NATIONAL ENERGY REGULATOR OF SOUTH AFRICA

CONSULTATION ON THE DEVELOPMENT OF THE STRATEGY FOR A GAS, RENEWABLES AND HYDROGEN PARTNERSHIP IN SOUTH AFRICA

This is the consultation document by the National Energy Regulator of South Africa (NERSA) on the development of the strategy for a gas, renewable energy and hydrogen partnership in South Africa. The document includes a brief summary of the issues under discussion, the consultation questions provided under specific themes, and an annexure providing background research on the study.

The document is intended to assist NERSA to solicit stakeholder comments, views and perspectives on the prospects of achieving a coordinated development of gas alongside renewable energy and hydrogen in the South African energy markets. In particular, this consultation seeks to gain insights on the current realities for gas in the evolving energy transition environment and to explore the related opportunities and challenges that may be critical to chart the strategic path forward for the further development of the gas industry in South Africa.

Stakeholders are hereby invited to provide written comments should they wish to do so. Submissions can be made on any or all the matters raised as consultation questions in this document. Information collected by NERSA during this consultation process will be used to inform the development of the strategy. Such information will not be attributed to a particular stakeholder, but a collective assessment of the views presented by stakeholders will be provided. **The closing date for the submission of comments is Friday, 13 January 2023.**

Written comments should be submitted to NERSA via email to: pipedgas@nersa.org.za or via post to: The National Energy Regulator of South Africa (NERSA)

Executive Manager: Piped-Gas Regulation
Postal Address: PO Box 40343, Arcadia, 0007
Street Address: Kulawula House, 526 Madiba Street, Arcadia, Pretoria.

Queries concerning this consultation paper should be sent to pipedgas@nersa.org.za.

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ABBREVIATIONS, ACRONYMS AND KEY DEFINITIONS

CNG	Compressed Natural Gas
CCS	Carbon Capture and Storage
CCUS	Carbon Capture Utilisation and Storage
CO_2	Carbon dioxide
DMRE	Department of Mineral Resources and Energy
GW	Gigawatts
H/H_2	Hydrogen/Hydrogen fuel (diatomic hydrogen)
HSRM	Hydrogen Society Road Map
IEA	International Energy Agency
IGU	International Gas Union
LNG	Liquefied Natural Gas
MW	Megawatts
NERSA	National Energy Regulator of South Africa
SANEDI	South African National Energy Development Institute
SMR	Steam Methane Reforming

Greenhouse Gases (GHGs) – gases (primarily carbon dioxide, methane, and nitrous oxide) in the earth's lower atmosphere that trap heat, thus causing an increase in the earth's temperature and leading to the phenomenon of global warming.

Grey hydrogen – hydrogen produced from fossil fuels (mostly natural gas and coal) through methane steam reforming.

Blue hydrogen – hydrogen produced via the combination of grey hydrogen and carbon capture and storage (CCS). CCS is added to reduce greenhouse gas emissions to the atmosphere.

Green or renewable hydrogen – hydrogen produced by splitting water into hydrogen and oxygen using electrolysers, powered by renewable electricity (e.g. solar or wind).

Turquoise hydrogen – Blue hydrogen produced from splitting natural gas into gaseous hydrogen and solid carbon via methane pyrolysis. This process does not yield CO_2 emissions.

Biogas – a mixture of methane and carbon dioxide gases that is produced via anaerobic digestion of biomass.

Biomethane – methane from biogas that has been upgraded to remove CO_2 and other impurities, such that it is of comparable quality to natural gas.

Low-carbon gas – a combined term for blue hydrogen and electrolysis hydrogen produced using electricity with a fossil carbon footprint.

1. PURPOSE OF THIS CONSULTATION

1.1 This is a consultation document on the development of a strategy for a gas, renewable energy and hydrogen partnership in South Africa. The purpose of the document is to solicit stakeholder views on the issues raised therein and any other relevant matters that will assist NERSA to better understand the current realities for gas in the context of energy transition developments, as well as the challenges and opportunities that this transition would bring to the domestic gas industry. In particular, NERSA seeks to draw a variety of perspectives from within the industry regarding, among others:

a) the challenges and synergistic opportunities that the increasing penetration of renewable energy and hydrogen development would likely bring to the gas industry;
b) the potential markets where gas can be appropriately positioned to support or complement South Africa's energy transition path to a low-carbon economy, and the related challenges that may impede the prospects of such developments; and
c) the potential and viability of the different innovative low-carbon and renewable gas technologies that are likely to increase the strategic role and value of gas in South Africa's decarbonised energy system.

2. INTRODUCTION

2.1 NERSA is currently developing a strategy for a gas, hydrogen and renewable energy partnership in South Africa. This is aimed at providing a regulatory perspective on the strategic path forward for the gas industry in South Africa within the evolving energy transition environment that is predominantly driven by climate change limitations, renewable energy growth and the pursuit of hydrogen as the preferred clean energy alternative for the global transition to a decarbonised energy system. NERSA is seeking to engage with interested stakeholders on their perspectives concerning the strategic role of gas and how the industry can adjust for its future in the country's low-carbon energy system that is likely to be dominated by green renewable and hydrogen energy in the long-term.

2.2 As such, a consultation paper consisting of a set of questions under specific themes is hereby presented to engage with stakeholders on a range of issues that are paramount to informing the development of the strategy. The strategy, once developed, would not constitute a policy document, but would assist NERSA to make effective and informed contributions to the ongoing policy debates regarding the energy transition pathways in South Africa, especially on matters connected to gas. NERSA intends to use the report to advocate for policy and regulatory changes that may have a positive impact on the future development of the gas market alongside the increasing renewable energy capacity and the prospects of hydrogen development in South Africa.

2.3 Appendix 1 of the consultation document provides the background research on the theoretical perspectives and analysis that the consultation questions are premised on, including:

a) the overview of the complementary roles among gas, renewable energy and hydrogen;
b) the potential interdependencies for gas, hydrogen and renewable energy in enhancing energy diversity and security of supply, while contributing to climate change mitigation in South Africa;
c) an assessment of the synergistic opportunities for a coordinated development of gas and the related infrastructure investment requirements, alongside renewable energy and hydrogen, in various energy markets in South Africa; and
d) an analysis of the existing relevant policy and legal framework with the objective of developing policy and legislative recommendations to gradually shape the development of integrated system for gas, hydrogen and renewable energies in South Africa.

2.4 The background research report is available for download on the NERSA website at www.nersa.org.za.

3. POLICY CONTEXT AND TARGETS

3.1 South Africa plans to transition to a low-carbon economy by 2030. The National Development Plan (NDP2030), adopted by Parliament in 2012, sets out this vision and these aspirations, which include the country's intent to reduce its dependency on carbon natural resources and energy by 2030, while balancing the transition with the objectives of increasing employment and reducing inequality.[1] To support this vision, numerous government-led initiatives are being undertaken, including action plans on climate change response, scaling-up renewable energy generation capacity through the Renewable Energy Independent Power Producers Procurement Programme, the development of a national Hydrogen Society Roadmap, and green hydrogen initiatives to kick-start the hydrogen economy.

[1] South African National Planning Commission, 2012. National Development Plan: Vision for 2030

3.2 The Hydrogen Society Road Map (HSRM) 2021, in particular, was released by the Department of Higher Education, Science and Innovation on 17 February 2022 to serve as a national coordinating framework to facilitate the integration of hydrogen-related technologies in various sectors of the South African economy and stimulate economic recovery, in line with the Economic Reconstruction and Recovery Plan. Notably, the HSRM set the target for a minimum of 1 MW of electrolysis capacity by 2024 for green hydrogen, which would be scaled-up to 15 GW by 2040. This green hydrogen is targeted for use in the decarbonisation of the heavy-duty transport sector, aviation, shipping and rail; the decarbonisation of the energy-intensive industry (steel, chemicals, mining, refineries and cement), greening of the power sector, and for creating an export market. The HSRM also recognises the need for the production, storage and distribution of all forms of hydrogen to support its objectives, while positioning the country to transition from grey, blue to green hydrogen to contribute to the achievement of climate change targets.[2]

3.3 Further, South Africa's overarching energy policy (the White Paper on Energy Policy of 1998) envisages the use of gas and renewable energy in the country's energy mix. The policy positions on gas are expressed in various government instruments, providing a comprehensive policy framework for the energy sector in the absence of a specific policy document for the gas sector. The Energy White Paper recognises that gas is an attractive option for South Africa and that the Government is committed to the development of this industry. A strong potential for significant growth of the SA gas industry based largely on regional gas trade is envisaged. Further, the NDP2030 envisions that gas would play a critical role as a transition fuel to decarbonise the SA economy; and provides as one of the infrastructure priorities, the construction of infrastructure to import LNG and to increase exploration to find domestic gas feedstock.

3.4 South Africa's policy positions on renewable energy are articulated in the Energy White Paper of 1998 supplemented by the sector-specific White Paper on Renewable Energy Policy of the Republic of South Africa of 2003 ('Renewable Energy White Paper'). Both policy documents pledge 'Government support for the development, demonstration and implementation of renewable energy sources for both small and large-scale applications'. The Renewable Energy White Paper sets out the policy principles, goals and objectives for promoting and implementing renewable energy in South Africa; and

[2] Department of Higher Education, Science and Innovation, 2022. Hydrogen Society Roadmap for South Africa 2021

mainly recognises the meaningful contribution of renewable energy in the power generation and non-electric technologies, such as solar water heating and bio-fuels.

3.5 A snapshot of the publicly available policy targets related to gas, hydrogen and renewable energy is provided below.

Gas	**Renewable Energy & battery storage**	**Hydrogen**
• 6 380 MW of gas/diesel power generation capacity envisaged in the IRP 2019 by 2030 • No other policy targets set for the use of gas in other energy markets beyond power generation	• 20 409 MW of renewable energy capacity complemented by 5 000 MW of battery storage projected by 2030 (IRP, 2019)	• Minimum of 1 MW electrolysis capacity by 2024 for green hydrogen, which would be scaled-up to 15 GW by 2040 (HSRM, 2021)

4. DISCUSSION AND CONSULTATION QUESTIONS

Figure 1 below provides a graphic depiction of the existing interface among gas, renewable energy and hydrogen.

