attributed to limited existing demand and potential from off-takers to commit to purchasing clean hydrogen. This uncertainty affects project developers and investors alike. Additionally, **inadequate or unreliable infrastructure**, including electricity grids, transportation networks, and water supply systems, presents significant challenges such as increasing costs and causing project development delays. Other significant risk factors emerging from the responses are market price uncertainty, lack of regulatory clarity and technological immaturity. A lack of skilled labour appears to only play a small role in investor considerations, and currency fluctuations are the least concern.

Figure 5. Overview of financial risk perceptions for clean hydrogen projects



Respondents collectively acknowledge the uncertainty and risk inherent in their respective assistance measures, necessitating collaborative efforts and knowledge-sharing for sector resilience. Implications for project planning and implementation underscore the importance of integrating clear market strategies, robust infrastructure planning, and stable regulatory environments, alongside the development of risk mitigation frameworks to ensure long-term success in the clean hydrogen sector.

Technical Assistance

Assessment and studies are the most prevalent technical assistance area at 34%, especially in strategies and policies where 15 institutions are represented. Capacity building and skills development claims a solid 21-24% of all covered technical assistance initiatives. There is a precedented need to centre assistance measures in line with the needs of the developing countries as principal producers of clean hydrogen. This will enable a quicker ramp up of production, stable distribution as well as the opportunity for local value chain development and creation of economic and social benefits within producer countries. One type of assistance that is currently underrepresented is equipment and infrastructure, accounting for only 11% and offered by one institution. Akin to the midstream segment of the value chain, equipment and infrastructure represent a key link and precondition for effective clean hydrogen use - as such, resources directed to its support need to be augmented in all areas whenever possible.

The cement sector presents significant findings: It accounted for about 3% of total global greenhouse gas emissions in 2019 (IEA), yet receives the least technical assistance attention of all downstream sectors at only 5% of the total. This is remarkable since its financial assistance share is about the same as all other downstream sectors, at around 8%. Only 5 technical assistance programmes each were directed at awareness and information dissemination (102 total, compare annex 2) for this sector as well as assessments and studies (95 total), while capacity building and training received 3 (62 total) and equipment and infrastructure only 1 (33 total). Considering that the cement sector is one of the most carbon-intense of all industrial sectors at about 0.6 tonnes of CO2 per tonne of cement produced (IEA, 2023), more action is required in this regard. For more information on the TA shares of other sectors, please consult the table in annex 2.

R&I and technical skills are the areas that received the least technical support, accounting for only 6% and 10% of technical assistance programmes respectively. Enhancing such technical assistance areas will be instrumental: Innovation is required to improve efficiency and price competitiveness, whilst no clean hydrogen production and use is possible without an adequately skilled workforce.

6. Conclusions and recommendations

The alignment of financial and technical assistance for clean hydrogen in developing countries along the value chain is essential in developing a holistic approach to upscale the hydrogen ecosystem, especially in developing countries, and thus achieve climate and sustainable development goals. The outcomes of the questionnaire point at a need for better coordination and balance across the value chain to promote supply & demand simultaneously. Currently, downstream applications receive the most financial and technical assistance, whilst the production and distribution of hydrogen require further support.

For financial assistance, the untapped potential of green bonds in financing clean hydrogen projects and call for fostering public-private partnerships and investors' confidence is recognized. To fully leverage the significant potential of the bonds market, financial institutions may consider introducing specific "clean hydrogen bonds". Strengthening the collaboration amongst governments, development finance institutions and international organizations is another promising path forward in financing clean hydrogen projects, as this fosters public-private partnerships which instil confidence in investors.

With regards to technical assistance, there is an identified need for developing adequate equipment and infrastructure. Addressing financial risk perceptions and infrastructure challenges are vital for effective technical assistance delivery, emphasizing the importance of clear market strategies, robust infrastructure planning, and stable regulatory environments. Overall, concerted efforts are needed to ensure a balanced and coordinated approach across all sections of the clean hydrogen value chain for sustainable development and climate mitigation.

