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DEUTSCHE ZUSAMMENARBEIT

H2 diplo
HYDROGEN DIPLOMACY

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Synthesis Report

Study on the policy and regulation framework for the build-up of a hydrogen market in Nigeria

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Abbreviations and Acronyms

ATR	Autothermal Reforming
BImSchG	Bundes-Immissionsschutzgesetz
Bln	Billion
BMWK	Federal Ministry of Economic Affairs and Climate Action
CCA	Climate Change Act
CCS	Carbon Capture and Storage
CCUS	Carbon Capture, Utilisation and Storage
CfD	Contract for difference
CO2	Carbon dioxide
CODAHEA	Consortium for the Development of Hydrogen Economy in Africa
CPR	Captive power regulation
DA	Delegated Act
DGIC	Delegation of German Industry and Commerce
DisCos	Power Distribution companies
DNOC	Abu Dhabi National Oil Company
DTCS	Dunatos Technology and Consulting Services
EC	European Commission
ECN	Energy Commission of Nigeria
ECR	Eligible Customer Regulation
EE	Energy Efficiency
EFTA	European Free Trade Association
EnWG	Energiewirtschaftsgesetz
EPSRA	Electric Power Sector Reform Act
ESIA	Environment and Social Impact Assessment
ETO	Energy Transition Office
ETP	Energy Transition Plan
ETWG	Energy Transition Implementation Working Group
EU	European Union
EUR	Euro
FCHO	Fuel Cells and Hydrogen Observatory
FGN	Federal Government of Nigeria
FME	Federal Ministry of Education
FMEnv	Federal Ministry of Environment
FMFBNP	Federal Ministry of Finance Budget and National Planning
FMITI	Federal Ministry of Industry, Trade and Investment
FMP	Federal Ministy of Power

FMSTI	Federal Ministry of Science, Technology and Innovation
FMWR	Federal Ministry of Water Resources
FUTMINNA	Federal University of Technology Minna
GDP	Gross domestic product
GenCos	Generation companies
GESI	Gender Equality and Social Inclusion
GH2	Green hydrogen
GHCS	Green Hydrogen Commercialisation Strategy
GHG	Greenhouse gas
GoA	Government of Australia
GoF	Government of France
GoN	Government of Namibia
GOs	Guarantees of origin
GW	Gigawatt
GWP	Global Warming Potential
H2-Diplo	Global Hydrogen Diplomacy
HINT.Co	Hydrogen Intermediary Company GmbH
ICPE	Installations classées pour la protection de l'environnement
IEA	International Energy Agency
IPCEI	Important Projects of Common European Interest
IPG	International Partners Group
IPP	Independent Power Producer
IRENA	International Renewable Energy Agency
IRP	Integrated Resource Plan
ITMO	International Transfer Mitigation Outcomes
JET	Just Energy Transition
kW	Kilowatt
LHP	Large hydropower plants
LT-LEDS	Long-Term Low-Emission Development Strategy
MJ	Megajoule
Mln	Million
MPR	Ministry of Petroleum Resources
Mt	Million tons
MW	Megawatt
NACCIMA	Nigerian Association of Chambers of Commerce, Industry, Mines and Agriculture
NBET	Nigerian Bulk Electricity Trading
NCCC	National Council on Climate Change

NDC	Nationally determined contributions
NEMP	National Energy Master Plan
NEMSA	Nigerian Electricity Management Services Agency
NEP	National Energy Policy
NEPC	Nigeria Export Promotion Council
NEPZA	Nigerian Export Processing Zones Authority
NERC	Nigerian Electricity Regulatory Commission
NESREA	National Environmental Standards and Regulations Enforcement Agency
NGP	National Gas Policy
NIMBY	Not in My Back Yard effect
NIPC	Nigeria Investment Promotion Commission
NIPP	National Integrated Power Project
NLNG	Nigeria Liquefied Natural Gas
NMDPRA	Nigerian Midstream and Downstream Petroleum Regulatory Authority
NNPC	Nigerian National Petroleum Company
NOA	National Orientation Agency
NPA	Nigerian Port Authority
NREEEP	National Renewable Energy and Energy Efficiency Policy
NUC	Nigerian Universities Commission
NUPRC	Nigerian Upstream Petroleum Regulator Commission
OVP	Office of the Vice President
PHCN	Power Holding Company of Nigeria
PIA	Petroleum Industry Act
PJ	Petajoule
PPA	Power Purchase Agreement
PPI	Presidential Power Initiative
PtX	Power-to-X
PV	Photovoltaic
R&D	Research and Development
RCF	Recycled carbon fuel
RCS	Regulations, codes, and standards
RE	Renewable energy
REAN	Renewable Energy Association of Nigeria
RED II	Renewable Energy Directive II
REMP	Renewable Energy Master Plan
RFNBO	Renewable liquid and gaseous transport fuels of non-biological origin
RTFO	Renewable Transport Fuel Obligation Order
SLNG	Synthetic liquid natural gas

SMR	Steam methane reforming
SNG	Synthetic natural gas
SCF	Standard cubic foot
SDG	Sustainable Development Goals
SE4ALL	Sustainable Energy for All
SEZ	Special Economic Zones
SMHP	Small hydropower plants
SMR	Steam Methane Reformation
SON	Standard Organisation of Nigeria
TCN	Transmission Company of Nigeria
TDP	Transmission Development Plan
TES	Total energy supply
TVET	Technical and Vocational Education and Training
TWh	Terawatt-hour
UAE	United Arab Emirates
UK	United Kingdom
UN	United Nations
USA	United States of America
USD	United States Dollar
WG	Working Group
WP	Work Packages

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01

Introduction

1 Introduction

In order to limit the global temperature rise below 2°C (ideally to 1.5°C) compared to pre-industrial levels by 2100 as set out in the Paris Agreement, more than 70 countries, including the biggest polluters – China, the United States of America (USA), and the European Union (EU) – have set a Net Zero emission target, covering about 76% of global greenhouse gas (GHG) emissions (UN, 2022). This ambitious target requires a rapid transformation of the energy sector by shifting away from the consumption of fossil fuels towards cleaner and renewable energy (RE) sources. However, some sectors of the economy, the "hard-to-decarbonise[1] (or hard-to-abate)" sectors cannot easily make the switch to RE. Green hydrogen (GH_2) and GH_2 derivatives known as Power-to-X (PtX) are regarded as a key element of this transformation, thanks to their capability of bridging the gap between RE electricity and the hard-to-decarbonize sector requirements.

To lay out the foundation for GH_2/PtX development and enhance their contribution to their carbon neutrality, over 30 countries had developed mid- and long-term H2 strategies by December 2022 (IRENA, 2022) while several others were still developing their strategies (e.g., Namibia and South Africa[2]) including supporting mechanisms and cooperation partnerships. The International Renewable Energy Agency (IRENA) classifies these countries into three groups: net-exporters, self-sufficient and net-importers[3] (IRENA, 2022). Australia, Chile, Morocco and Spain, for instance, are among net H_2 exporters while China and the USA are classified among self-sufficient with regards to future GH_2 production and consumption. Countries that will need imports to satisfy domestic demand (net importers), include Japan, the Republic of Korea, and parts of Europe. In particular, Europe is regarded as the main destination of export GH_2/PtX due to the EU's ambitious climate goals.

To ensure the delivered GH_2/PtX products are zero- or low carbon, a growing number of importer countries/regions[4] have set or are currently setting sustainability criteria (standards) that any GH_2/PtX producer wishing to trade GH_2/PtX products with these countries/regions must comply with. The compliance is usually testified by a certificate of conformity issued by an accredited body.

The global decarbonisation trends will likely cause revenue declines in countries such as the Republic of Nigeria (Nigeria) where the export of fossil fuel products represents a considerable share in the

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1 Hard-to-decarbonize/Hard-to-abate sectors: steel, cement, chemicals, long-haul road transport, maritime shipping, aviation, chemical feedstock

2 Namibia published its GH_2 Strategy in 11/2022, while South Africa released its draft GH_2 Strategy in 12/2022 to the public for comments.

3 Net-exporters: countries with large RE potential and low-cost GH_2 production; self-sufficient: countries with sufficient production potential to cater to their own needs without resorting to imports; net-importers: countries that will need imports to satisfy domestic demands.

4 E.g. The Renewable Energy Directive II of the EU as well as Japan and South Korea working currently on their sustainability criteria.

national Gross Domestic Product (GDP). For instance, in Nigeria, crude oil exports accounted for some 76 percent of the country's total exports in 2021 (Statista, 2023) whilst the oil and gas sector accounts for about 10% of GDP (Guardian, 2021). To support countries such as Nigeria to both preserve their energy export-oriented economic model and decarbonize national economies, the German Federal Foreign Office has initiated the programme “Global Hydrogen Diplomacy (H2-Diplo)”. The H2-Diplo programme seeks to support fossil fuel exporting countries in understanding the expected global demand for GH_2/PtX as an opportunity for a sustainable national economy in order to avoid destabilization due to declining economic performance.

The “Study on the policy and regulation framework for the build-up of a hydrogen market in Nigeria” (hereafter the Study) was commissioned by the German-Nigerian Hydrogen Office, which is part of the Global H2-Diplo programme. The aim of the study was to elaborate and support the establishment of an appropriate regulatory framework for the production and use of GH_2/PtX in Nigeria. The study included four Work Packages (WP):

- Benchmark analysis;
- Review of regulatory framework and regulatory bodies in Nigeria;
- Needs assessment of the policy and strategic framework in Nigeria, and
- Policy roadmap.

For each of the four WP a report was prepared; the present document provides a summary of the four reports. More details can be found in each individual report.

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Benchmark analysis

2 Benchmark analysis

The successful development of the green and blue H_2 economy requires the existence of an enabling environment to build confidence for investors, financiers, project developers and off-takers of H_2/PtX products. The following sections summarise recommendations by international organisations active in the GH_2 space on the deployment of GH_2 technologies. The section also highlights approaches undertaken by front-runner countries in developing GH_2 related policy and regulatory frameworks. More details can be found in the report "*Benchmark analysis*" elaborated as part of this Study.

2.1 Colours of hydrogen

H_2 can be produced from different energy sources (e.g., fossil fuels, renewables and nuclear) through a variety of production technologies and routes (e.g., reforming, gasification, electrolysis, and pyrolysis). Nowadays, H_2 is assigned a colour code depending on its production route. The main colours are grey, blue, and turquoise and green (Figure 1). Grey H_2 is from coal gasification and natural gas through Steam Methane Reformation (SMR) without Carbon Capture and Storage (CCS) while blue H_2 is grey H_2 with CCS facilities. Turquoise H_2 is produced via a thermal process (methane pyrolysis), whereas GH_2 is obtained from the electrolysis of water using 100% RE.