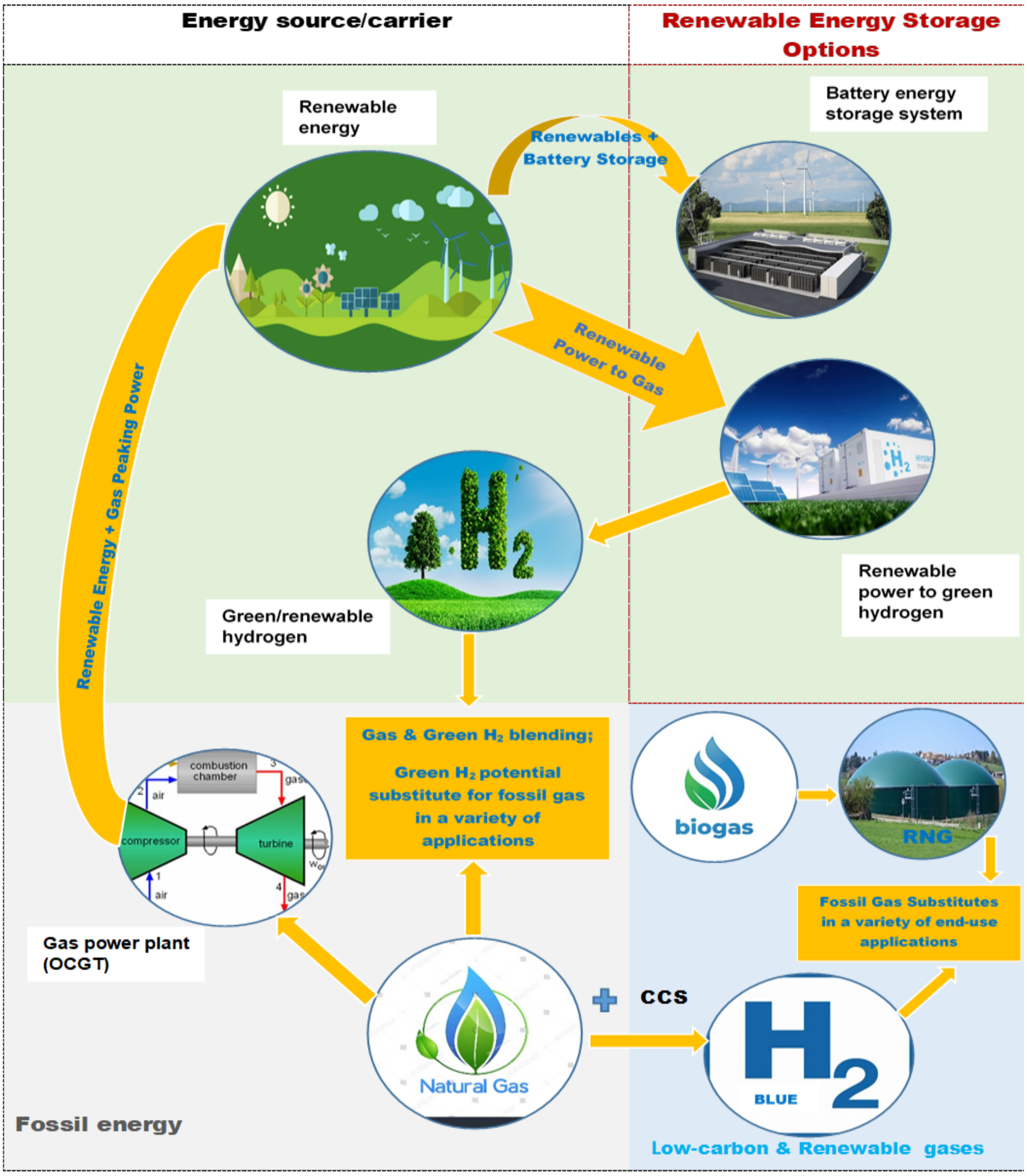

Figure 1: Graphic Illustration of the Gas, Renewable Energy and Hydrogen Interface

Source: Own synthesis

4.1 Gas and Renewable Energy Interface

4.1.1 Literature suggests that a complementary relationship exists between gas and renewable energy in the power generation sector (see Appendix 1 for a more detailed discussion). In this instance, gas is cast as a conventional back-up for intermittent renewables, where gas-fired power provides flexibility to electricity systems and fill the supply gap when variable renewable solar, wind and hydro plants fall short or are unable to produce enough electricity to meet existing demand.

4.1.2 Nonetheless, a combination of renewable energy and battery energy storage is viewed as more suitable than a renewable energy and gas power option, from an environmental standpoint. Battery storage is regarded as a natural complement to variable renewable energy and a more competitive option than gas. However, it is also argued that batteries are most suited to providing a short-term energy storage solution, given the physical limitations, such that a fundamentally different technology solution like power-to-gas is required to serve as a long-term energy storage medium. In this instance, excess renewable energy is used to produce green or renewable hydrogen via water electrolysis. The green hydrogen can be converted back to power through hydrogen-fuelled power generation when needed, be injected into existing gas networks, or be used as a substitute for gas in a variety of applications.

4.1.3 Stakeholders are requested to comment on the following issues:

Consultation Questions

(i) What are the technical and regulatory barriers in linking gas and renewable energy in South Africa?

(ii) Do you view the relationship between gas and renewable energy as complementary or competitive in nature in terms of power generation?

(iii) What is your view on battery energy storage technology? Do you think the technology is capable of providing a short-term and long-term energy storage solution to manage renewable intermittency?

(iv) What should the role of gas-fired power be in South Africa’s electricity generation mix? What mechanisms should be put in place to make gas a prominent feature in SA’s power generation mix?

(v) What are the competitive advantages for conventional gas-fired power vs battery storage and the power-to-gas technologies in ensuring power system stability and managing renewable intermittency?

(vi) What are the prospects and key considerations for power-to-gas in SA?

(vii) What are the efficiency considerations concerning the direct use of renewable electricity vs using it to produce green hydrogen via water electrolysis?

4.2 Gas and Hydrogen Interface

4.2.1 According to literature (see Appendix 1), a synergy between natural gas and hydrogen is plausible in a variety of sectors, including transportation, industrial and buildings (commercial and residential), in that hydrogen can be transported, stored and used the same way as natural gas. In this instance, the relationship between gas and hydrogen is depicted as follows:

a) using existing steam methane reforming (SMR) and carbon capture and storage (CCS) technologies to reduce carbon emissions in gas-fired power plants or gas fuelled operations;
b) blending blue hydrogen (produced from natural gas via SMR coupled with CCS) in existing natural gas pipelines to aid storage and transportation to existing gas markets, thus partly lowering the methane emissions content;
c) the direct substitution of fossil gas with hydrogen (low-carbon or green hydrogen) in a range of uses, including on-land and marine transportation, heat and power for commercial and residential buildings, heat and power for industry, and industrial feedstock;
d) repurposing the existing natural gas network to transport pure hydrogen, which could be low-carbon or renewable hydrogen; and
e) sector coupling (power-to-X pathways), including renewable power-to-gas and renewable power-to-liquids (PowerFuels).

4.2.2 Both gas (a primary energy source) and hydrogen (an energy carrier) can be used for heating and cooking in households and commercial settings, direct feedstock or fuel in industrial applications, fuel for transportation, and fuel to generate steam and heat in power generation. In South Africa, gas (natural and synthetic) is widely used in the industrial sector, whereas its use in the transport, commercial and residential sectors is negligible. According to the Department of Mineral Resources and Energy (DMRE) (2021), the industrial sector consumed about 51% of the total energy supplied in South Africa in 2018, with gas meeting about 29% of that energy demand. The chemical sub-sector is the biggest consumer of gas, followed by iron and steel, pulp and paper, and food and tobacco.[3] Gas for use in power generation is minimal, but the concept is widely accepted to have huge potential with the appropriate policy mechanisms in place.

4.2.3 Hydrogen in South Africa is currently not well developed for energy applications, however, the country has a long history of grey hydrogen produced from coal and natural

[3] DMRE, 2021. The South African Energy Sector Report 2021

gas feedstocks, mainly for limited use in the industrial sector. South Africa produces approximately 2% (2.5 million tonnes) of global hydrogen output, with Sasol being the leading producer through its Fischer-Tropsch (FT) CTL-fuel process.[4] Blue and renewable/green hydrogen are still a foreign concept in South Africa; whereas the use of hydrogen is completely non-existent in the transportation, commercial and residential building sectors. As stated above, South Africa's Hydrogen Society Roadmap (2021) envisages the shift from grey to blue to green hydrogen over time, aiming to achieve electrolysis capacity of 15 GW of green hydrogen by 2040.

[4] Sasol, 2021. Sasol Climate Change Report 2021

Consultation Questions

(i) Please comment on the prospect of gas and hydrogen co-existing as complementary rather than competing fuels in the energy system. What are the key issues of risks and opportunities that should be of consideration?

(ii) Both gas and hydrogen are not widely in use in the residential and commercial buildings and transportation sectors in South Africa. What is your view on the prospects of both fuels in these markets?

(iii) Given that substituting gas with hydrogen is considered a future alternative to decarbonising the gas market and achieving net-zero emissions targets, should South Africa consider gas as a bridging fuel or look directly into the future of sustainable hydrogen in these markets? Please comment in respect of each market (power generation, industrial, transportation, commercial and residential), where possible.

(iv) What are the costs and opportunities for consumers of using gas vs hydrogen in the transportation, industrial, power generation, and commercial and residential building sectors?

(v) What are the safety considerations to the transportation, storage and public usage of gas and hydrogen?

(vi) Regarding the prospects of blending natural or synthetic gas with hydrogen, what are the key technical and safety issues that should be considered?