Annex 1. Heatmap of financial assistance along the value chain

Overview of financial assistance along the value chain														
Placement in value chain / Type of assistance	Upstream	Midstream		Downstream (end-use)									Total amount	Total %
	Production	Storage	Distribution	Chemicals	Cement	Metallurgy	Mobility	E-fuels	Power	Heating	Others	Trade		
Grant	10	7	7	6	4	6	7	5	5	5	4	1	67	28%
Non-concessional loan	3	3	3	3	3	3	3	3	3	3	3	2	35	15%
Concessional loan	6	4	4	4	4	4	5	4	4	4	3	2	48	20%
Equity	3	3	3	3	3	3	3	3	3	3	3	1	34	14%
Bond	1	0	0	1	1	0	0	1	1	0	0	0	5	2%
Risk guarantees	5	3	3	2	2	2	2	2	2	2	3	1	29	12%
Subordinated debts	1	1	1	1	1	1	1	1	1	1	1	1	12	5%
Others	3	1	1	0	0	0	1	1	0	0	2	0	9	4%
Total	32	22	22	20	18	19	22	20	19	18	19	8		
%	13%	9%	9%	8%	8%	8%	9%	8%	8%	8%	8%	3%	239	
	13%	18%					65%					3%		

Annex 2. Heatmap of technical assistance along the value chain

Overview technical assistance along the value chain														
Placement in value chain / Type of assistance	Upstream	Midstream		Downstream (end-use)									Total amount	Total %
	Production	Storage	Distribution	Chemicals	Cement	Metallurgy	Mobility	E-fuels	Power	Heating	Others	Trade		
Awareness raising and information dissemination	12	9	10	11	5	10	10	9	9	7	1	9	102	35%
Assessments and studies	14	9	12	10	5	8	9	7	7	5	1	8	95	32%
Capacity building and trainings	9	7	8	5	3	3	7	6	6	3	0	5	62	21%
Equipment and infrastructure	4	3	5	3	1	3	5	3	4	2	0	0	33	11%
Equipment and infrastructure	0	0	0	0	0	0	0	1	0	0	1	0	2	1%
Others	39	28	35	29	14	24	31	26	26	17	3	22		
%	13%	10%	12%	10%	5%	8%	11%	9%	9%	6%	1%	7%	294	
	13%	21%					58%					7%		

Annex 3: Glossary of terms

The glossary aims to provide detailed information regarding the common terminologies introduced within the questionnaire.

Section 1. Identifying hydrogen initiatives along the value chain.

The hydrogen sector requires significant ramp-up in the deployment of financing across the value chain. This section of the questionnaire aims to identify which clean hydrogen financing initiatives are applied across the value chain.

Upstream	**Production**	Clean hydrogen refers to both hydrogen produced through electrolysis using electricity from renewable sources such as solar or wind power ("green hydrogen"), and hydrogen produced from natural gas reforming with carbon capture and storage ("blue hydrogen"). • The production of green hydrogen also includes initiatives on the manufacturing, infrastructure, desalination and wastewater treatment associated with its production. • The production of blue hydrogen includes Steam Methane Reforming (SMR) or Autothermal Reforming (ATR) to allow the conversion of natural gas into hydrogen with carbon capture and storage (CCS) technology to mitigate the associated carbon emissions. This section excludes initiatives that only focuses on financing renewable energy and desalination for purposes other than hydrogen.
Mid-stream	**Storage**	Includes storage facilities and the development of infrastructure for gas compression or liquefaction to enable hydrogen storage.
	Distribution	Necessary infrastructure for the transport of hydrogen is considered, including manufactured trucks, rail wagons, gas tankers etc. This also includes initiatives which support the building of infrastructure and retrofitting existing gas lines for hydrogen transport.
Downstream	**End-use**	**Chemical** Initiatives for retrofitting and adaptation of clean hydrogen utilized in chemical sectors including: ammonia and methanol, to reduce emissions from both feedstock production and chemical processes. **Cement** Initiatives on the use of clean hydrogen to reduce emissions from both fuel combustion and the calcination process. **Metallurgy** Clean hydrogen initiatives encompassing various processes involved in decarbonizing the extraction, refining and processing of metals including iron and steel, and aluminum production. **Mobility** Fuel cell electric vehicles, heavy-duty transportation (e.g. trucks, buses and trais), and hydrogen refueling infrastructure such as refueling stations for its widespread adoption are considered. **E-fuels** The production of synthetic e-fuels or electrofuels, gained from renewable energy sources and CO2 air capture is considered. **Power generation** Initiatives on hydrogen application for heating and its relevant adaptations to existing infrastructure and appliances: • Residential and commercial heating through utilizing hydrogen combustion or hydrogen fuel cells to generate heat. • District heating through integrating hydrogen boilers or hydrogen-power heat pumps and distributing heat through network of pipes.
	Trade	Initiatives that support and facilitate trade transaction of hydrogen derived products and its commodities (e.g. green ammonia, methanol and transport fuels) are considered. Contracts for difference are included in this categories.