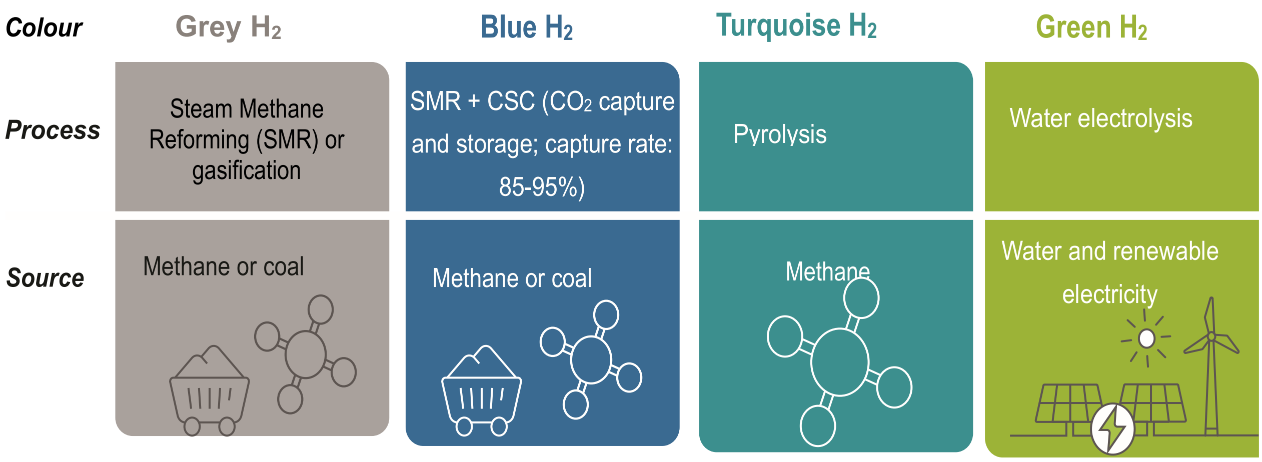

Figure 1: Main colours of hydrogen

Source: IRENA (2020)

2.2 Development of a national GH_2 program

The design of a national H_2 program undergoes several steps, and followed approaches may differ from one country to another. The International Energy Agency (IEA), the International Renewable Energy

Agency (IRENA) and the Hydrogen Council have analysed different undertaken approaches by various countries as highlighted below.

According to IRENA (2020), four key steps are recommended when designing a national H_2 program:

- Research and Development (R&D) programs: to understand the fundamental principles of the H_2 technology, develop the required knowledge base, and explore different H_2 opportunities.
- Formulation of a vision: to guide research, industry efforts and early demonstration programs.
- Elaboration of a roadmap: define an integrated plan and activities needed to better assess the potential for H_2, major milestones and targets, and indicative timeline for scaling up.
- Development of the strategy: define necessary actions to achieve the targets set in the roadmap, and address concrete policies that are needed to ensure the deployment of H_2 technologies across the system and to evaluate their coherence with existing policies. Beside IRENA, the IEA (2021) has identified five key areas that are necessary to define comprehensive policy frameworks in order to facilitate H_2 adoption across the energy system:
- Establishment of targets and long-term policy signals: setting policies that send signals about the role of H_2 to support decarbonisation efforts in order to boost stakeholder confidence in the development of a marketplace for H_2 and related technologies.
- Demand creation: develop and implement policy mechanisms that make projects bankable and overcome deployment hurdles (e.g., policies to close the gap between grey and GH_2).
- Mitigation of investment risks: address risks related to demand uncertainties, lack of experience and value chain complexity as well as risks linked to capital and operational costs.
- Incentivising R&D, innovation and demonstration projects: to stimulate innovation and bring affordable technologies to the market.
- Harmonisation of standards and the removal of barriers: analysis of national regulations to determine whether H_2 can be considered within relevant existing regulations or if a separate regulation needs to be developed. This area also ensures that appropriately applicable Regulations, Codes, and Standards (RCS) are in place to guide the design, manufacturing, operation and use of H_2/PtX related specific equipment and products.
- In addition to IRENA and IEA recommendations, the Hydrogen Council (Hydrogen Council, 2021) has identified six pillars of efficient policy design for low carbon and renewable H_2 (i.e. GH_2):
- Make use of local strengths & benefit from cross-border cooperation and trade to unlock efficiency gains.
- Create certainty through targets and commitment to drive down cost and attract investment through legislation, reducing policy risks and market uncertainty.
- Provide H_2 specific support across the value chain to catalyse and grow new markets
- Support robust carbon pricing to drive efficient and effective uptake in the longer term, whilst mitigating carbon leakage.

- Harmonize certification schemes to develop H_2 economy and enable cross-border trade of H_2.
- Factor in societal value and values to make a positive contribution to United Nations Sustainable Development Goals (SDG).

2.3 International experience around GH_2 policies and strategies

As of January 2023, over 30 countries had already announced their H_2 strategies. A direct comparison between the strategies is not expedient, as they are specific to each country, however, the following selection may serve as a source of ideas for Nigeria due to their level of advancement and the fact that as point of departure they coincide well with the Nigerian context.

2.3.1 Australia

The Australian H_2 strategy puts emphasis on production and export while also considering its own consumption. The strategy identified 57 actions grouped in seven areas[5] to be implemented in two phases: (1) foundations and (2) demonstrations and large-scale market activation.
In the first phase, which is underway, the strategy targets to (GoA, 2019):

- Create, test and prove Australia's clean H_2 supply chains,
- Encourage global markets to emerge in line with mutual interests, and
- Build cost-competitive production capability.

One of the key tools of the strategy to achieve the first stage objective is the creation of H_2 hubs[6] to allow for efficiencies of scale and cost reductions, and facilitate information, expertise and experience sharing. To facilitate access to export, some hubs shall be located in proximity to ports.

2.3.2 The European Union

In 2020, the EU released its "H2 strategy for a climate-neutral Europe" that complements the EU's vision of achieving the European Green Deal and the energy transition to net zero GHG emissions. The strategy prioritizes investments and regulations, promotes research and innovation, international cooperation and breaks down into three phases (EC, 2020):

- Phase I (2020-2024): achieve at least 6 GW of GH_2.
- Phase II (2024-2030): achieve at least 40 GW of GH_2 and import up to 10 Mt/year of GH_2.

[5] 1. National coordination; 2. Developing production capacity, supported by local demand; 3. Responsive regulation; 4. International engagement; 5. Innovation and R&D, 6. Skills and workforce; 7. Community confidence
[6] A hydrogen hub is a cluster of local hydrogen production, storage, and demand

- Phase III (2030-2050): GH_2 reaches technological maturity, is deployed at large scale and reaches sectors that are considered hard to decarbonize.

As part of the strategy, several measures shall encourage H_2 demand, namely:

- Strategic Forum for Important Projects of Common European Interest (IPCEI) helped identify a range of large investment projects along the strategic H_2 value chain and receive member state subsidies (EC, 2020).
- Clean Hydrogen Partnership as a public-private partnership between the European Commission, the H_2 industry and academia to support research and innovation on H_2 technologies in Europe (Clean Hydrogen Partnership, 2022).
- European Clean Hydrogen Alliance launched in 2020 as a collaboration between government, industry and civil society groups to guide the investment in H_2 technologies and promote the production and consumption of clean H_2 (EC, 2021).

The EU Strategy emphasizes the need to foster international cooperation regarding H_2 technologies and identifies a medium-term target for imports from its potential H2 partners for 2030. In the context of satisfying this demand through imports, the EU's Renewable Energy Directive II (RED II) and the associated Delegated Acts (DA) set the (import) standard for H2 use across all EU sectors.

To create a favourable investment framework and support investments into GH_2, the EU plans to establish a European Hydrogen Bank. The set-up of the bank and financing mechanism are currently under development. The launch of the Bank is expected in autumn 2023.

2.3.3 The Federal Republic of Germany

Germany published its National H_2 strategy in 2020. The strategy includes a EUR 9 billion funding programme out of which EUR 7 billion are earmarked for the development of H_2 technologies in the country and EUR 2 billion to support green H_2 production abroad. The strategy provides for a coherent framework and contains 38 concrete measures to support decarbonisation, create new value chains for the economy and foster international energy policy cooperation (BMWK, 2020, p. 5). The strategy originally targeted a domestic GH_2 installation capacity of 5 GW by 2030, but was raised to 10 GW in the recent German government's coalition agreement. However, this planned domestic generation is far from sufficient to provide the quantities of GH_2 needed for the desired decarbonization; therefore, a large part of Germany's GH_2 demand will still be covered through imports.

In Germany, the State Secretaries' Committee on Hydrogen (Figure 2) establishes a flexible and result-oriented governance structure, underpinned with an advisory high-level National Hydrogen Council with expertise from business, science and civil society in fields such as production, R&D, decarbonisation of industry, transport, buildings, infrastructure, and international partnerships.