(vii) Is this scenario of hydrogen–natural gas blends considered to be good use of the green hydrogen vs using the renewable electricity for direct consumption?

(viii) What will be most commercially viable applications for each type of hydrogen (grey, blue or green hydrogen)?

(ix) Regarding the prospects of repurposing existing natural gas networks to accommodate sustainable low-carbon or green hydrogen gases in the gas market, what are the technical and social issues that should be of consideration?

Blue hydrogen and CCS technology

4.2.4 Blue hydrogen is viewed as an intermediate solution to decarbonise fossil natural gas en route to a carbon neutral world. Blue hydrogen production only accounts for 0.5% of the current global hydrogen production (IGU, 2021). According to the IEA (2020), the CCS technology enabling blue hydrogen production offers significant strategic value in the transition to net zero in that it can be retrofitted to existing gas-fired power and industrial plants; used to tackle emissions in hard-to-abate industries (iron and steel, chemicals, cement, long-distance road transport and aviation); and combined with bioenergy or direct air capture for the removal of CO_2 from the atmosphere.

4.2.5 South Africa has thoroughly researched CCS technology and its potential uses through the South African Centre for Carbon Capture and Storage, previously administered by SANEDI, now administered by the Council for Geosciences.[5] The commercial application of the CCS technology is yet to be realised locally.

Consultation Questions

(i) Is the CCS technology a feasible solution to making gas sustainable for the domestic market?

(ii) What are the technical and economic implications of integrating CCS technology into conventional gas business and operations?

(iii) What environmental considerations should be taken into account in relation to the carbon capture and storage technologies?

(iv) What are the feasible methods or technologies for CCS in South Africa? What would the risks, challenges and opportunities be of the prospects of storing CO_2 underground?

[5] In 2009, the South African National Energy Development Institute (SANEDI) created the South African Centre for Carbon Capture and Storage, which is funded by the South African Government, the World Bank, the European Union, Eskom and private sector companies such as Anglo American. The centre is mandated to explore carbon capture and storage (CCS) in the country and has made good strides in the research into CCS and its potential use through the collaboration. Efforts in this area are being stepped up to include SANEDI's recent membership of the Global CCS Institute and the DMRE's continuing participation in the carbon capture, utilisation and storage work of the International Energy Agency (IEA). The Minister of Mineral Resources and Energy has recently approved the transfer of the CCUS Programme from SANEDI to the Council for Geosciences.

4.3 Renewable Gases

4.3.1 Renewable gases are receiving attention as key assets to decarbonising the gas industry. Renewable gases comprise biogas, biomethane and green hydrogen produced from renewable electricity. Biomethane and green hydrogen, in particular, are alternative gases that are capable of substituting fossil gas in a variety of uses or applications, including cooking and heating, power generation, transportation (as bioLNG and bioCNG), and industrial uses. The use of biogas is more favourable for in situ production and use for combined heat and power or agricultural operations, as it cannot be directly injected into gas pipelines without first being upgraded to a gas of higher value (biomethane).

Biogas and biomethane potential

4.3.2 According to the IGU (2021), the combined global scale of biogas and biomethane production is around 40 bcm, which is equivalent to 1% of global natural gas production. About 75% of this production occurs in Europe (Germany, Denmark, Netherlands, France, Italy, UK) and China. Most of the biogas is produced near the points of consumption for combined heat and power in rural communities. Only 10% of the biogas production in Europe is upgraded to biomethane that is suitable for injection into the gas pipeline network.[6]

4.3.3 The IGU further estimates that biogas supply has the potential to rise to 20% of the global natural gas demand in the long term. However, this would require a strong government policy focus to facilitate significant investments and the rapid increase of biogas production that can be upgraded to biomethane. The availability of feedstock supply, high production costs and scale are highlighted as key potential impediments to the upscaling of biogas and biomethane production to match the current levels of natural gas demand. In the South African context, biogas is produced from waste material via anaerobic digestion in rural communities, mostly for heating and electricity, near the source of production. NERSA oversees the registration of biogas production activities in terms of section 28 of the Gas Act, 2001 (Act No. 48 of 2001) and has since registered both large- and small-scale biogas projects across various provinces in the country (KwaZulu-Natal, Gauteng, Limpopo, Western Cape, and Mpumalanga). According to the Southern African Biogas Industry Association, biogas has the potential to displace about 2500 MW of grid electricity in South Africa. This potential could be high given the

[6] International Gas Union, 2021. Global Renewable and Low-Carbon Gas Report

multitude (about 108 million tonnes) of landfill waste and agricultural waste (40 million tonnes) produced in this country every year.

Consultation Questions

(i) What is the scale of the opportunities and the potential to accelerate the production of renewable gases (biogas, biomethane and green hydrogen) in South Africa?

(ii) What are the key technical, economic and regulatory barriers that should be considered and addressed to support the development of these gases?

(iii) Please comment on the viability of biogas and biomethane projects, focusing on the resource and commercial factors.

(iv) What potential policy and regulatory mechanisms are required to stimulate the demand and uptake of green hydrogen, biogas and biomethane supplies in the SA energy markets? Please comment on the gas relevant to your experience.

(v) What are your views on the arguments that renewable gases, particularly green hydrogen, should only be targeted for sectors that are hard to abate, such as marine transport, high-heating industries (iron and steel) and aviation?

(vi) Given that the renewable gas market is currently non-existent, should fossil gas be considered a transitional fuel in the initial stages of development? Or should long-term policy efforts be made to establish the renewable gas markets, including biogas, biomethane and green hydrogen? What are the primary issues or challenges that should be considered?

(vii) What are the specific roles that can be played by industry, the Regulator and the Government to facilitate the development of biogas, biomethane and green hydrogen markets in South Africa, as well as to facilitate their social acceptability and consumer confidence in the usage of these renewable gases?

(viii) What are the key benefits, risks and potential impacts of these unfamiliar energy sources on the various end-user markets?

(ix) Are there unforeseen or unintended consequences regarding these energy sources/carries that you would like to bring to the attention of the Energy Regulator?

(x) What are the economic outputs or benefits (including employment opportunities) associated with renewable gas initiatives or projects? Please also comment on the scale of such opportunities, where possible.

Novel renewable gas technologies

4.3.4 Biogas, biomethane and renewable/green hydrogen are currently not produced at scale. The comparative benchmarks for the costs, efficiencies and performance for the different technologies involved in the production and use of these gases are yet to be established globally. Like other novel technologies, it is possible that geographic or local factors would influence the scale and pace at which these gases may be upscaled.

Consultation Questions

(i) What is the likely timing of the technical maturity and economic viability of biomethane and renewable hydrogen as potential direct substitutes for fossil gas?
(ii) Does South Africa have sufficient workforce skills and knowledge to develop biogas, biomethane and green hydrogen capabilities and associated markets and industries?
(iii) If not, please elaborate on what skills are required to facilitate the development of these renewable gases and at what scale?
(iv) What can be done from an industry and government policy perspective to build those skills and capabilities that are required to facilitate or support the development of renewable gases?
(v) If skills are to be imported in the initial stages of market development, what skills transfer methods can be put in place to develop local capabilities and expertise?
(vi) What other economic opportunities or benefits may arise from the existence of domestic supply chains for renewable gases (i.e., their local production, transportation, storage and use)?

4.4 Regulatory and Policy Framework

4.4.1 Policy and regulatory support is crucial to enable the development of new markets and for the deployment of new technologies. Support mechanisms evident in literature that are aimed at promoting and facilitating the development of renewable gases include the improvement of policies and regulations to create and sustain an enabling environment for new investments, public funding for technology-related research and development and demonstration projects, financial incentives, and improvement of technical standards and codes to integrate emerging technologies.

Consultation Questions

(i) Do you think the Gas Act, 2001 is suitable and adequate to regulate renewable gases (the biogas, biomethane and green hydrogen)? Please elaborate on your answer.

(ii) If not, what are the key changes that must be made to accommodate renewable gases in the framework?

(iii) What other regulatory options should be considered to aid the development of renewable gases in the domestic market?

(iv) In relation to policy, does South Africa need to develop a cohesive policy framework across biogas, biomethane and green hydrogen industries? What should be the key features informing that policy?

5. NEXT STEPS

5.1 Stakeholders are requested to comment on the consultation document concerning the development of a strategy for a gas, renewable energy and hydrogen partnership. **Written submissions must be submitted by 13 January 2023** via email to: pipedgas@nersa.org.za or to:

The National Energy Regulator of South Africa (NERSA)
Executive Manager: Piped-Gas Regulation
Postal Address: PO Box 40343, Arcadia, 0007
Street Address: Kulawula House, 526 Madiba Street, Arcadia, Pretoria.

5.2 Stakeholders who wish to share additional information or other reports with NERSA in relation to any of the issues raised in this consultation document are welcome to do so.