Section 2. Identifying the type of technical assistance provided for clean hydrogen.

The technical assistance measures are categorized into key areas to identify the development, implementation and scale-up of clean hydrogen initiatives.

Awareness raising and information dissemination	Dissemination of knowledge through workshops, seminars, stakeholder outreach activities and public-private consultative dialogue sessions are relevant. Includes knowledge-sharing platforms.
Assessments and studies	Assessments and studies which identifies the feasibility, viability and impact of clean hydrogen are relevant. Examples include; national roadmaps, strategies, environmental impact assessments, life cycle assessments, technical pre-feasibility and feasibility studies assessing the design, construction and operation of hydrogen production, storage, transportation and end-use.
Capacity building and trainings	Initiatives that aim to build skills and expertise to support the deployment, operation, and maintenance of clean hydrogen are relevant. This includes vocational training programmes, capacity building for policymakers and regulators to develop institutional knowledge and policy environments. Such capacity building and training activities take part in form of workshops and conferences, online training.
Equipment and infrastructure	Examples of equipment and infrastructure needed for clean hydrogen include; electrolyzers, compressors, storage tanks, fuel cells, pipelines and transportation infrastructure, renewable energy sources for green hydrogen. In the case of blue hydrogen, this entails carbon capture, utilization and storage equipment and relevant natural gas infrastructure including pipelines, processing plants and storage facilities.

Section 3. Identifying specific activities to create an enabling environment for clean hydrogen.

Governments of developing countries need to create policy and regulatory frameworks, training and skills development and R&I to incentivize investments. This section aims to identify if the initiatives specifically tackle activities that aim to create an enabling environment for clean hydrogen.

Environmental and social impact evaluation	Environmental and social assessments conducted throughout project development, implementation and operation. Integration of climate change and social objectivities (e.g. emissions intensity, water and land usage, job creation, life cycle analysis of green hydrogen).
Regulation	Legal frameworks that are binding in nature and established by governmental or authoritative bodies. Hydrogen regulations include market-based support schemes (e.g. subsidies, incentives, emissions trading schemes), safety protocols, emissions limits, environmental protection, permit schemes and licensing requirements. Hydrogen standards are distinguished in a different category to better understand the technical assistance towards quality infrastructure, testing, performance and evaluation of hydrogen technologies and international trade facilitation.
Strategy and policy	Activities to support strategy and policy design, to provide an integrated approach to guiding decision-making and facilitating implementation of initiatives. • A strategy articulates the priorities of a country for hydrogen development, identifying key development objectives and the strategic direction it will take to achieve these. A strategy helps to make strategic decisions to allocate resources, prioritize actions and guide activities towards achieving specific outcomes. • Policy consists of a set of measures and means which will be used to achieve the key development objectives defined in the strategy. It focuses on the "how and what" questions related to how/what investment/skills/regulations etc will help to achieve the development, adoption and application of hydrogen objectives specified in the strategy.
Investment	Investment activities include conducting financial assessments, market research and analysis, competitive analysis and the development of investment strategies.
Standards	Activities on standard development related to production, transportation, storage of hydrogen, technical and safety standards, gas quality and carbon intensity of hydrogen. It also includes support to quality infrastructure institutions in charge of assessing the compliance of standards: certification, inspection and/or verification, laboratories.
Technical skills	Upgrading skill activities ensuring the technical skills development in areas along the value chain for clean hydrogen.
Research and innovation	Innovation and research programmes, technology centers, innovation accelerator programmes for clean hydrogen.