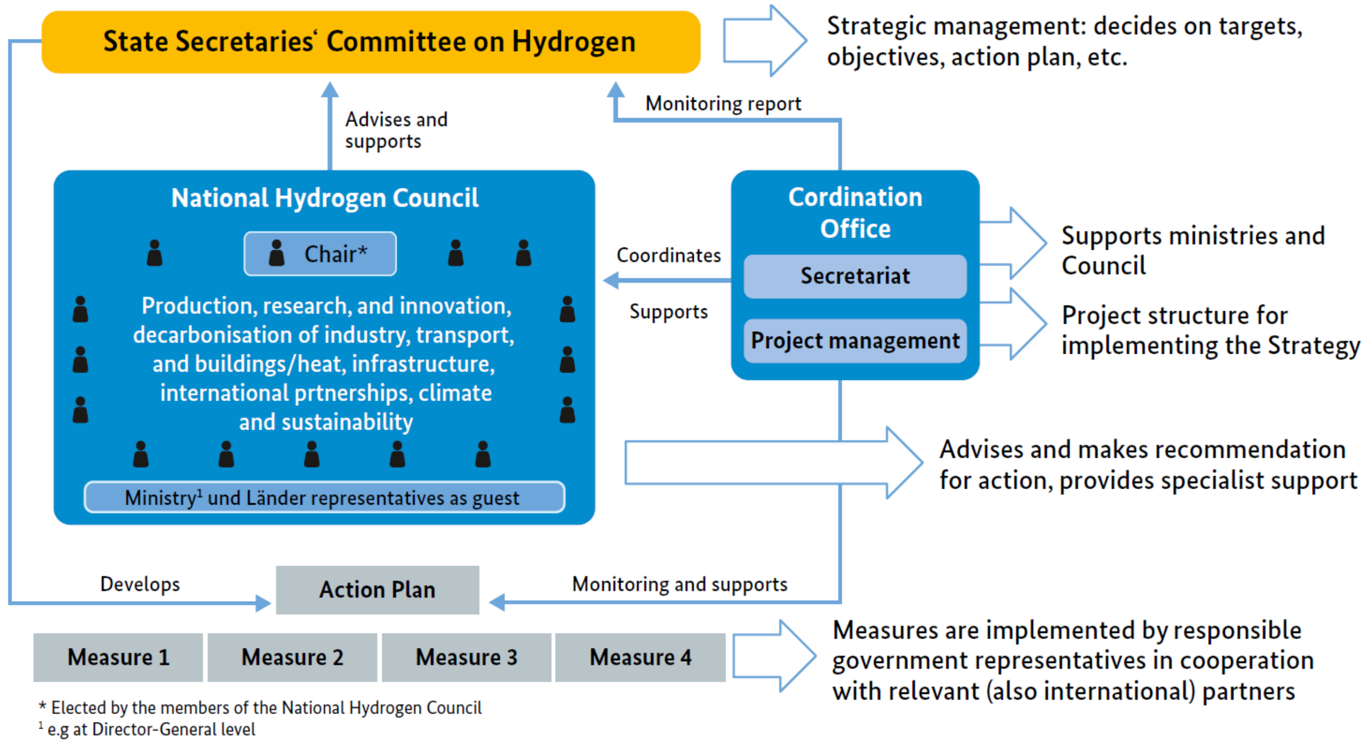

Figure 2: Governance structure of the National Hydrogen Strategy

Source: BMWK (2020)

In addition to the Strategy, Germany has launched the “H2Global programme” to create business cases and investment security through a financial compensation with a solvent contract partner in analogy to a contract for difference (CfD) mechanism. On both the purchase and on sales sides, the GH2 price is determined via a competitive bidding procedure. The Hydrogen Intermediary Company GmbH (HINT.Co), will conclude long-term purchase contracts on the supply side and short-term sales contracts on the demand side. To minimise the price difference to be compensated, the lowest bid price and the highest selling price meeting sustainability criteria are awarded contracts.

2.3.4 Saudi Arabia

Saudi Arabia’s ‘Vision 2030’ foresees a pivotal role for H_2 to become less reliant on domestic oil as the key source of income from global markets. The “Economics and Resource Potential of Hydrogen Production in Saudi Arabia” of November 2021, outlines the country’s endeavours towards H_2 development and usage (Shabaneh, 2021). Whilst Saudi Arabia is moving towards the production of blue H_2 based on natural gas, its geographical location offers great potential for the cost-parity production of GH_2 in the medium term (Shabaneh, 2021). The RE potential in PJ/year can support more than 4,800 GW of solar (utility-scale solar capacity) and 36 GW of wind installations in the country. By 2026, Saudi Arabia will manufacture green H_2 with RE at a EUR 5 billion project in Neom, in the northwest region of the Kingdom. The plant shall comprise 4 GW of dedicated renewable electricity production to produce 650 tons of GH_2 daily via water electrolysis. The GH_2 shall then be used to produce 1.2 million tons of ammonia per year for transport purposes (Bloomberg, 2022).

2.3.5 Namibia

Namibia published its “Green Hydrogen and Derivatives Strategy” in November 2022, making the country the first nation with a H_2 strategy on the continent. The elaboration of the strategy was coordinated by “Namibia’s Green Hydrogen Council” with support from an “Inter-ministerial Green Hydrogen Technical Committee” and “Namibia Green Hydrogen Association” (grouping key GH_2/PtX private sector actors). Namibia anticipates a production at 10-12 Mt H_2 equivalent per year by 2050, most of which will be for export (GoN, 2022). To implement the strategy, the country plans to launch an infrastructure fund that will initially mobilize USD 1 billion in concessionary and commercial capital to provide capital for the three different project development phases: development, construction and operations. Each will have a different risk-return profile achieved by ‘blending’ donor and development finance institution capital to attract commercial investors according to their mandate requirements.

2.3.6 South Africa

South Africa’s ambition to take part into the growing GH_2/PtX market is reflected in its draft Green Hydrogen Commercialisation Strategy (GHCS). The strategy was developed by a “Panel” that consists of private and public sector champions in the potential GH_2 value chain. On December 09, 2022, the GHCS was released to the public for comments. The reception of comments was closed on February 03, 2023. At the time of writing this report, the Panel was updating the strategy based on received comments. The draft GHCS anticipates an installed electrolyser capacity of 41 GW by 2050, producing around 3.8 Mt H_2 equivalent per year, including 1.9 Mt for export and 1.9 Mt for domestic consumption (dtic, 2022). The GHCS will be implemented as part of South Africa’s Just Energy Transition (JET) for the initial period 2023-2027. The estimated budget for H_2 related activities is USD 21.3 billion, including USD 0.7 billion from the USD 8.5 billion contribution of International Partners Group (IPG) to the JET (The Presidency, 2022).

2.4 International experience around GH_2 regulatory frameworks

Several jurisdictions have initiated processes to put in place comprehensive regulatory frameworks to govern the development of their GH_2 economy by either considering H_2 within existing relevant regulations or by developing dedicated regulatory frameworks. Covered GH_2 aspects include:

- Definition and classification of H_2;
- Definition of H_2 production, processing and storage facilities;
- Third party access to pipelines, processing and storage facilities;
- Unbundling of pipeline and processing and storage facilities ownership, and
- Applicable tariff for the use of pipelines, processing and storage facilities.

In the following, we provide a high-level overview of state of the art of H_2 regulatory frameworks to inform production, transmission and use.

2.4.1 Australia

In August 2021, the Government of Australia(GoA) initiated the reform of its national gas regulation to include H_2, renewable gases and blends (GoA, 2022). Key amendments include:

- Classification of H_2 as "*primary gas*" alongside natural gas, bio-methane, etc.
- "*Blend processing facilities*": facilities that provide for the blending of primary gases to create a gas blend for injection into a pipeline, or the deblending of a gas blend withdrawn from a pipeline to separate one or more of its primary gases.
- Two methods for blending and deblending: '*In-pipeline*' that involves direct injections of covered gases into the pipeline (blending occurs within the pipeline), and '*Stand-alone blending*' that involves the use of a stand-alone blend processing facility, meaning that blending occurs before the product is injected into the pipeline.
- Access to pipeline and blend processing facility by a third party applies to all gas pipelines to encourage competition, increase efficiency and avoid infrastructure duplication.
- Ownership unbundling: pipeline and blend processing service providers are prohibited from producing H_2, unless they obtain a ring-fencing exemption.

2.4.2 European Union

The regulatory framework for H_2 in the EU remains dynamic. To date, the production, transport and use of H_2 in the EU are governed by the regulatory documents presented below.

- EU Directive (2018/2021), RED II (EU, 2018):
  - Proposes policy measures to achieve RE share from energy consumed by the electricity, heating, cooling, and transportation sectors in the EU.
- Delegated Act (DA) to RED II (EC, 2023):
  - Lays down detailed rules for the production of GH_2/PtX.

    - Specifies a methodology to assess GHG emission from renewable liquid and gaseous transport fuels of non-biological origin (RFNBO) and from recycled carbon fuel (RCF)[7].
    - Establish a minimum threshold for GHG emissions savings of RCF
- Recast Directive 2009/73/EC & Regulation EC 715/2009 (EU, 2021):
    - Establishes rules for transport, supply and storage of H_2 using the H_2 system.
    - Lays down the rules on the organisation and functioning of this sector.
    - Specifies conditions for access to the natural gas transmission networks.

2.4.3 The Federal Republic of Germany

In July 2021, the German Parliament passed an amendment to the Energy Industry Act (*Energie-wirtschaftsgesetz*, EnWG) to introduce a separate regulation that differentiates H_2 from gas (BMJ, 2022). In addition to the EnWG, adjustments remain pending to the Energy Act to reflect updates to the EU Gas Directive, the key provisions of which summarise as follows.

- <u>H_2 classification and regulation</u>: H_2 is classified and regulated as *a separate energy carrier* as long as it is fed into purely H_2 dedicated pipelines (§ 3 no. 14). H_2 blend into existing natural gas pipelines remains under *gas definition* while it is classified as *biogas* if it is produced via water electrolysis using electricity predominantly from RE sources (§ 3 no. 10f).
- <u>Separate rules for H_2 and natural gas networks</u>: The Energy Act differentiates “Hydrogen network” from “Gas network”. It defines “Hydrogen network” as a network for the purpose of supplying customers with H_2 (§ 3 no. 39a).
- <u>Third parties access to network pipelines</u>: H_2 network operators shall grant access and connection to their H_2 networks based on the principle of negotiated network access (§ 28n)
- <u>Separate network tariffs and subsidies</u>: the terms and tariffs for access to H2 networks must be designed in an appropriate, non-discriminatory, and transparent manner (§ 28o).
- <u>H_2 production facility</u>: To build and operate a H_2 production facility, an authorisation from the Federal Emission Control Act (*Bundes-Immissionsschutzgesetz*, BImSchG) is required after meeting the requirements set out in the BImSchG (UBA, 2009).

2.4.4 France

The regulation of H_2 in France follows the provisions stipulated in the French Energy Code amended by Ordinance No. 2021-167 of February 17, 2021 to include H_2 regulatory aspects (GoF, 2022):

- <u>H_2 definition</u>: the Energy Code defines H_2 as a “*gas*” composed of dihydrogen molecules, obtained after implementation of an industrial process (Article L811-1).

[7] Liquid and gaseous fuels produced from liquid or solid waste of non-renewable origin , which are not suitable for material recovery in acc. with Article 4 of Directive 2008/98/EC

- H₂ production and storage facilities: classified as "installation for the protection of the environment" (*installations classées pour la protection de l'environnement* – ICPE), and are therefore subjected to an authorization after proving their compliance with numerous regulations for the prevention of environmental risks (Article R3420 of the ICPE).
- Transport and distribution of H_2 blend: network operators implement the necessary provisions to ensure the proper functioning and balancing of the networks, the continuity of the transmission service and delivery of natural gas and the safety of persons and property.