APPENDIX 1

Background Research Report: Development of a Strategy for a Gas, Renewable Energy and Hydrogen Partnership in South Africa

APPENDIX 1

NATIONAL ENERGY REGULATOR OF SOUTH AFRICA

BACKGROUND RESEARCH REPORT

Strategy for a Gas, Renewable and Hydrogen Energy Partnership in South Africa

A regulatory perspective

October 2022

Contents

Abbreviations and acronyms

Bcm	Billion cubic metres
CNG	Compressed natural gas
CCS	Carbon Capture and Storage
CCUS	Carbon Capture Utilisation and Storage
CO_2	Carbon dioxide
DMRE	Department of Mineral Resource and Energy
EU	European Union
EJ	Exajoule
GW	Gigawatts
H/ H_2	Hydrogen/ Hydrogen fuel (diatomic hydrogen)
IEA	International Energy Agency
IGU	International Gas Union
KG	Kilogram
LNG	Liquefied Natural Gas
MW	Megawatts
MTPA	Million tonnes per annum
NERSA	National Energy Regulator
SANEDI	South African National Energy Development Institute
Tcm	Trillion cubic metres
TWh	Terawatt-hour
USA/US	United States of America
UK	United Kingdom

1. INTRODUCTION AND CONTEXT

South Africa's energy economy is gradually shifting from the traditional solely fossil-based towards a diversified energy system likely to be characterised by high concentration of low-carbon and renewable energy supply in future. The National Development Plan (NDP2030), adopted by Parliament in 2012, sets out (in Chapter 5) the vision and framework for a transition to a low-carbon economy. It is envisioned that by 2030 South Africa will be in the process of transitioning to a low-carbon, resilient economy and just society. One of the notable aspiration in the vision is that South Africa will have reduced its dependency on carbon natural resources and energy, while balancing the transition with the objectives of increasing employment and reducing inequality. The NDP2030 recognises the country's long history of dependency on fossil based energy, particularly coal. Coal played a significant role to industrialise the country's economy as the cheapest and abundant primary energy source, and remains an important component of the economy to date.[1]

Gas currently plays a minimal role, contributing about 3% in the South Africa's energy mix (DMRE, 2021). On the contrary, gas currently provides 25% of the world's total primary energy supply (138 exajoule (EJ) out of a total of 557 EJ) and is expected to retain a major role as a source of flexibility and back-up in the energy system leading up to the net-zero Emissions Scenario by 2050 (IGU, 2021). From the strategic context in the global energy mix, gas is seen as a transition fuel capable of enabling the shift from high carbon intense to clean energy pathways likely to be dominated by renewables and green hydrogen energy sources in future.[2][3]

In this context, gas has a significant role to play to amongst others help transition the country into a low carbon economy as envisaged in the National Development Plan 2030, which recognises the need for gas and see it as a potential alternative to move South Africa into a low carbon economy. Further, the White Paper on Energy Policy (1998) is supportive of diversity of supply and refers specifically to natural gas and coal bed methane. The Integrated Resource Plan for electricity generation 2019 (IRP2019) envisages a diversified power generation mix that includes gas. It is anticipated that gas/diesel will contribute about 8.1% (6 3800 MW) of the projected total installed capacity of 77 834 MW by 2030.

Nevertheless, the harsh realities for gas is that it faces strong social and environmental opposition because it also emits carbon and greenhouse gases although relatively low compared to coal and oil emissions. Consequently, this puts gas on strong commercial

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[1] South African National Planning Commission, 2012. National Development Plan: Vision for 2030
[2] Department of Mineral Resources and Energy, 2021. The South African Energy Sector Report 2021
[3] International Gas Union, 2021. The Global Gas Report

competition with renewables and soon green hydrogen. Further, the efforts towards decarbonising the energy system as a response to climate change challenges puts gas at the back foot of renewable energy and green hydrogen as the preferred clean alternative energy solutions into the zero carbon future. Despite the underlined competitive aspects, global assumptions suggest that gas still has a role to play in the sustainable energy mix as a transitional fuel towards 2050. Gas is expected to deliver a substantial decrease of CO_2 emissions mainly in the power generation sector through coal/oil to gas switching in the near term while efforts are being made to scale-up renewable energy investments and address the technology challenges slowing down the large –scale deployment of renewable energy in various economies (IGU, 2021). Further, gas is considered as a potential solution to decarbonise hard-to-abate industries such as marine transportation, heat extensive steel manufacturing, and aviation sectors.

From the local perspective, several studies already exist that highlight the role of gas in South Africa's transition or path towards a low-carbon economy. However, the views do not converge on the scale and limitation of that role when the transition to clean energy solutions accelerate. Some have taken the narrow view that gas is only suited for power generation therefore concluding that gas-fired power is not needed in the country's power generation mix mainly for environmental reasons; while others have highlighted the broad critical role beyond power generation that gas can play to contribute to the country's decarbonisation efforts and energy security. None of these studies has attempted to assess the role of gas within the confines of the existing policy frameworks and government's plans for alternative energy development, especially in markets that can be also served by gas.

At the backdrop of these debates is that South Africa has limited natural gas resources discovered to date. The only indigenous gas fields that produced large-scale gas quantities have depleted and there were no reliable domestic resources to immediately replace that production. High environmental activism continues to hamper the development of recently discovered offshore indigenous resources in the West Coast driving away potential investment in domestic gas production. Several smaller onshore gas fields discovered in isolated locations are considered to be sub-commercial under the present market conditions, while the only successful onshore gas find in Virginia, Free State is considered too small to meet the current and future gas domestic demand. On the other hand, unconventional natural gas resources such as coal bed methane (CBM) and shale gas are said to have big potential; but they are yet to be explored and proved. Thus, indigenous gas production in South Africa is unlikely to increase substantially in the near future.

Since 2004, South Africa imports about 160 million gigajoules per annum of natural gas from the Pande and Temane gas fields in Mozambique to Secunda via the transmission pipeline owned by the Republic of Mozambique Pipeline Investment Company (ROMPCO). These resources are also facing a potential decline in gas production from 2025 that may pose a gas supply risk and security of supply challenge to the South African market. Therefore, the need for alternative gas supplies becomes more crucial.

2. PROBLEM STATEMENT

Although a myriad of government policies (including the National Development Plan 2030, energy policy of 1998, gas industrialisation policy, and IRP 2019) recognise the need for gas in South Africa's energy mix, the gas industry remains nascent and has not seen significant development beyond the Sasol Mozambique natural gas project. While opportunities that seek to drive gas development exist, the industry is faced with challenges and barriers that continue to undermine the critical role that gas can play to contribute to the country's energy security and climate change goals.

The gas industry in South Africa does not exist in a vacuum therefore cannot develop on its own without support and proper coordination of other various sectoral policies within the energy sector. Although versatile in its application, gas has to compete with conventional mature fuels for a prominent place in the energy mix. The markets for gas are not readily available; they are created overtime and require the co-development of gas supplies and corresponding demand for the gas as well as infrastructure to enable the supply of that gas to the specific target markets.

Further, the developments on energy transition and decarbonisation currently happening globally put the role of gas in the future energy mix into question. There is growing consensus among international bodies/agencies that gas needs to adapt to a low-carbon pathway in order to claim a prominent place in a more sustainable energy mix globally beyond 2050. Further, global industry players are making concerted efforts to find ways or solutions for gas to thrive in a carbon neutral world where greenhouse gas emissions (including carbon) are gradually eliminated. The gas decarbonisation pathways emerging from these efforts are focused on:

(i) gas playing a supportive role for the vast expansion of renewable electricity generation;

(ii) Aggressively reducing the greenhouse gas emissions associated with the use of natural gas; and

(iii) Gas providing a backbone for the development of the hydrogen economy.

Despite the potential complementarities of gas with renewable energy and hydrogen, the gas and renewable energy markets in South Africa continue to be developed in parallel without proper coordination from the policy perspective. It is highly likely that the same parallel approach would be followed to develop the domestic hydrogen economy that is still conceptual.

Considering these historical and transitional challenges for gas, NERSA has decided to develop a strategy for a gas, renewable energy and hydrogen partnership in South Africa. The aim is to provide the regulatory perspective on the strategic path forward for the gas industry in South Africa within the evolving energy transition environment that is predominantly driven by climate change limitations, renewable energy growth and the pursuit of hydrogen as the preferred clean energy alternative for the global transition to a decarbonised energy system.

The strategy, once developed, would not constitute a policy document but would assist NERSA to make effective and informed contributions to the ongoing policy debates regarding the energy transition pathways in South Africa, especially on matters connected to gas. NERSA intends to use the strategy document to advocate for policy and regulatory changes that may positively impact on the future development of the gas market alongside the increasing renewable energy capacity and the prospects of hydrogen development in South Africa. This report provides a background research on the key features and issues that will inform the strategy.

3. OBJECTIVES

The purpose of the study is to elucidate the realities facing the gas industry, highlight the challenges and the potential benefits of gas that are not self-evident to the South African market, and explore the opportunities and areas where gas can be properly positioned to play a significant role in the country's future energy mix within the context of the energy transition and sustainable energy development. In particular, NERSA aims to:

(a) Assess the potential interdependent roles of gas, hydrogen and renewable energy in enhancing energy diversity and security while contributing to climate change mitigation in South Africa;

(b) Explore the synergistic opportunities for a coordinated development of gas and related infrastructure investment requirements alongside renewable energy and hydrogen in various energy markets in South Africa;

(c) Assess the current relevant policy and legal framework with the objective of developing policy and legislative recommendations to the Department of Mineral Resources and Energy that would gradually shape the development of integrated system for gas, hydrogen and renewable energies in South Africa.

(d) Recommend strategic policy goals and targets that should be set to position gas to have a meaningful contribution to the country's economy alongside published renewable energy and hydrogen policy goals and targets; as well as the related gas infrastructure requirements and viable options for achieving such goals.

Key questions that NERSA seeks to answer include:

(a) What are the areas or potential markets where South Africa could attract influence and facilitate the increased use of gas in the country - how these markets can be best served with gas?
(b) How is the industry planning to adapt for its future in the country’s low-carbon energy system?
(c) Can renewable gases contribute to increasing the strategic role and value of gas in South Africa’s decarbonised energy system?
(d) What are the potential policy measures that could be explored to resolve the existing challenges and facilitate the development of the future gas industry in SA in the context of decarbonisation, renewable growth and clean hydrogen development?
(e) What should be done to create an interdependent policy relationship between gas, renewable energy and hydrogen? What integrated policy action plans should be put in place to realise the opportunities of these options together in achieving the energy policy goals for energy diversity and security of supply, amongst others?
(f) What policy and regulatory mechanisms are required to foster gas, hydrogen and renewable energy planning coordination and investment in related infrastructures.
(g) What are the policy goals and targets that should be set to position gas to have a meaningful contribution to the development of the country's economy alongside the renewable energy and hydrogen policy goals and targets? What would be the related gas infrastructure requirements and viable options for achieving such goals.