2.5 Sustainability criteria

As part of the international available standards, sustainability criteria apply in countries/regions for both potential importers and exporters. Main sustainability criteria include (dena, 2022):

- Renewable electricity: various jurisdictions have set power supply requirements to ensure the sustainability of PtX products. The below table presents EU's requirements for power supply (EC, 2023).

Table 1: Power supply requirements for GH2 production in the EU

Criteria	Delegated Act (02/2023)
Geographical correlation[8]	• The electrolyser must be located in the same/neighbouring bidding zones[9] as the installation generating RE electricity
Temporal correlation[10]	• Until the 31/12/2029: PtX production during the **same calendar month** as RE installations • From the 01/01/2030: PtX production during the **same one-hour** period as the RE installations
Additionality[11]	• The RE installation came into operation not earlier than 36 months before PtX installation • The RE installation has not received support in the form of operating aid or investment aid

- GHG threshold: apart from meeting with electricity source requirements, GHG emissions resulting from GH2/PtX production have to fall within allowable limits. For instance, any GH2/PtX traded and consumed in the EU should not exceed 28.2 gCO_{2eq}/MJ.

[8] Geographic correlation: the location of the electrolyser and the RE installation supplying electricity to the electrolyser
[9] A bidding zone: largest geographical area within which market participants are able to exchange energy without capacity allocation
[10] Temporal correlation: the timeframe in which both the RE power plant output and the electrolyser power consumption need to match
[11] Additionality: when an organization's PPA has the direct effect of adding new RE generation to the grid

Other sustainability criteria include (dena, 2022):

- Water supply: an environment and social impact assessment (ESIA) must be carried out.
- Eligible carbon sources: CO_2 used for synthetizing PtX must come from sustainable source.
- Land use: restrictions have to be taken into account when developing H2/PtX project.
- Socio-economic impacts: local employment, health, and consumer choice, among others need to be considered when planning and implementing H2/PtX projects.

2.6 Green hydrogen standards

H_2 standards covering different segments of its value chain have been developed over the years to ensure safe operation, handling, and use of H_2 and H_2 systems. The standards provide guidelines and technical definitions to be followed when designing, manufacturing, operating and using specific equipment and products. The Fuel Cells and Hydrogen Observatory (FCHO) has compiled H_2 related standards into user-friendly database, accessible free of charge from FCHO's website[12].

[12] FCHO website: https://www.fchobservatory.eu/observatory/policy-and-rcs/standards

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Hydrogen Development Status in Nigeria

3 Hydrogen development status in Nigeria

In August 2022, the Federal Government of Nigeria (FGN) has launched the country's Energy Transition Plan (ETP), which is the basis for Nigeria's commitment to net zero emission economy by 2060. In recognition of the key role that RE and H_2 will play in its carbon neutrality, Nigeria is putting down plans to fully develop and exploit its vast RE resources and H_2 opportunities. Nigeria's plans for RE includes fully utilizing its water, solar, wind and biomass resources, and H_2 production and use. The introduction of H_2 in Nigeria's economy presents the country with an alternative energy export product and can help Nigeria remain as a global player in the future energy market.

To this end, Nigeria has put in place a number of key policies and plans, which have laid down pathways, and have provided action plans for the integration of RE in the energy mix of Nigeria. Some of these policies and plans are the:

- National Energy Policy (NEP), approved in 2022,
- National Energy Master Plan (NEMP), approved in 2022,
- Sustainable Energy for All (SE4ALL) Action Plans, approved in 2016,
- Nigeria's Energy Transition Plan (ETP) launched in 2022, and
- Nigeria Electricity Bill (which is awaiting presidential assent).

Of these policies and plans, only the NEP, the NEMP and the ETP make some provisions for H_2 forming part of Nigeria's energy mix. These provisions however, as will be presented in ensuing sections, are not sufficient to provide the right policy and regulatory framework to aid the development of H_2 across the H_2 value chain (production, transportation, storage, and utilisation). Interestingly, the National Gas Policy (NGP) and the Petroleum Industry Act (PIA) 2021 (both being instruments of the FGN outlining the plans and laws that will enable Nigeria to fully develop the gas sector) do not recognize and acknowledge the relationship between gas and H_2. Hence none of these two instruments of the FGN makes provisions for the development of H_2. The FGN can however still address this by promulgating relevant H_2 regulations pursuant to the PIA, i.e. provisions for the production of blue and turquoise H_2 and regulation of the blue/turquoise H_2 value chain, as well as provisions for the storage and transportation of GH_2 (by blending of GH_2 in natural gas pipelines). In order to create an enabling policy and regulatory framework for H2 and PtX, the FGN shall develop and approve a stand-alone policy for H_2, which will lay down more detailed plans, strategies, and implementation pathways for H_2 across its value chain.

3.1 Nigeria’s fossil energy resources

The main fossil energy resources of Nigeria comprise crude oil, natural gas, coal, and tar sands. The majority of Nigeria’s crude oil reserves are located along the Niger Delta regions, and offshore in the Bight of Benin, the Gulf of Guinea, and the Bight of Bonny. The quantity of available resources for each type varies on a year-to-year and publisher-to-publisher basis. The 2022 data released by the Nigerian Upstream Petroleum Regulator Commission (NUPRC) put Nigeria’s oil reserves at 37.046 billion barrels, while gas reserves were put at 208.6 trillion cubic feet (tcf) as of January 2022 (Business Day, 2022).

The table below provides a breakdown of Nigeria’s fossil energy resources, reserves, production rate and domestic utilization rate as released by the Energy Commission of Nigeria (ECN) in 2019 and 2022.

Table 2: Nigeria’s fossil energy resources and their utilisation rates

S/N	RESOURCES	RESERVES	PRODUCTION	DOMESTIC UTILIZATION
1	Crude Oil	37.2 billion barrels	0.774 billion barrels	0.098 billion barrels @ 4.9% capacity utilization (2015)
2	Natural Gas	203.45 trillion tandard cubic foot (scf)	2.9 trillion scf (2015)	88% utilized (2015) and 12% flared (2015)
3	Coal and lignite	2.734 billion tons	0	Negligible
4	Tar sands	31 billion barrels of oil equivalent	0	18.25 illion barrels (2014)

3.2 Nigeria’s Renewable Energy Resources

Nigeria has huge RE potential (Table 3) that can be utilized to end the country’s energy supply challenges and allow the country to achieve its goal of becoming a net zero emissions economy. The Main RE sources of Nigeria are set out in the table below (as released by the ECN in 2022) and comprises of solar photovoltaic (PV), large and small hydropower, wind, and biomass.

Table 3: Nigeria's RE resource potential and their utilisation levels

S/N	RESOURCES	Potential	UTILIZATION LEVEL
1	Large hydro	24,000 MW	1,900 MW
2	Small hydro	3,500 MW	64 MW
3	Solar PV	3.5 – 7.0 $kWh/m^2/day$	30 MW solar PV stand-alone

4	Wind	2-4m/s at10 m height	10 MW wind farm in Katsina
5	Fuel Wood	13,071,464 Hectares	43.4 million tons of firewood/year
6	Municipal waste	30 million tons/year	No data
7	Animal waste	61 million tons/year	No data
8	Crop residues	83 million tons/year	28.2 million hectares of arable land, only 8.5% cultivated

3.3 Nigeria's Energy Demand and Supply

Nigeria is one of the countries that heavily depend on biomass to meet their energy needs. Wood, animal dung, municipal waste and agricultural residues are used as a major source of energy for cooking and heating, especially in rural and peri-urban areas. According to the International Energy Agency (IEA, 2022), the Nigerian total energy supply (TES) in 2020 was over 6.6 Petajoules (PJ), with biomass accounting for over 75% of the TES.

As for electricity generation, the total installed grid capacity is estimated at 10,396 MW (NERC, n.d.). With regard to transmission, the current total transmission wheeling capacity is7,500 MW. There are also over 20,000 km of transmission lines in Nigeria (NERC, 2022). The Nigerian Electricity Regulatory Commission (NERC) attributes this low capacity to the fact that the entire transmission infrastructure is radial, lacking redundancies to serve as backup in the event of failure of the single system. Currently, there are over 26 power plants connected to the Nigerian national grid with a total capacity of about 10 GW, including 32% owned by the PHCN (Power Holding Company of Nigeria) generating companies (GenCos), 19% owned by Independent Power Producers (IPPs), and 49% owned by the National Integrated Power Project (NIPP) (ECN, 2019b).

The FGN has set a very ambitious target to attain 80% electrification rate by 2030, by increasing the country's installed power capacity to 45 GW, including 32 GW on-grid, 8 GW off-grid, and 5 GW self-generation (FMP, 2016). The FGN intends to achieve this by utilizing a diversified energy mix of fossil fuels and renewables. This goal is also captured in Nigeria's Electricity Vision 30:30:30 that seeks to install additional 30 GW by 2030 with 30% RE share (FMP, 2016). The vision projects a combined generating capacity of 13.8 GW from RE by 2030 comprising 4.7 GW from large hydropower plants (LHP), 1.2 GW from small hydropower plants (SMHP), 1.1 GW from biomass, 1.0 GW from solar thermal, 0.8 GW from wind and 5 GW from solar PV (FMP, 2016).

The Renewable Energy Master Plan (REMP) for Nigeria is also aligned with the Vision 30:30:30, as it seeks to increase Nigeria's share of RE in the power generation mix from 13% (mainly met by large hydro) in 2015 to 23% by 2025 and 36% by 2030 (ECN, 2007).

3.4 Current Energy Laws, Policies and Strategies

The FGN of Nigeria has developed a number of polices and plans, some of which have been referenced in preceding sections. The FGN has laid down ambitious plans for energy access, which will see Nigeria having 80% electricity access and increasing total generating capacity (on- and off-grid) to 45 GW by 2030. The table below outlines some of the strategies through which the FGN intends to achieve these plans.