To begin the strategy development process, NERSA has compiled this background research report providing project context and objectives; baseline information on related gas, hydrogen and renewable energy industries; theoretical perspectives concerning the existing interplay among gas, renewable energy and hydrogen in various energy markets as well as related international experience and key strategic drivers; and local policy context relating to the three energy sources. Further work will be conducted to assess the practical realities for achieving a coordinated development of gas alongside renewable energy and hydrogen in the South African energy markets, amongst others.

4. LITERATURE REVIEW

4.1 Gas highlights and global assumptions

According to the International Energy Agency (2021a), gas is the third largest consumed primary energy source globally behind coal and oil, with most of the demand arising from the industrial and power generation sectors.[4] Gas is a widely used primary energy resource in the world and accounted for 24% of the global total primary energy consumption in 2021 (British Petroleum, 2022). The IEA estimates that global gas demand will continue to grow modestly in the next coming years following the significant drop in energy demand across all primary energies caused by the COVID-19 pandemic. However, this scenario is likely to change as clean energy transitions accelerate with the scaling up of more renewable energy resources, electric mobility and renewable gases including green hydrogen and biomethane.

In terms of supply, global proven natural gas reserves grew by 27% from 138 trillion cubic metres (tcm) in 2000 to 188,1 tcm in 2020. According to the current BP's reserves-to-production ratio, these reserves are sufficient to meet about 49 years of global production. In 2021, global production and consumption of gas was at 4036.9 billion cubic metres (bcm) and 4037.5 bcm respectively. About 516 bcm of this gas was traded via LNG, while 505 bcm comprised inter-regional pipeline trade.[5]

Traditionally natural gas has been produced and transported by pipeline from source to market in its gaseous form. Technological innovations have made it possible for natural gas to be transported over long distances and traded across continents in its liquid form where pipeline transportation would not be feasible. In this case, natural gas is liquefied and supercooled to temperatures below -160°C and shipped to the markets via custom-built cryogenic vessels. The LNG is then converted back to the gaseous form through a regasification process before send-out to consumers.

The introduction of the LNG technology has catalysed the development of the global LNG market which has changed the way the global gas industry operates. Traditional regional gas markets have defined the structure of the global gas industry predominantly in the 20th century. The LNG evolution has enabled energy poor and resource scarce countries to rely on LNG

[4] International Energy Agency, 2021a. World Energy Outlook 2021
[5] British Petroleum Statistical review 71 edition, 2022

imports to address energy security issues. The imports of LNG across continents is creating an interconnectivity between the regional gas markets and gravitating them towards an integrated global gas market.

Gas is the cleaner fossil fuel, and can be a reliable and secure energy source in developed gas markets where there is abundant commercially recoverable domestic gas reserves or secured adequate import supply and reliable gas transport infrastructure. Unlike coal, gas is always readily available for use as it can be stored in its transportation and supply system connected to the source. Both pipelines and virtual mobile infrastructure serve as the integrated gas transportation, storage and supply system to the customer. Gas is flexible as it can be turned off at the switch of the tap when not needed.

Even when domestically available, gas resources are localised too far from the market and require infrastructure to transport the gas produced from the fields to the market. Pipelines with fixed high costs serve as traditional means for gas transportation infrastructure however; virtual pipelines in the form of CNG and small-scale LNG operations have emerged as strong contenders to provide viable alternative transport solutions for gas. Regardless of the transportation mode, the capital investment of gas infrastructure is sunk costs therefore a guaranteed market and secured gas supply are prerequisites for any gas infrastructure development.

Gas is versatile and used as a direct fuel for boilers and furnaces in the manufacturing industry, vehicle transport, domestic purposes, power generation, or as an industrial feedstock for petrochemical, hydrogen, and other chemical production. The power generation, industrial application, and commercial and residential building heating/cooling are known as historical traditional markets for gas. The modern uses for gas have gained momentum in the transportation sector (land and maritime) in the form of CNG and LNG, while renewable gases such as biogas, biomethane and green hydrogen are becoming a critical consideration as potential substitutes for fossil natural gas in the energy transition.

Gas competes with other energy carriers including coal, fuel oil, nuclear and renewable resources in the end-user markets. Figure 1 shows the most recent global gas demand profile by sector. The power generation sector followed by remained steady drivers of global gas demand until 2021. The IEA (2022) predicts that industrial uses will surpass power generation to account for more than 50% of the gas demand growth in the mid-term from 2021 – 2025. The gas demand for gas-fired power generation is expected to shrink due to a combination of factors including high gas prices, renewable capacity additions and lower demand for electricity, while further demand growth although moderate is expected to come from the transportation and residential sectors.[6]

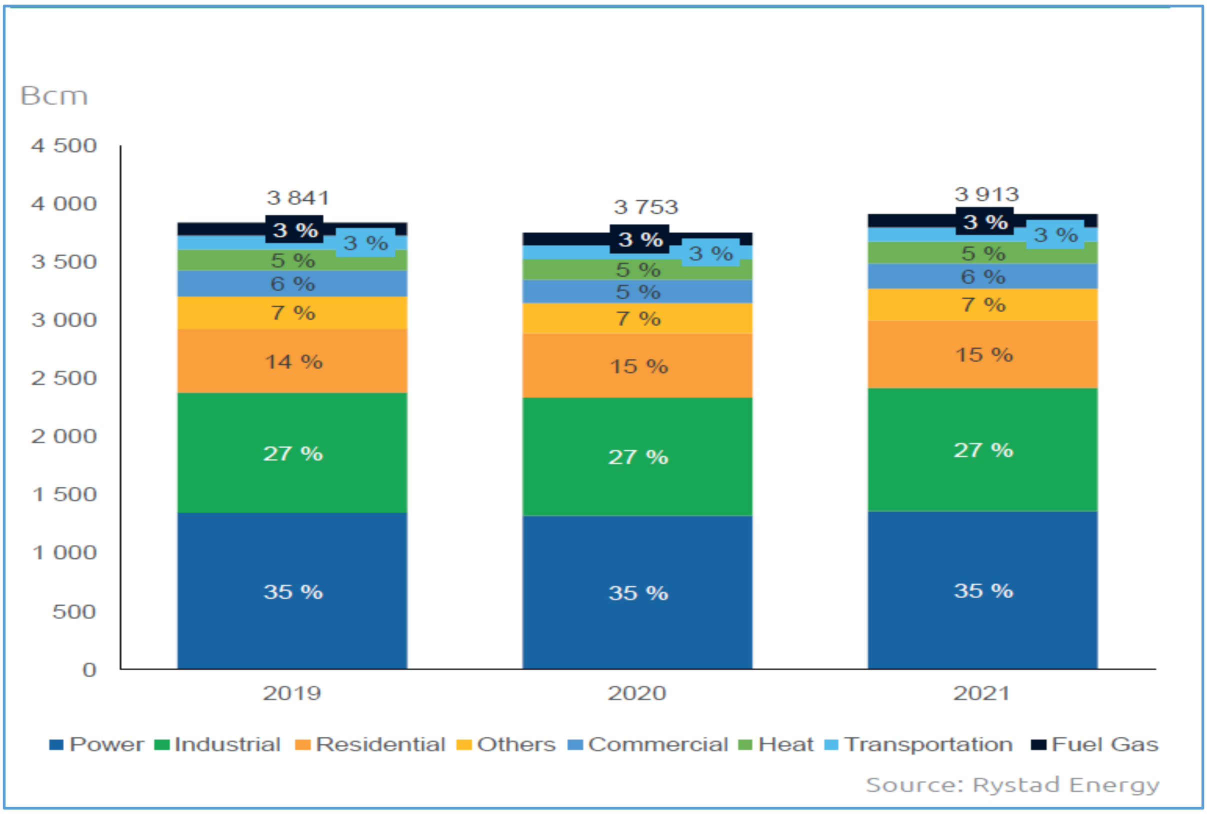

Figure 1: Global gas demand (2019- 2021), split by demand sector

Source: IGU, Global Gas Report 2022: page 13

4.2 Gas route-to-market options

4.2.1 Gas-to-power

Gas currently accounts for 23% of the electricity consumed globally and this is largely attributed to the deployment of intense environmental and carbon pricing policies from the mid-2000 that prompted more oil/coal-to-gas switching for power generation plants. The IEA (2021) predicts that natural gas-fired power plants will continue to play an important role in the electricity generation mix until 2030 to displace coal-fired power generation towards the net-zero carbon emissions scenario. However, a sharp decline of gas-fired power generation is expected beyond 2030 with the acceleration of renewable power and green hydrogen deployment in the energy system. Until 2030, it is envisaged that the significant growth of gas-fired generation will occur in China, India, the Middle East and some countries within the

[6] IEA, Global natural gas demand per sector, 2007-2025, IEA, Paris https://www.iea.org/data-and-statistics/charts/global-natural-gas-demand-per-sector-2007-2025

Organisation for Economic Cooperation and Development (OECD), as gas-fired plants are relatively competitive compared to coal due to efficiency improvements and carbon pricing. Shorter construction lead times and less capital investment requirements for gas-fired power plants add to their potential economic benefits over coal and nuclear plants. In the IEA projections, CCGT plants remain the dominant gas-fired generation technology compared to OCGT, and is said to account for more than 60% of the global growth in gas-fired generation.

As stated above, gas-fired power generation has been the key driver of growing natural gas demand globally. Literature suggests (Rongchun, Yufeng, Yaohua, Liping & Jun, 2006) that the evolution path of gas-fired power generation follows three basic models representing the way of the European and American countries, Japan and South Korea, and South America. Security of supply in terms of gas resource and infrastructure availability, structure of the energy industry and the competitiveness of gas power plants determine the development path for gas-fired power that a particular country would take. Figure 2 below provide for more details on the gas-fired power development paths followed by the EU, US, Japan and other key markets.

The key fundamental difference between electricity and gas is that the latter is a primary energy source while electricity is a secondary energy source produced from other energy carriers including gas through different generation technologies. The global evolution of gas-fired power generation has stimulated a reliability interface between the electricity system and gas networks which gave birth to the growing interdependency experienced globally between the electricity and gas industries (Li, 2008; Peters, 2012).[7][8] The ability for power generators to switch between gas and other alternative energy sources enhances the convergence of the gas and electricity markets.