Table 4: Key Energy Laws, Policies and Strategies in Nigeria

S/N	Law/policies/plan	Key provisions
1	National Energy Policy (NEP) 2022	Framework for sustainable energy development in Nigeria with the overall objective of providing clean, affordable, adequate, and reliable energy.
2	National Energy Masterplan (NEMP) – 2022	The NEMP intends to achieve the goals of the NEP by converting the strategies outlined in the NEP into actionable programmes, activities, and projects.
3	Nigeria Energy Transition Plan (ETP) – 2022	The ETP emphasises the level of effort that Nigeria would need to make in order to achieve its net-zero emission target by 2060 whilst meeting the nation's energy needs
4	Nigeria Renewable Energy Masterplan (REMP) - 2005 (Revised 2012)	The REMP sets a national vision, targets, and a road map for addressing key development challenges facing Nigeria through the accelerated development and exploitation of RE.
5	National Gas Policy (NGP) – 2017	Vision, goals, strategies, and implementation plan of the FGN to introduce and implement the right institutional, legal, regulatory, and commercial framework for the development of the gas sector.
6	Petroleum Industry Act (PIA) – 2021	Provides for the legal, governance, administrative, regulatory and fiscal framework for the Nigerian petroleum industry and development of host communities.
7	Electric Power Sector Reform Act (EPSRA) – 2005	The EPSRA was enacted to liberate the electricity sector, drive market reforms, and set down an effective governance structure, as well as to develop competitive electricity markets in Nigeria.

8	Climate Change Act (CCA) – 2022	Framework for mainstreaming climate change actions in Nigeria. The CCA also provides for a system of carbon budgeting, establishment of the climate change fund, and the establishment of the National Council on Climate Change.
9	Nigeria Sustainable Energy for All Action Agenda (SE4ALL) – 2016	SE4ALL Action Agenda of Nigeria is Nigeria's national tool for implementing SDG7 goals.
10	The Nigerian Electricity Management Service Agency Act (NEMSA) - 2015	NEMSA Act established the Nigerian Electricity Management Agency (NEMSA) that is charged with the responsibility of ensuring efficient production and delivery of safe, reliable, and sustainable electric power supply in Nigeria.
11	The Nigeria Electricity Bill	In July 2022, the Nigerian Senate passed the Nigeria Electricity Bill 2022, which is awaiting presidential assent. The bill will repeal the EPSRA and provide a comprehensive legal and institutional framework for the post-privatization phase of the power sector

3.5 Nigeria's Hydrogen Policy and Plans

Nigeria's ETP makes provision for H_2 as part of the RE share in Nigeria's energy mix, towards the attainment of increased generating capacity, increased energy access, and attaining Nigeria net-zero emission goals. Provisions are also made for H_2 in Nigeria's NEP (revised) 2022, the NEMP (revised) 2022, and the REMP (revised) 2012. Specifically, these policies and plans lay down research information and policy statements on H_2.

The ETP lays down a pathway for the integration of H_2 in Nigeria's transition to more renewable forms of energy. H_2 features in the RE mix from 2040 accounting for 46 TWh of almost 450 TWh growth in centralized electricity demand across different segments (FGN, 2022). The decarbonisation strategy laid down by the ETP factors in a progressive centralized production capacity growth of over 240 GW in 2050, largely by RE sources, of which H_2 contributes 9 GW to centralised production capacity in 2040 and 34 GW in 2050 (FGN, 2022).

The NEP 2022 and the NEMP 2022 also lay down the FGN's objectives with regards to H_2, as well as the H_2 development plan for Nigeria and short-mid-to-long term strategies on measures to be taken to ensure that H_2 is integrated as an energy source in Nigeria's energy mix. The objectives and strategic actions outlined in the NEP 2022 and NEMP 2022 are highlighted in Section 3.4 of this report (i.e. Current Energy Regulations, Policies and Strategies).

Notwithstanding these policy statements, strategies, development, and action plans for H_2 contained in the various policies and plans outlined, Nigeria does not have a standalone policy for H_2. There is also no primary legislation (Act) or secondary legislation (regulations) on H_2 currently in force in Nigeria. There is also no specific institution currently charged with the responsibility of actioning out these H_2 strategies and plans which resulted in limited progress towards these goals. However, it should be noted that the oil and gas sector currently generate grey H_2, and has I77the capacity to generate blue H_2, but Nigeria lacks the right infrastructure for proper carbon capture and storage (CCS), as well as for transportation and distribution of H_2.

3.6 Key Energy Sector Stakeholders

There is no single institution charged with the sole responsibility of managing all affairs relating to the country's energy. Rather, the varied roles in the energy sector are undertaken by several governmental institutions as outlined in the below table with a focus on H_2 development in Nigeria.

Table 4: Key Nigerian institutions directly involved in H2 development

Institution	Role/mandate related to Hydrogen
Office of the Vice President (OVP) / Energy Transition Office (ETO)	Overall coordination of Nigeria's energy development plans.
Federal Ministry of Power (FMP)	Initiate and coordinate policies and strategies for the development of reliable power supply in Nigeria (incl. the national power transmission system required to wheel RE electricity to H_2/PtX production facilities)
Ministry of Petroleum Resources (MPR)	Formulate policies, supervise their implementation and regulate the Nigerian Oil and Gas (Energy) Industry. This include natural gas for blue H_2 production and gas infrastructure for transporting and handling H_2
Federal Ministry of Water Resources (FMWR)	Water licencing and permitting (shall include water needs for green H_2 production)
Federal Ministry of Science, Technology and Innovation (FMSTI)	Conduct R&D on all energy sources and carriers, incl. hydrogen, methanol, etc. Integrate hydrogen into education and training curricula
Federal Ministry of Environment (FMEnv)	Lead the implementation of the ETP in coordination with the ETO, develop RE policy and regulate ESIA activities
Federal Ministry of Industry, Trade, and Investment (FMITI)	Develop industrial policies, support RE technologies and provide industrial incentives for RE applications. These can be extended to H_2/PtX products.

Federal Ministry of Finance, Budget and National Planning (FMFBNP)	Provision of funds for infrastructure development (electricity and gas) and other incentives
Energy Commission of Nigeria (ECN)	Strategic planning and coordination of national policies in the field of Energy in all its ramifications
National Council on Climate Change (NCCC)	Develops policies and make decisions on all matters concerning climate change in Nigeria. The NCCC is also responsible for harmonising all issues relating to Climate Change, Energy Transition Plan, Emissions Trading Scheme and the Carbon Trading Framework. Designation national authority for all UNFCCC mechanisms.
Nigerian Electricity Regulatory Commission (NERC)	Regulates the generation, transmission, distribution, and sales of electricity, including developing and enforcing regulations as well as for issuing and monitoring various licenses and permits in the power industry
Nigerian Export Promotion Council (NEPC)	Promotion, development and diversification of exports
Nigerian Midstream and Downstream Petroleum Regulatory Authority (NMDPRA)	Responsible for the regulation of the midstream and downstream petroleum operations in Nigeria, incl. technical, operational, and commercial activities.
Standard Organisation of Nigeria (SON)	Sole statutory body that is vested with the responsibility of standardising and regulating the quality of all products in Nigeria
The Nigerian Investment Promotion Commission (NIPC)	Offers a “One-Stop Investment Centre” and is an investment promotion instrument that assists companies with administrative procedures such as obtaining company registrations and energy generation licences
Nigerian Electricity Management Services Agency (NEMSA)	Enforces NERC’s technical standards and also inspects electricity infrastructure and enforces compliance with safety measures

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04

Needs Assessment of the Policy and Strategic Framework in Nigeria

4 Need Assessment of the Policy and Strategic Framework in Nigeria

The identification of key needs to develop a green and blue H_2 economy in Nigeria was based on in-depth analysis of international approaches and experience from the countries most advanced in deploying GH_2 technologies, an analysis of Nigeria's policy and regulatory frameworks, the consultation with potential stakeholders through workshops and interviews, and Consultant's experience in similar assignments across the globe.

The identified needs have been clustered into the following ten categories:

- Stakeholder engagement, contributions and coordination ;
- Certification requirement of green hydrogen export;
- Hydrogen policy and regulation;
- Power sector regulation and operation;
- Gas sector and gas pipeline regulation;
- Technical knowledge and skills;
- Electricity and gas infrastructure capacity, readiness and operation;
- Technology readiness;
- Market and financial opportunities, and
- Security and safety standards for hydrogen handling and use.

4.1 Stakeholder engagement, contributions and coordination

The stakeholder landscape for green and blue H_2 is very complex due to its nature, involving water and land use, electricity generation from RE or natural gas extraction, H_2 infrastructure development, storage, transport, distribution as well as environmental and social aspects and implications. Therefore, a strong cooperation and coordination of various stakeholders is key for the successful deployment of green and blue H_2 technologies. This can be achieved by establishing a Committee or Panel consisting of public and private sector across the entire green and blue H_2 value chain.

4.2 Certification of GH_2 for export

GH_2/PtX offer Nigeria a unique opportunity to compensate part of the expected declines in revenue from oil and gas exports as the world shifts from fossil fuel-based energy system towards cleaner and RE. However, delivered GH_2/PtX products will need to meet the standards set by potential importing countries (e.g., EU, Germany and the United Kingdom). Since project developers will need permits from

Nigerian authorities to install and operate GH_2/PtX that meet export requirements, regulatory agencies should be aware of such standards in order to provide relevant documentation accordingly.

4.3 Hydrogen policy and regulation

Apart from some statements on H_2 contained in the ETP, NEP and NEMP, there are no H_2 dedicated policy and regulatory frameworks currently in force in Nigeria. It is therefore necessary to establish a H_2 regulatory and policy structure to guide the deployment of H_2 technologies in Nigeria and provide necessary information for investment decisions. Since developing a new regulation may take longer and delay the deployment of H_2 technologies, an interim solution would be to integrate H_2 within existing regulations, while a separate policy and regulatory framework is being developed.

4.4 Power sector regulation and operation

To supply power to electrolysers, GH_2 producers may choose to build their own RE power plants or purchase electricity from one or several IPPs and use the transmission or distribution grid to wheel the purchased power to their production sites. Depending on how the power is supplied to the GH_2 production facility and the mode of operation, four cases can be distinguished as described below.

a) Electrolyser drawing its power from a public power grid

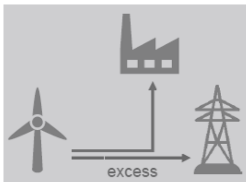
This case consists of drawing power directly from the power grid, and embedded GHG emissions depends on the share of RE in the electricity supply mix. For EU regulation, for instance, H_2 produced under this condition qualifies as GH_2 if the average share of RE exceeded 90%, corresponding to a GHG emission intensity of 28.2 gCO_2/MJ (EC, 2023). Yet, the GHG intensity of the Nigerian power grid is about 112 gCO_2/MJ (Transparency, 2020), which makes this option unfeasible for Nigeria.

b) Electrolyser directly connected to a dedicated RE installation

Under this case, the electrolyser is directly connected to an off-grid RE installation. This option is the easiest to implement since the electrolyser is isolated from the main grid. As such, the Captive Power Regulation (CPR) and the Eligible Customer Regulation (ECR) can be adjusted to govern the supply of electricity to this type of GH_2 production facility.

c) Electrolyser directly connected to a RE installation with power export option

This case is the same as the previous case except the fact that the RE installation can be oversized so that excess power from the RE installation can be sold to a third party via the national grid. This scenario could also be covered by the CPR and ECR regulations.



d) Electrolyser connected to a dedicated RE installation via a public power grid

Under this connection option, a dedicated RE power installation powers the electrolyser via the power grid. This case is the most complex to monitor, because proving that the renewability of the electricity drawn from the grid may be challenging (electrons do not have any RE attributes). The EPSR Act, the CPR, and the ECR could be adjusted to govern the power supply under this case.

4.5 Gas sector and gas pipeline regulation

In Nigeria, the PIA is the principal legislation regulating the gas sector, however, this legislation does not yet cover H_2 and H_2-related activities. In its Chapter 2, part IV, the PIA makes provisions for the administration of midstream and downstream gas operations like gas processing, bulk gas storage, gas transportation and distribution, gas pipeline licensing, etc. Regulations can be made pursuant this chapter to include H_2 related activities. In addition to the PIA, the Oil Pipeline Act of 1956 provides relevant laws for the construction, operation, maintenance of gas pipelines and the bulk storage of gas. These laws can be extended to include H_2 transportation and distribution via pipeline networks.

4.6 Technical knowledge and skills

Although Nigeria can capitalise on its transferrable skills from the oil and gas sector, green and blue H_2 technologies are new in the country, education and training programmes. It is therefore necessary to re-skill existing workforce for potential new jobs in green and blue H_2 areas. The preliminary list of required knowledge and skills include:

- Capacity building of public and private institutions on various aspects of GH_2/PtX
- Integration of green/blue H_2 technologies in higher education and R&D programmes.
- Integration of green and blue H_2 in Technical and Vocational Education and Training (TVET).
- Large public awareness campaigns on green and blue H_2 technologies and applications.

This list is based on both interviews with stakeholders and the Consultant's experience. The exact needs can be identified through a dedicated study on job potential analysis across the whole green and blue H_2 value and supply chains.

4.7 Electricity and gas infrastructure capacity, readiness and operation

Power transmission system constraints:

Depending on demand locations, some GH_2 producers may have no other options than purchasing power from IPPs and use the public grid to wheel electricity to their production sites. Since this option requires several GW of available grid capacity, the currently available grid transmission capacity will be insufficient (TCN, 2021). There is, therefore, an urgent need to increase the grid capacity in order to allow GH_2 producers to wheel electricity to their GH_2/PtX production facilities.

Apart from the grid capacity issue for GH_2 production, there is also an operation issue given the context of Nigeria's power shortages. The grid operator may decide to dispatch the power initially intended for GH_2 production, which will lead to the reduction or stop of H_2 production for a few hours to prevent load shedding and reduce the use of expensive peaking plants. A compensatory mechanism should be in place in order to regulate the operation under such conditions.

Gas infrastructure readiness

The blending of H_2 in natural gas networks can support initial deployment of green and blue H_2 technologies until dedicated H_2 infrastructure is developed and/or existing infrastructure is upgraded. However, H_2 blending faces some barriers, such as H_2 embrittlement[13], natural gas quality issues (e.g., composition, calorific value), metering issues, necessity for deblending, as well as requirements of certain end use equipment. Although Nigeria can capitalise on its existing infrastructure (e.g., natural gas pipelines, export infrastructure, gas liquefaction terminals), it is imperative to assess the extent to which this existing infrastructure can be used without compromising both the integrity of the gas transmission system as well as the proper operation of end-use equipment using natural gas.

4.8 Technology readiness

Nigeria's ETP anticipates that 33% of ammonia production in 2030 would come from blue H_2 (67% being grey H_2), while in 2060, 65% would be covered by blue H_2 and 35% from GH_2. However, the potential CO_2 storage sites as well as their storage capacity have not been identified yet. The lack of this information may hinder the deployment of blue H_2 technology and may compromise the country's ambitions since investors need reliable information to make investment decisions. As the technology matures, turquoise hydrogen might become a better option as it does not require CCUS and can be produced right next to where it is consumed.

In addition, the deployment of CCUS technology requires the support from the communities since this technology comes with different perceptions, such as the negative NIMBY[14] (Not in My Back Yard) effect that may hamper the deployment of the technology. It is therefore necessary to engage local communities at an early phase to prevent the NIMBY effect.

4.9 Market and financial opportunities

Since green and blue H_2 technologies are still at their nascent stage in many countries, including in Nigeria, information on project and funding opportunities is necessary for national and international project developers to take investment decisions. While GIZ has recently commissioned a study to assess Nigeria's technical and commercial potential of green PtX technologies, the same should also

[13] H_2 Embrittlement: chemical reactions between H_2 and steel that can lead to fissures in pipelines
[14] NIMBY refers to the opposition of the public/residents to a neighbourhood designated new development (e.g. CCUS storage site) describing it as inappropriate or unwanted for their local area due to the perceived risks or its lack of fairness.

be done for blue H_2. With regard to project funding, there is a cost gap between grey H_2 and green and blue H_2 products, meaning that the provision of financial incentives, subsidised loans, grants or dedicated funds will be key in order to make green and blue H_2 projects competitive. A number of funding instruments to advance GH_2 technologies already exist, and a compilation of such instruments would allow investors to explore these supports, which would make their projects more feasible.

4.10 Security and safety standards for H_2 handling and use

Like other energy carriers, H_2 presents certain health and safety risks when used on a large scale. Safety considerations and incidents can slow, or even prevent, the deployment of H_2 technology if the risks are not well communicated and managed. Unlike H_2, consumers are familiar with the health and safety issues of established energy carriers like gasoline, natural gas and electricity, etc., and these issues can be managed to the satisfaction of users. Moreover, H_2 transportation and distribution pose specific issues in terms of safety due to the chemical and physical properties of H_2. These issues include H_2 embrittlement of materials, the fact that H_2 escapes easily from its containers, the wide flammability range of H_2, and the low amount of energy needed to ignite it. Standards and protocols for H_2 safe handling must be in place before deploying the technology at large scale.

Another challenge of H_2 is its Global Warming Potential (GWP) when it leaks to the environment. A recent study by Warwick et al. (2022) concluded that hydrogen's 100-year GWP is 11 ± 5, which is twice as high as previously thought, and its 20-year GWP is 3 times higher than its 100-year GWP.

05

Policy and Regulatory Roadmap

5 Policy and Regulatory Roadmap

In order to develop green and blue H_2 successfully, enabling frameworks should be in place to build confidence for investors, financiers, project developers and off-takers of H_2/PtX products. To foster the successful deployment of green and blue H_2 in Nigeria, this study formulated 15 recommendations based on the needs analysis presented in the previous Section. The recommendations are clustered into 6 categories: (1) Policy frameworks, (2) Regulatory frameworks, (3) Infrastructure, (4) Market development, (5) Capacity building, and (6) Just transition.

5.1 Policy frameworks

5.1.1 Establish political leadership for hydrogen on a national level

Many of different segments of H_2 value chains do not fall under the mandate of a single institution, which requires an effective cooperation and a good coordination of involved stakeholders for the development of a H_2 economy. This can be achieved by establishing a “Hydrogen Committee or Panel” to guide and lead the development of the H_2 economy in Nigeria. Given the complexity around H_2 development as well as current framework conditions in Nigeria, the Presidency (possibly through the OVP) would be well positioned to lead and supervise the development of a H_2 economy in the country. While relevant public actors (federal ministries and agencies) would provide both technical support and inputs in line with the national Net Zero emission objective, the private sector would contribute with views, needs, expectations and priorities as well as by deploying and financing H_2 technologies. Moreover, relevant expertise and innovation can be added from science and education, whilst the buy-in from civil society actors is needed to build confidence in technology and for social acceptance.

Key members of the Committee shall include the FMEnv, the FMP, the MPR, ECN and NCCC. The Federal Ministry of Finance, Budget, and National Planning (FMFBNP) should be included in the Committee to ensure that proposed plans are in line with available budget. It is recommended to create such a committee, or embed H_2 development in the activities of an already existing interministerial structure such as the Energy Transition Working Group, no later than mid-2023.

5.1.2 Harmonise national energy planning documents

In Nigeria there are several planning documents with different or without targets and timelines. The most important ones include the NEP, Nigeria’s ETP and the Nationally Determined Contributions (NDC). These documents have different targets in terms of RE to be deployed that need to be harmonised in order to provide investors with reliable information on what RE capacity development is needed in the country. In October 2022, the NDC Partnership (2022) on behalf of the FMEnv and the ETO in the OVP launched a call for proposals to harmonise the ETP, the NDC, the Long-Term Low-

Emission Development Strategy (LT-LEDS), and the Integrated Resource Plan (IRP). This harmonisation should not end with the listed documents but should be extended to the NEP as well as the NEMP. In this regard, the ECN should be involved in the process since it is responsible for strategic planning and coordination of national policies in the field of energy in all its ramifications. The harmonisation of national energy and climate policies should also foresee the transversal integration of H_2 in view of the Net Zero 2060 target. The inclusion of H_2 in the next NDC submission 2025 is a relevant target to be established in order to raise its ambition.

5.1.3 Develop a stand-alone H_2 policy

Currently, Nigeria does not have a national H_2 policy, apart from some statements in the NEP and the NEMP. The NEP states that the "nation shall integrate H_2 as an energy source in the energy mix" without providing specific targets. On the other hand, the NEMP lists some strategies and implementing agencies, but it does not provide details on the activities and timelines. Since the H_2 value chains go beyond its use as an energy carrier, a stand-alone H_2 policy will be pivotal. The policy shall set out the required steps (roadmap, strategy and action plan) to develop a Nigerian H2 economyby providing a coherent framework for the production, transport, storage and use of H_2 in Nigeria as well as for H_2 export. ECN would coordinate the development of the stand-alone H_2 under the leadership and supervision of the proposed "Hydrogen Committee". This action can be initiated after the establishment of the Committee and completed within six months from its establishment.