[7] Li, T 2008. Interdependency of natural gas network and power system security. IEEE Transactions on Power Systems

[8] Peter, G. 2012. Gas and electric infrastructure interdependency analysis

European Union

Gas currently accounts for 18% in the EU power generation mix, a drop from the 22% pre-pandemic level due to the prevailing gas crisis in the EU.

- The EU already had matured competitive gas markets long before the introduction of gas-fired power in their generation mix.
- Gas became prevalent in the EU energy mix after the 1970s oil price shocks, which compelled most countries to look for more reliable and secure energy sources.
- Gas was used mainly for residential and commercial purposes, and this promoted gradual investment and development of the gas network infrastructure.
- The role of gas expanded to power generation in the 1990s as the EU governments became aware of the environmantal effects of energy production from coal. Environemntal sustainability policies became a norm and the use of gas as an alternative fuel to displace coal and oil was encouraged.
- At the time, the EU had self-sufficnent gas reserves regionally and the pipeline gas network was fasr better developed in most of the EU conutries and inter-linked regionally. In countries where gas was a limited resource, security of supply was guaranteed through long-term take or pay contracts.

United States

Natural gas accounted for about 40.5% of the total net generatin capacity in 2021

- The US gradually developed its gas industry mailny through residentail and commercial demand.
- Gas became prevalent in the energy mix after the 1970s oil price shocks. Even then gas was only used minimally for power generation due to a moritorium that was placed by the US government on the construction of new oil and gas generating power plants.
- The deregulation of the gas industry in the early 1990s and the lifting of the moratorium for the construction of new oil and gas plants presented the opportunity for fuel switching between oil and gas for peaking generation.
- Between 2000 and 2010, lower natural gas prices and improved CCGT tehcnology increased gas-fired generation.
- The shale gas revolution cemented the dominant role of gas in the generation mix as the US became energy self-sufficient and gas prices dipped further to much lower levels. Gas became competitive to displace some coal and oil generation capacity for baseload power by 2012. However, the oversupply of domestic coal in 2012 pushed prices down and made coal more competitive than gas, which propmpted some generators to switch back to coal.
- Fuel switching and the competition between coal and gas for power generation in the US have become a common norm as both resources are abundantly available domestically.

Japan & South Korea

Gas-fired power contributes about 39% and 32% to the generation mix in Japan and South Korea, respectively.

- Japan and South Korea have limited domestic natural gas resources and therefore rely on imported LNG to satisfy the demand for gas.
- Gas-fired power generation was the key driver of gas market development in both Japan and South Korea. In the initial development of their gas markets, the gas pipeline infrastructure was underdeloped and the demand for gas in residential and commercial sectors was insufficient to support the development of LNG import projects.
- An integrated development path was followed where the LNG power plants anchored the development of the LNG import projects. In this development model, long-term take-or-pay LNG purchase and sale contracts, gas supply agreements and power purchase agreements are guarantees required to anchor the development of the infrastructure.

South America

- Gas-fired power generation plays a minimal role in South America. The electricity generation mix is diverse and dominated by hydropower that is currently contributing 67% of the region's net generation capacity.
- The share or deployment of gas-fired power generation varies from country to country within the region and is expected to account for 29% of the region's electricity generation capacity by 2035.
- The key drivers of increasing gas-fired power in the region is the unreliability of hydropower, as many countries in South America are susceptible to prolonged dry seasons producing low rainfall levels. Gas is needed to provide backup power when hydropower declines. For example, in 2021 drought in Brazil forced the country to import more LNG to meet power demand. This trend is similar in neighboring Chille and Argentina.

Figure 2: International experience on gas-fired power generation

The analysis regarding the international experience on gas-fired power highlights the fact that availability of domestic gas resources and infrastructure facilitate the introduction and growth of gas-fired power in a country's generation mix. However, the cases for Japan, South Korea and South America demonstrate that it is possible for gas-fired power to be developed in gas resource constrained countries if there is a political will. Other factors that plays a crucial role in the policy decisions on gas-fired power include the following:

- Its ability to compete against cheap coal and oil in a lower gas price environment;
- Economic factors such as technology costs and fuel costs that are dominant factors in the investment decisions for natural gas-fired power generation.
- The flexibility, efficiency, availability and faster construction times of the gas technology that are sustaining the prominence of natural gas in the power generation mix alongside increasing renewable energy growth.
- The cleaner burning properties of natural gas compared to other fossil fuels that makes it a fuel of choice compared to coal and oil to address environmental concerns, more so this trend is expected to grow in the energy transition to a carbon neutral world.

4.2.2 Industrial application

The industrial sector consumes 27% of the natural gas supplied globally, and provides for the second largest demand for gas behind power generation (IGU, 2022).[9] In the industrial sector, gas is used directly as a fuel or feedstock in various industrial processes. Gas is used as a raw material/feedstock in the production of chemical products such as ammonia and methanol and converted to fuels in petrochemical industry including gas-to-liquid (GTL) and dimethyl-ether (DME). Gas also supply process heat and steam by fuelling steam and boilers for most industrial processes including metal & steel production; manufacturing of plastics, glass, paper and textiles as well as food processing & electronics manufacturing.

According to the IEA (2014), about 625 bcm of natural gas will be consumed by industry globally by 2040, with GTL production expected to uptake a significant portion of the demand.[10] GTL has always been viewed as one of the potential anchors of additional gas imports to South Africa. State owned entity, PetroSA, has been conducting feasibility studies since 2007 for the development of an LNG regasification terminal to import more gas to provide supplementary feedstock to its GTL plant in Mossel Bay. PetroSA has submitted that

[9] International Gas Union, 2022. The Global Gas Report
[10] International Energy Agency, 2014. World Energy Outlook

its existing GTL facility alone is not sufficient to justify the upfront capital requirements for an LNG import facility. An LNG import project could only succeed if jointly anchored by the GTL plant and the Eskom OCGT power plant in Atlantis.

Gas for industry in South Africa is consumed mainly in chemicals and petrochemicals, iron & steel, non-ferrous metals, pulp & paper, food and tobacco, and non-metallic minerals. Gas provides about 29% of the energy consumed in the country's industrial sector.[11]

4.2.3 Transportation

The use of gas in transportation either in the form of CNG or LNG have become popular in recent years. CNG and LNG serve as substitutes for conventional petroleum fuel in vehicles including light passenger cars, buses and heavy-duty trucks. Natural gas improves air quality by greatly reducing emissions of the air pollutants that cause urban smog. NGVs can be dual-fuel or dedicated engine vehicles.

Compressed gas or CNG, in particular, is widely used as a transport fuel for light passenger vehicles and fleet buses and trucks. According to the latest NGV (natural gas vehicles) Global statistics, there are currently 28,5 million natural gas vehicles (NGVs) on the road worldwide of which more than 90% are found in China, Iran, India, Pakistan, Brazil, Argentina and Europe. North America and Africa contribute very little to the global NGV growth with 224,500 and 295,349 NGVs, respectively. The adoption of CNG for mobility in these countries is largely fuelled by the need to reduce air pollution emissions as the countries look for cleaner alternatives. In some countries, the development of NGVs is driven by private sector investment.[12]

The CNG market in South Africa is still developing with only about 700 vehicles reported to be operating on dual fuel including the conventional fuel and CNG. Eight NGV stations are operational in the country to date. There has been signals for support for the development of the NGV sector in South Africa; however, there is no policy drive to ascertain large-scale development. The penetration of NGVs in the SA's transportation sector is constrained by the need for appropriate policies and related regulations to foster market development, insufficient gas supply, limitations of existing gas infrastructure, and limited socialisation or acceptance of CNG as a vehicle fuel.

LNG in transportation can be used as a bunker fuel for marine ships in the shipping industry and road vehicles, especially of heavy-duty trucks. LNG can be retailed through distribution to end users via LNG trailer trucks or rail tankers to LNG fuelling stations and industrial users.

[11] Department of Mineral Resources and Energy, 2021. The South African Energy Sector Report 2021
[12] http://www.iangv.org/current-ngv-stats/

The LNG mobility technology presents an opportunity to create new demand for gas from ships, long-haul trucks, and heavy-duty trucks to customers who cannot be economically supplied by pipeline in South Africa. The potential for growth is in the bunker fuel and heavy-duty truck markets that are large consumers of diesel and heavy fuel oil emitting large quantities of greenhouse gases with detrimental effect to the environment.

According to the Shell (2022), about 251 LNG-fuelled vessels are currently in operation globally and an additional 403 is likely to come on stream by 2027.[13] The use of LNG as a transportation fuel is yet to take off in South Africa following the recent licensing of several private companies to trade in LNG for vehicle refuelling.

The most common challenges relating to the adoption of both CNG and LNG in the transportation sector include lack of refuelling infrastructure network, lack of supportive government policies, lack of access to reliable and affordable gas supply for small-offtakers. The chicken and egg dilemma is also an impeding factor as demand is pivotal to pull large-scale production of NGVs and roll-out of the CNG/LNG refuelling stations; while prospective customers would only convert to gas if there's security of supply.

Other key factors that may influence end users to switch to LNG or CNG include price competitiveness against substitute fuels, technical feasibility, economic incentives for switching and other location specific factors. It is important that these factors be thoroughly considered from the policy and regulatory perspectives as well in order to promote and encourage the use of gas in transportation.

4.2.3 Building (residential and commercial)

The primary use for gas in commercial and residential buildings is space heating/cooling, water heating, and cooking. The commercial sector, in particular, has a large customer base for gas including hotels, restaurants, convenience and groceries stores, hospitals and nursing homes, schools and universities, shopping malls, office buildings, warehouses, laundries, discount stores, gym facilities and saloons. Building heating/cooling (air conditioning) is the main prevalent use for gas in commercial buildings, while water heating is prevalent in establishments that use large volumes of hot water such as saloons, laundries, gyms, and gas cooking is most common in restaurants, hospitals and schools.

According to the IEA (2021a), about 850 bcm of gas demand is consumed in residential and commercial buildings at present. The demand for gas in buildings is likely to rise by 70 bcm

[13] Shell LNG Outlook 2022

by 2030; however, the acceleration of decarbonisation efforts and the likely shift away from fossil gas in the sector may see the current demand fall by 300 bcm in the net-zero scenario.

The direct use of gas in buildings competes directly with electricity and oil-refined liquid petroleum gas (LGP), mostly in the residential sector. The fuel and transport costs for gas as well as resource availability influence its the competitive position in this market. Commercial users need affordable and reliable access to gas supply to sustain their business operations; whereas residential customers expect fuel gas and gas heated water to be available when needed also at affordable prices.

Gas demand in commercial and residential buildings may be threatened by the fast pace and scale of adoption of electric heat pumps, solar water heaters/coolers and more efficient combined heat and power technologies to displace gas boilers or heating units. Improved energy efficiency and electrification are currently regarded as the most effective ways to reduce carbon emissions in the sector while the use of renewable gases such as biomethane are considered future substitutes for fossil gas in the building sector.

In South Africa, some of the natural gas imported from Mozambique is consumed in the commercial and residential sector in some parts of Gauteng, although the demand is negligible compared to the electricity and LPG usage. The DMRE energy balances (2021) assumes that electricity supplied about 76% and 34% of the energy consumed in the residential and commercial sectors, respectively.

4.3 Key developments impacting on gas

4.3.1 Climate change commitments and decarbonisation

In 2015, 196 countries came together in Paris to ratify an international treaty on climate change under the United Nations Framework Conventions on Climate Change Programme. This Agreement (also known as the Paris Agreement or Paris Climate Change Accord) aims to strengthen the global response to the threats of climate change, in the context of sustainable development and efforts to eradicate poverty by, amongst others, limiting rising global temperatures to well below 2 degrees Celsius. Countries pledged their ambitious goals to reduce their greenhouse gas emissions by 2050 to contribute towards the attainment of the goals of the Paris Agreement (termed National Determined Contributions or NDCs). These NDCs are country specific and outline plans that the individual countries will take to build resilience to adapt to the impacts of rising temperatures. *The Paris Agreement laid the* *foundation, inviting countries to pledge immediate action to reduce emissions, and then keep ratcheting up ambition to reach net-zero emissions by 2050.* [14]

Greenhouse gas emissions, predominately CO_2 has for decades been at the centre of global warming and natural disasters experienced across the globe that are widely attributed as catastrophic effects of climate change. Carbon dioxide is an air pollutant that is produced as a by-product from most industrial processes, including oil refining and power generation. Carbon dioxide is also a large factor in the air emissions associated with the burning of natural gas or methane as an energy source. Largely, the energy sector is the biggest emitter of greenhouse gases into the atmosphere and has become the target of every government in its quest to reach low-carbon emissions goals. The IEA (2020) reported that about 33.3 gigatonnes of CO_2 emissions per year are contributed by the energy sector as at 2019.[15][16]

In its response to the climate change challenges, the energy sector is shifting from the traditional norms of fossil-based energy towards cleaner energy sources and smart ways of providing energy services to end consumers. These changes are more evident in the electricity sector where the energy decarbonisation policies in most economies across the globe have led to the growth in renewable energy technologies and pursuit of other green energy solutions.

Several major economies including China, Japan, European Union (EU), South Korea, Australia, United States of America (USA or US), Norway and some parts of Africa are shifting to clean energy pathways to decarbonise their energy systems. This trend resulted in the increased production and supply of renewable energy (including solar, wind & hydropower) reaching about 3 TW by 2021.[17] The use of variable renewable solar and wind comes with its limitations as these energy sources cannot be completely deployed at large-scale without efficient energy storage systems and backup power to fill the gap when these resources are unavailable. Technologies such gas-to-power and battery storage have been explored as potential solutions to provide backup for the intermittent renewables. However, the negative impact of the carbon emissions associated with natural gas or methane disadvantages gas-to-power from the emissions standpoint, while production costs and availability of the technology currently remain a challenge for the battery storage solution.

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[14] www.unfccc.int

[15] IEA.2020. Global Energy Review 2020: The impacts of Covid-19 crisis on global energy demand and CO_2 emissions

[16] IPCC.2020. A Special Report on the Impacts of Global Warming of 1.5°C above pre-industrial levels

[17] IRENA. Renewable Energy Statistics 2022

Historically, natural gas has been regarded as the fossil fuel of choice compared to oil and coal due to its inherent relatively low-carbon content and being a reliable and environmentally friendly energy source. Gas in the energy transition is expected to retain a major role as a source of flexibility and back-up in the energy system leading up to the net-zero Emissions Scenario by 2050. [18] Although many zero carbon scenarios promoted recently completely phase out natural gas from the global energy mixes in the long-term, well respected institutions in the field of energy (including the International Energy Agency and International Gas Union) envisage that gas would remain part of the solution in the transformation of the energy sector.

According to the IEA (2019), the net-zero emissions pathway requires multiple approaches, policies, and technologies at different times; emphasising that there is no single solution to the energy transition.[19] While renewables are expected to dominate the net-zero emissions pathway, coal/oil to gas switching is likely to play an important role in power generation and other sectors within certain timeframes during the transition.

Although the environmental benefits of using natural gas in certain sectors are evident, the low air pollutant emissions resulting from gas combustion and from methane leaks makes it incompatible with the envisioned sustainable or net-zero emissions future. There is growing consensus among international bodies/agencies that gas needs to adapt to a low-carbon pathway in order to claim a prominent place in a more sustainable energy mix globally beyond 2050. Further, global industry players are making concerted efforts to find ways or solutions for gas to thrive in a carbon neutral world where greenhouse gas emissions (including carbon) are gradually eliminated. The gas decarbonisation pathways emerging from these efforts are focused on:

(i) gas playing a supportive role for the vast expansion of renewable electricity generation; and

(ii) Aggressively reducing the greenhouse gas emissions associated with the use of natural gas.

The projected scenarios concerning the role of gas in the energy transition suggest that gas will play a vital role in decarbonising the energy mix as follows:

- **Up to 2030 (near-term)** – gas is expected to deliver a substantial decrease in CO2 emissions mainly in power generation and other sectors through (i) coal/oil to gas switching and (ii) scaling-up renewable energy investments and pairing that with investments in gas-fired power plants to stabilise and secure the energy supply.

[18] International Gas Union, 2021. Global Renewable and Low-Carbon Gas Report
[19] International Energy Agency, 2019. The Role of Gas in Today's Energy Transitions

- **Beyond 2030 (long-term)** – the CCUS or CCS technology whether in retrofit or Greenfield installations in fossil-based plants or processes as well as the use of renewable gases (biomethane and green hydrogen) are projected to dominate and change the natural gas supply chain leading to the near-zero emissions. The blue hydrogen and the CCUS/CCS pathway is viewed as a transition option until the green solutions (mainly green hydrogen and biomethane) are available at scale. Also, the cost and application of the CCUS or CCS technology would determine how long the role of gas would be in certain sectors.

4.3.2 Renewable Energy

Renewable energy resources, characteristically dubbed replaceable or replenishable naturally occurring resources, are one the fastest growing energy sources in the world, currently accounting for 13.8% in the total energy mix globally (IEA, 2021a). Renewable energy resources including hydro, solar, wind, geothermal and biomass are used to produce electricity, heat and biofuels. The IEA (2021a) predicts that renewables growth will reach 19% of the total primary energy share by 2040, driven by the increasing deployment of renewable power generation capacity in China, Europe, United States and India and the ambition to meet carbon neutrality by 2050.[20]

According to International Renewable Energy Agency (IRENA, 2022) renewable energy contributed about 27.7% of the total electricity produced globally in 2020 with the biggest contributions coming from hydro, solar and wind energy resources. The IEA (2021b) predicts that renewables would contribute about 37% of global electricity generation by 2026, surpassing current leaders coal and natural gas.[21][22]

According to IRENA (2022), hydropower is currently the largest source of renewable power generation accounting for 44% in the global market share, followed by solar (28%) and wind (27%). By 2026, hydropower generation is expected to decline while solar PV and wind based power grow. The IEA (2021b) attributes the expected rise of renewable solar PV and wind to the relatively low cost technology, widespread availability of the resource and policy support in more than 130 countries. It is worth noting that other commercial technologies such as bioenergy, geothermal, concentrating solar power and offshore wind are projected to contribute in their small way to the future expansion of renewables.

[20] IEA (2021a). World Energy Outlook 21
[21] IRENA. Renewable Energy Statistics 2022
[22] IEA (2021b). Renewables 2021 – Analysis and Forecasts 2026

The clean characteristics of renewable energy resources particularly - wind, solar, geothermal and hydro have planted renewable energy alongside renewable hydrogen as the only viable option for curbing energy related CO_2 emissions to create a sustainable net-zero energy future by 2050. The rapid growth of renewable energy technologies experienced globally in power generation is driven by decarbonisation policies, government subsidies and technology innovations which drives down costs to make renewables technologies competitive than other power generation technologies, including gas.

In the IEA World Energy Outlook (2021), the share of renewable energy increases significantly in all scenarios as renewables are set to become the foundation of electricity systems across the globe. Renewable growth has both negative and positive impacts on gas, amongst other carbon emitting fuels in the various energy markets. For instance, the availability of reliable renewable energy supply erodes the share of fossil gas-to-power in the electricity generation market; and only low capacity factors for gas-fired power plants are used where gas is needed to provide backup power for the variable renewables. This reduces the overall demand for gas and future investment needs that may slow down the overall growth of the gas market. The comforting prospect is that gas is becoming renewable with the expansion of the market structure to include green gases such as biogas, biomethane and green hydrogen from renewables.