5.2 Regulatory frameworks

5.2.1 Urgently create a responsive hydrogen regulatory framework

The existence of a clear and comprehensive regulatory framework is prerequisite to provide investors and project developers with clarity and indications on applicable regulations and standards, necessary for investment decisions. The framework shall provide direction on how the H_2 industry will be regulated in the future, in order to create certainty for investors and industry stakeholders. The framework shall make provisions on H_2 classification in the Nigerian context, H_2 production facilities, priority access to the power grid (for RE for H_2 production), third party access to (H_2 and natural gas) pipelines, terminals, storage and blending/de-blending facilities as well as provisions on network tariffs and any subsidies.

The creation of such a regulatory framework can draw on international experience and best-practices from most advanced countries and whose examples are worthwhile with a view to the possible replication or adaptation to the Nigerian context. Since not all H_2-related activities can be regulated by a single regulator, a H_2 regulator Panel or Working Group (WG) from all the relevant H_2 related regulatory areas can be tasked to develop the H_2 regulatory framework. Key members of this suggested

WG can include the National Environmental Standards and Regulations Enforcement Agency (NESREA), the NERC, the SON, the NMDPRA, and the Nigerian Port Authority (NPA).

It is recommended to establish the proposed WG as soon as possible (e.g., second quarter of 2023) with a target of having the regulation not later than mid-2024.

5.2.2 Elaborate a wheeling framework and wheeling charges for GH_2 projects

Three main supply models can be distinguished when considering locations of RE installations, GH_2 facility and GH_2 demand point:

- Producing RE electricity and GH_2/PtX at the point of consumption (co-location);
- Centralising RE power plant and the GH_2 production facility and transport the produced GH_2/PtX to the demand/market, and
- Locating the electrolysis plant near the GH_2/PtX demand node, and wheel RE electricity to the electrolyser and demand location.

Since most of the GH_2/PtX demand centres will be located far away from the RE resources, the transport of GH_2/PtX in the form of molecules (via pipeline, road transport, maritime, etc.) or electrons (via transmission lines) will be inevitable. The choice of one model over the other depends on the possibilities of achieving economies of scales. It is therefore urgent to develop a wheeling framework that enables bilateral transactions by providing a transparent, fair and practical framework for the determination and implementation of wheeling services and charges for the use of Nigeria's power transmission and distribution networks.

This action can be performed by TCN and Nigeria Bulk Electricity Trading (NBET) as lead actors alongside NERC with the guidance from the FMP and contributions from the power Distribution companies (DisCos). The timeline would be during the course of 2023.

5.2.3 Elaborate/adopt standards for hydrogen blending with natural gas

H_2 can be blended with natural gas and transported using existing natural gas pipelines as a temporary solution until dedicated H_2 transport systems are developed[15]. H_2 can be injected into gas networks either directly in its pure form or as "premix" with natural gas. If the end use requires pure H_2, a H_2 de-blending facility can be installed to extract pure H_2 from the natural gas. However, transporting H_2 via existing gas pipeline presents a number of challenges that have to be studied case-by-case in order to

[15] It is worth noting that the share of H_2 in the blend (e.g., 10%) does not mean that the gas grid is decarbonized at that level, but rather at a lower level due to due to the difference in volumetric energy densities of natural gas and H_2.

set relevant regulations and standards accordingly. These challenges include H_2 embrittlement[16], supplied natural gas quality (due to changes in natural gas composition, calorific value and Wobbe index[17]), H_2 purity requirements of certain end users influence the quantity of H_2 that can be mixed with natural gas (IEA, 2021).

To ensure that H_2 blending with the natural gas will not undermine the existing gas infrastructure, systems operation as well as end use equipment in Nigeria, it is crucial to commission a detailed study on the readiness of the existing infrastructure to handle H_2 as well as the proper operation of end-use equipment. The Ministry of Petroleum Resources (MPR) and the NMDPRA would be the appropriate stakeholders to undertake this activity with the involvement of indigenous gas companies. This action shall be concluded by end-2024.

5.3 Infrastructure development

5.3.1 Urgently develop power transmission infrastructure

To produce GH_2/PtX for both the domestic and export markets, GH_2/PtX producers will need to purchase electricity (GW scale) from one or several Independent Power Producers (IPPs) and use the public transmission or distribution grid to wheel the purchased power to their production sites. However, during the interview with the Federal Ministry of Power (FMP) it was confirmed that the current available grid transmission capacity to absorb new power generation is about 1 GW. This lack of transmission (and also distribution) capacity constitutes the main bottleneck of the Nigerian power sector in general and particularly for the development of a H_2 economy. The Presidential Power Initiative (PPI[18]) under implementation aims to achieve a 25 GW operational capacity by 2025. However, this capacity is intended for the universal electricity access to supply reliable power to the country's population that currently relies on more expensive and polluting decentralised fossil fuel-based power generation, meaning that the capacity available for GH_2 will be very limited. Furthermore, Nigeria's ETP states that the capacity of the centralised power transmission grid will gradually be increased to reach about 258 GW by 2060 (incl. 34 GW of RE for GH_2 production), whilst there is no power Transmission Development Plan (TDP) developed yet. It is urgent to develop and implement such a TDP with clear annual incremental grid capacity and how this capacity would be allocated between the national electrification and GH_2 production. The FMP and Transmission Company of Nigeria (TCN) would be in a best position to lead the development and implementation of the TDP with the financial support from the FGN. The development of TDP could be completed by mid-2024.

[16] Chemical reactions between H_2 and steel that can lead to fissures in pipelines
[17] The Wobbe index is an indicator used to assess impact of changing fuels to power end-use equipment
[18] PPI is a strategic and systematic approach to solving Nigeria's perennial problems of unreliable and inadequate electricity supply.

5.4 Hydrogen market development

5.4.1 Establish an electricity balancing market mechanism

One of the key elements that influence the cost of GH_2 production is the utilisation factor of electrolysers: a higher utilisation factor at similar power prices leads to lower production cost, which as a result increases the viability of the project. The utilisation factor is enhanced by oversizing the capacity of RE power installations powering the electrolysers with the possibility of selling surplus electricity to a third party, which means a connection to the national power grid is required. However, selling surplus electricity in excess of 1 MW in Nigeria requires a generation licence in accordance to Section 62(2) of the EPSR Act. The set-up of an electricity balancing market mechanism in Nigeria (via ECN power grid) and the removal of the existing 1 MW limit for selling surplus electricity to a third party would significantly improve the economics the projects and de-risk them substantially.

This action can be undertaken by the NERC together with the FMP and the TCN. This should go hand in hand with the strengthening and modernisation of the electricity network. The removal of the 1 MW limit would allow potential GH_2 project developers to include the opportunities to sale surplus electricity to a third party in their project design. This is a determining factor to make GH_2 projects financially viable. The process could be initiated in mid-2023 with a completion target of mid-2024.

5.4.2 Initially focus on hydrogen export to develop the market

Several potential importing countries/regions (e.g., Germany, Japan and EU as whole) are willing to pay green premiums for GH_2 related products in order to support the market ramp-up for GH_2. These opportunities include, for instance, the H2Global funding instrument of the German Government that has released 900 million euros for the GH_2 market ramp-up globally, with further funding already earmarked for 2023. The H2Global funding instrument targets the supply of GH_2 from outside the EU and the European Free Trade Association (EFTA) countries[19]. This presents a huge opportunity for Nigeria with competitive advantages, including RE resources, existing industrial capacities along with its transferrable skills from the oil and gas sector. However, to fully take advantage of this opportunity, it is imperative to develop necessary infrastructure, mainly RE installations, power transmission lines, H_2/gas pipelines, port terminals as well as shipping and associated logistics. The choice on where to focus first (domestic or export) requires a high-level decision, and this can be done by the FGN or any Government institutions mandated by the FGN. Such a decision will not only promote local H_2 market but also will keep Nigeria as a key player in the global economy for future energy.

5.4.3 Promote carbon finance mechanisms and introduce carbon tax

[19] EFTA countries: Iceland, Liechtenstein, Norway and Switzerland

Carbon intensive companies can be taxed on their direct emissions, and carbon tax revenues can be reinvested in a fund for climate change mitigation projects, including GH_2. This is very relevant especially for carbon-intensive goods for export that will need to pay a "carbon border adjustment" fee when entering export markets such as the EU to prevent "carbon leakage". It would be beneficial to implement this carbon-charge in Nigeria and use the revenues to promote sustainable technologies, including GH_2. The entities responsible for carbon finance and carbon tax are NCCC, and FMITI. Another source of funding is to use the possibilities offered under Article 6 of the Paris Agreement. Under this article, Parties may choose to pursue voluntary cooperation and use of International Transfer Mitigation Outcomes (ITMO) to comply with the NDCs of the countries participating in the agreement. However, in order to tap into this alternative source of financing, it would be necessary for the FMEnv and NCCC to come to a conclusion regarding the modalities (national Art. 6 Framework) on whether and under which conditions approvals for corresponding Article 6 projects/programmes may be granted. Green bonds could be another source of financing for H_2 related projects. Nigeria could capitalize on its experience and lessons learnt from its previous issuance of sovereign green bonds in order to deliver on its NDCs and commitments to the Paris Agreement.

5.4.4 Create hydrogen valleys and Special Economic Zones

A hydrogen valley (H2V) is a geographical area (a city, a region, an island or an industrial cluster) where several H_2 applications are combined together into an integrated H_2 ecosystem that consumes a significant amount of H_2, improving the economics behind the project (EC, 2019). A H2V aggregates multiple demand segments along key H_2 production routes within a specific geographic region.

Apart from being business oriented, existing infrastructure in a H2V can be capitalised on to develop capacity building programs as well as on the-job-training for technicians, engineers and public sector officers based on a concrete project. Furthermore, the RE capacity necessary for the GH_2 production can be leveraged on for both the export and the local market, having positive effects on the balance of payments, i.e., direct income from export and reduction of import. Moreover, regulatory and policy frameworks that are necessary to create the enabling environment for the GH_2 business can be tested in H2V and then extended/endorsed at national level. The results of the ongoing GIZ study on "Hydrogen Potential in Nigeria" may reveal potential suitable sites for the development of H2Vs, otherwise, a separate study should be commissioned. Such a study would provide required elements for the selection of potential H2V sites, prepare the H2V framework (policy, economic, regulatory) and design the valley in terms of available industries and the ones to be developed around H_2.

Another potential enabler of Nigeria's H_2 economy is the creation of GH_2 Special Economic Zones (SEZs), where companies planning to locate into these zones can benefit from various incentives that may entail simplified permitting procedures for GH_2 installations, special taxation regimes for industries located in the SEZ, access to finance at convenient conditions and other benefits. The most appropriate industrial areas should be assessed and selected to serve as H2V. The proximity to ports and links to main transport hubs are for example key characteristics to maximise the benefits of hydrogen technologies applications for both local and export markets. The FMITI would be the qualified stakeholder to lead both the establishment of H2Vs and SEZs supported by the Nigerian Export Processing Zones Authority (NEPZA).

5.5 Capacity building

5.5.1 Strengthen the capacity of key stakeholders

To deploy H_2 technologies successfully, it is necessary to ensure that involved actors have a common understanding of their roles and responsibilities, and have the knowledge and skills needed to perform these. Therefore, it is necessary to develop and implement training programs for these stakeholders in order to equip them with the necessary knowledge and skills. The Federal Ministry of Education (FME) and Nigerian Universities Commission (NUC) would be in a good position to lead the capacity development of the stakeholders listed in the table above. This should start already now and be completed by end of 2024.

5.5.2 Introduce hydrogen into the national education, R&D, and training

To design, build, operate, maintain and manage H_2 projects and infrastructure, different types of knowledge and skills will be required. It is therefore necessary to assess knowledge gaps in the scientific and technological bases for H_2 across its value chain, in order to identify high-priority fundamental research directions that would likely have high impact on enabling a H_2 economy. While some knowledge gaps can potentially be filled by existing workforce (e.g., re-skilling the workforce in the oil industry), new knowledge such as the engineering of electrolysers requires long-term education at university level. A national training program in universities, R&D institutions as well as in TVET needs to be developed and implemented while taking into account Gender Equality and Social Inclusion (GESI) aspects.

5.5.3 Develop a national awareness campaign on hydrogen technologies

Awareness amongst the public, industries, entrepreneurs and key decision makers about the challenges, benefits and safety of using H_2 and its derivatives is key for a successful deployment of H_2 economy. Apart from statements in the ETP, NEP and NEMP, green and blue H_2 are not yet an integral part of Nigeria's energy strategy, and currently there is no broad awareness among the stakeholders. The lack of awareness could not only lead to resistance of people living in or near potential areas for green and blue H_2 projects, but also could compromise the adoption of H_2 applications by potential end-users. Communities living in neighbourhoods of H_2-related projects should be consulted and involved at an early stage of the projects to prevent the negative NIMBY effect. Awareness campaigns can be realised through a number of communication multipliers leading to the establishment of a large and diverse target audience, including, but not limited to, websites of relevant ministries and agencies, press releases, TV channels and radios, social media as well as physical events and demonstration projects to practically demonstrate different aspects of H_2 technologies. The awareness raising campaign could be led by the FMSTI supported by the National Orientation Agency (NOA) right away starting from the beginning of 2023.

5.6 Just energy transition

5.6.1 Ensuring a "just transition"

A "just transition" approach assesses the impacts of the energy transition (incl. net benefits and the distribution of costs and benefits among winners and losers), engages stakeholders (both losers and winners), develops necessary institutional and policy frameworks (incl. capacity building and re-skilling), and mobilises required human and financial resources to implement the "just transition". A "just transition" is already considered in the ETP.

Although Nigeria's ETP could create significant employment opportunities that could partly compensate job losses in the oil industry, it is necessary to ensure provisions for people whose jobs and income cannot be compensated by the implementation of the ETP. Furthermore, several oil and gas projects risk becoming stranded as a result of the expected deep decarbonisation of both local and global economy. A detailed study is recommended to evaluate the impacts of the energy transition in order to develop and implement appropriate measures to ensure a "just transition". The ETO under the OVP would be the relevant stakeholder to lead the "just transition" since Nigeria's ETP has already assessed several elements of the "just transition" such as the potentials for job loss and creation as well as required financial support.

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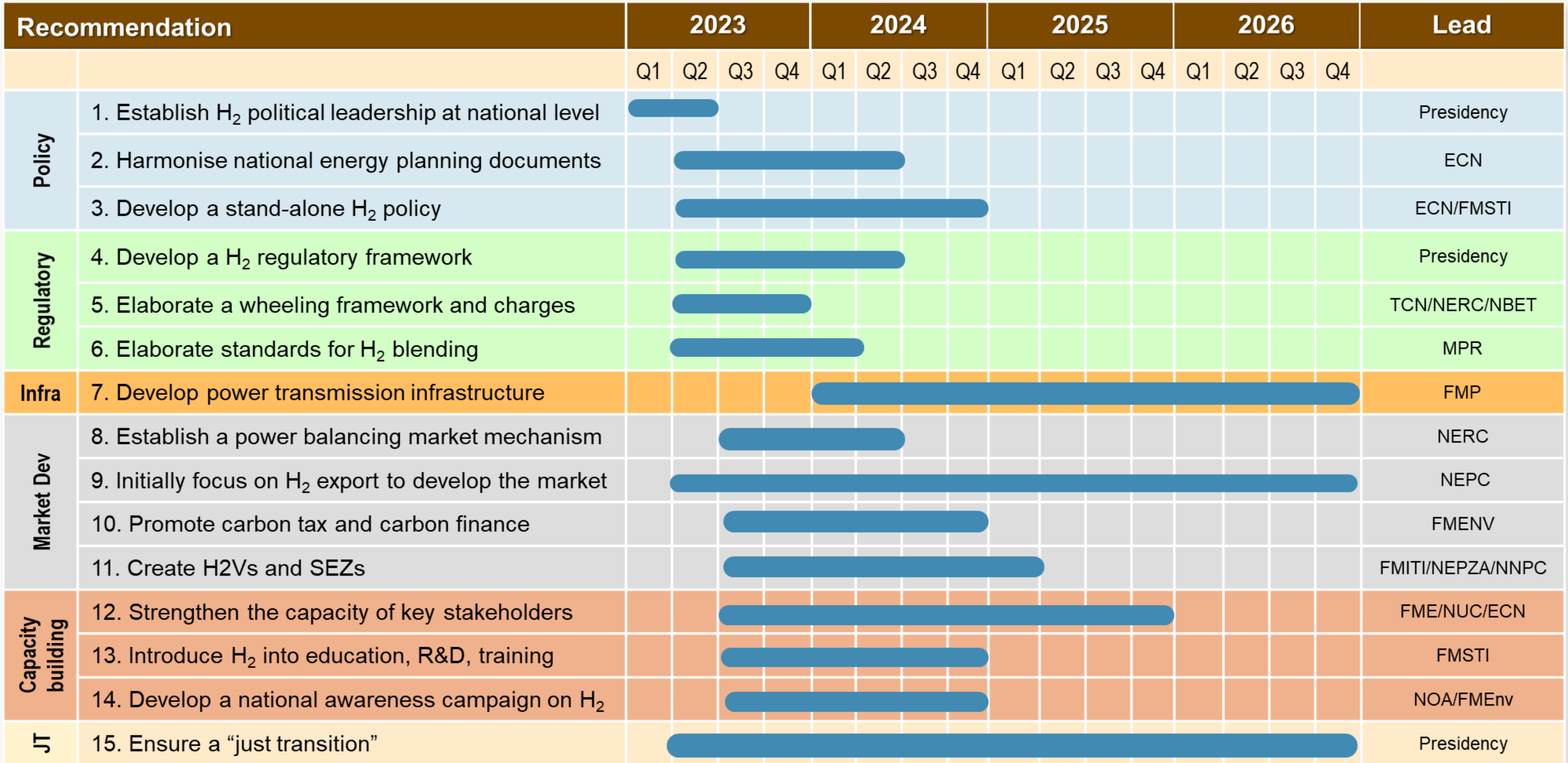
Figure 3. Suggested time plan for implementation of key recommendations



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Conclusions and recommendations

6 Conclusions and Recommendations

GH_2 has emerged as a key enabler for achieving global CO_2-neutrality, and several countries have begun to develop GH_2 related policy and regulatory frameworks by adjusting existing or developing new policies and regulations to facilitate GH_2 integration into their economies.
Key frameworks include the:

- Development of mid- and long-term H_2 strategies;
- Supporting mechanisms and cooperation partnerships;
- H_2 definition, classification and regulation;
- H_2 production and storage facilities, and ownership unbundling, and
- Third party access to H_2 and pipelines, and storage, blending and de-blending facilities.

Concerning Nigeria, the country is endowed with huge RE and natural gas resources that can be exploited to produce green, blue and turquoise H_2 necessary to achieve its 2060 Net Zero goal. Furthermore, the introduction of H_2 in Nigeria's economy presents the country with an alternative energy export product and can help Nigeria remain as a global player in the future energy market. However, Nigeria does not have neither a standalone policy for H_2 nor a primary legislation (Act) or secondary legislation (regulations) on H_2 currently in force. Approaches by frontrunner countries such as the ones presented in this paper, can be adopted and adapted to the Nigerian context.

This Study identified the following ten levers that would enable a successful deployment of green and blue H2 technologies in Nigeria for both national and international markets.

- Stakeholder engagement, contributions and coordination
- Certification requirement of green H2 for export.
- H2 policy and regulation.
- Power sector regulation and operation.
- Gas sector and gas pipeline regulation.
- Technical knowledge and skills;
- Electricity and gas infrastructure capacity, readiness and operation.
- Technology readiness.
- Market and financial opportunities.
- Security and safety standards for H2 handling and use.

Based on the needs, the Study recommends the following 15 key actions (clustered into the following six categories) to foster the successful deployment of green, blue and turquoise H2 in Nigeria.

1. **Policy frameworks**
    - Establish political leadership for H2 on a national level
    - Harmonise national energy planning documents
    - Develop a stand-alone H2 policy
2. **Regulatory frameworks**
    - Create a responsive H2 regulatory framework
    - Elaborate a wheeling framework and define separate wheeling charges for H2 projects
    - Elaborate/adopt standards for H2 blending with natural gas
3. **Infrastructure**
    - Develop power transmission infrastructure
4. **Market Development**
    - Establish an electricity balancing market mechanism
    - Initially focus on H2 export to develop the market
    - Promote carbon tax and carbon finance
    - Create H2 valleys and Special Economic Zones
5. **Capacity building**
    - Strengthen the capacity of key stakeholders
    - Introduce H2 into the national education, R&D, and training
    - Develop a national awareness campaign on H2 technologies
6. **Just transition**
    - Ensure a “just transition”

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Imprint

Publisher:
Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Headquarters:
Bonn and Eschborn, Germany

Project name:
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Stand:
March 2023

GIZ is responsible for the content of this publication

On behalf of the Federal Foreign Office

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