Nonetheless, renewable energy resources are part of the primary energy supply options and has unique attributes including the challenges of natural variability or intermittency that propels the need for instant back-up power and storage energy systems where utilised. This is discussed in detail in section 4.4 below.

4.3.3 Hydrogen

Hydrogen as a carbon free element is set to play a significant role to decarbonise the energy system. Hydrogen can be used as a feedstock in most industrial processes and as an energy carrier similar to electricity.

According to the International Energy Agency (IEA, 2021), about 90 million tonnes of hydrogen was produced predominantly from natural gas and coal in 2020, with low-carbon hydrogen contributing less than 1% of the global production of hydrogen. Hydrogen can be produced from natural gas via steam methane reforming, coal via coal gasification or renewable energy resources from water electrolysis. The energy source and the production method determine whether the hydrogen is classified as grey, blue or green hydrogen in today’s terminology. Hydrogen has been produced, stored and used (often in large quantities) safely for decades in the chemical industry, mainly as a feedstock for industrial processes which accounts for about 99% of global hydrogen demand produced from fossil fuels. According to the IEA (2019), oil refining (33%), ammonia production (27%), methanol production (11%) and steel production via the direct reduction of iron ore (3%) account for the top four single uses of hydrogen today (in both pure and mixed forms). [23][24][25]

Hydrogen has recently been gaining momentum as an energy carrier as the need to decarbonise the global energy systems and to strengthen energy security for present and future generations rapidly grows. Further, the advancement of the hydrogen fuel cell technology is increasing the appetite for hydrogen in mobility (transportation) and energy storage, amongst others.

According to the World Energy Council (2020), major economies (mostly with rich history on natural gas) across the globe have displayed a growing appetite for hydrogen as a means to decarbonise their economies and developed dedicated hydrogen strategies. It is projected that hydrogen demand would scale-up to 270 million tonnes per annum by 2050, and this would be consumed in countries representing over 80% of global Gross Domestic Product (GDP).[26] Although varying from country to country, five common goals drive the global energy transition or adoption of hydrogen as a decarbonisation solution, namely -

- Clean energy to reduce carbon emissions
- Energy security through diversification
- Integration of renewable energy
- Foster economic growth
- Support national hydrogen technology development- to attain technology leadership globally

Figure 3 below depicts the multiple pathways of the hydrogen supply chain reflecting the various hydrogen production, storage and transportation methods as well multiple applications (end-uses).

[23] IEA.2019. The Future of Hydrogen – seizing today's opportunities
[24] World Energy Council.2020. Hydrogen Economy- Hype or Hope?
[25] International Energy Agency. 2019. The Future of Hydrogen
[26] World Energy Council. 2020. International Hydrogen Strategies

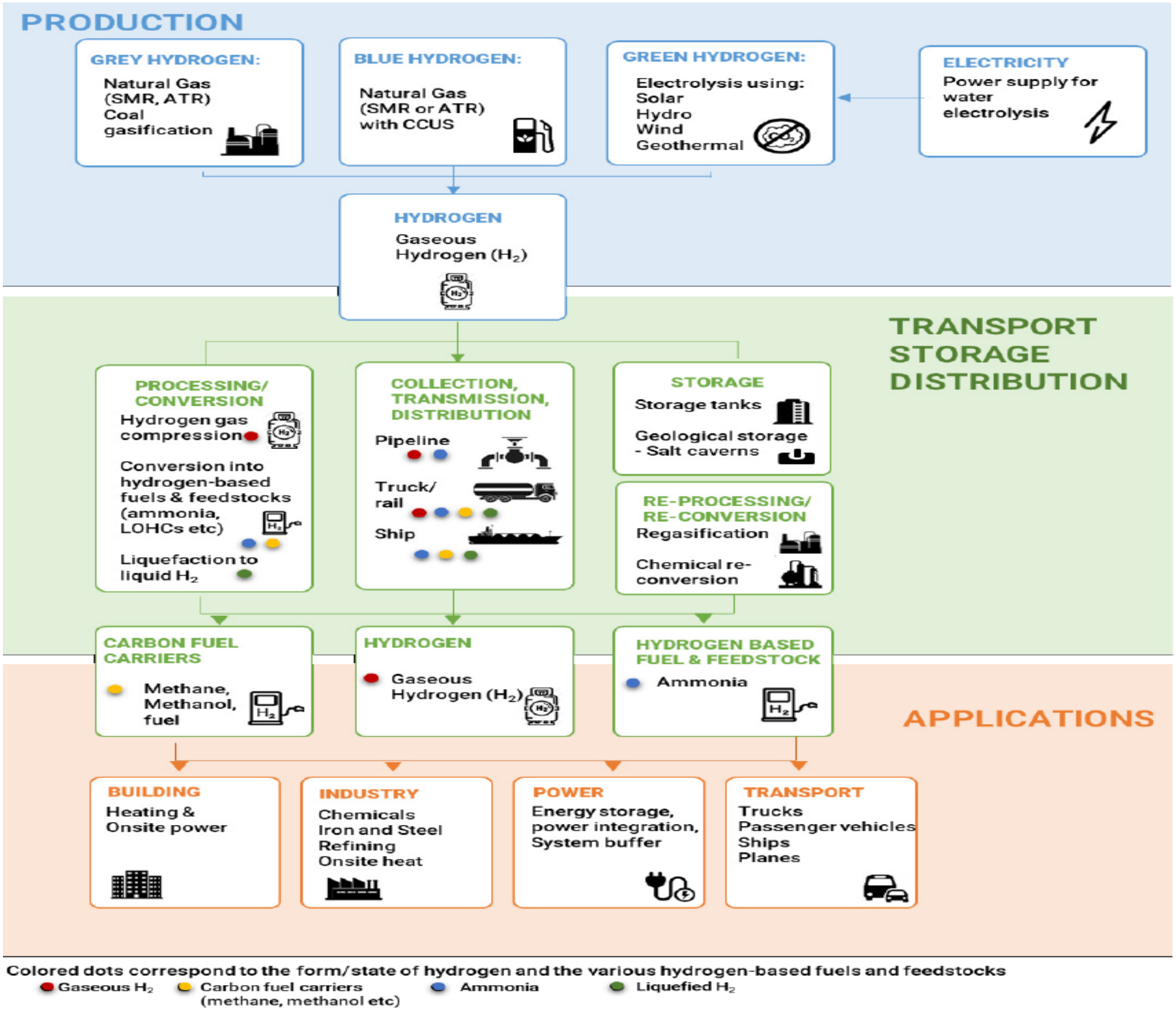

Figure 3: Schematic Hydrogen value chain

Source: Goldman Sachs (2020). The Rise of Clean Hydrogen

Hydrogen has a variety of uses including industrial feedstock in petroleum refining, ammonia fertiliser and methanol production, power generation either through hydrogen-fired turbines or fuel cells, energy source for high temperature processes e.eg., steel making and cement, transportation fuel for light and heavy duty transport, aviation fuel and marine shipping & rail transport, and direct heating/cooling in buildings. In the net-zero energy transition, hydrogen is expected to play a critical role to:

- Enable large-scale renewable energy integration. Hydrogen can serve as a chemical energy storage where surplus renewable energy can be converted and stored in the form of hydrogen through electrolysis and converted back to electricity when needed. The hydrogen can also be used directly as a feedstock to other processes to produce valuable products.
- Provide clean feedstock for industry.

- Decarbonise the transportation and industrial sectors.
- Decarbonise building heating and power.
- Distribute energy across sectors and regions.

Hydrogen has the niche clean characteristics and versatility that makes it an attractive option as a clean alternative to fossil fuels, including natural gas. The developments around hydrogen are creating global shifts in the natural gas industry as – gas producing countries look to decarbonise their natural gas industries to keep it competitive in the era of clean energy transitions; and gas importing countries relook at the future role of natural gas in their energy mixes as clean technology solutions become readily available, including renewables and green hydrogen technologies.

According to market studies, by 2050, hydrogen will represent 18% of the total worldwide energy consumption. This would decrease the amount of CO_2 released in the atmosphere by 6 gigatons per year and, at the same time, create 30 million of jobs within an industry worth 2.5 trillion dollars annually.[27] As a result, the drive to have a well-established hydrogen market by 2050, with green hydrogen playing a significant role to decarbonise the energy system to achieve net-zero emissions is increasing.

As much as the hype around hydrogen is increasing, the development of the hydrogen economy faces numerous challenges which vary by sector. The lack of government policies to support hydrogen related investments and research remain a common challenge although efforts have been made in major economies to develop national hydrogen strategies. Government policies are expected to play a significant role in transforming energy systems to hydrogen economies. So far the major difficulty of utilising hydrogen as a fuel or energy carrier has been the absence of practical solutions to facilitate the adoption of the hydrogen technologies in the mainstream markets in line with existing national hydrogen strategies. The challenges can be viewed within the frame of the following factors that influence the development of the hydrogen economy.

[27] Hydrogen Council, 2017

Hydrogen infrastructure

- Lack of dedicated hydrogen infrastructure likely to slow the successful adoption and commercialisation of hydrogen.
- The energy sector would require integrated hydrogen production points, distribution and storage systems to facilitate the access of hydrogen to the markets
- In the transportation sector, hydrogen refuelling stations network is a critcal element of the value chain, and storage availability is needed to ensure security of supply. The lack of hydrogen refuelling infrastructure may disciurage prospective customers from converting.

Hydrogen technology

- High technology costs and inefficiences are a challenge for the novel hydrogen technologies
- Technology risks are also cited as a challenge especially where opportunities exist for daily public use ofhydrogen for domectic ad commercial space heating.
- Chiken and egg dilemma faces the hydrogen mobility sector; demand is pivotal to pull large-scale production of hydrogen-fuelled vehicles and roll-out of the hydrogen refuelling stations.

Hydrogen safety and public perception

- Public acceptance of hydrogen as an alternative fuel not only depends on its practical and commercial appeal but also on its safety record in widespread use.
- Hydrogen is a highly flammable, volatile , and permeable substance; and its affinity to may chemical elements raises concerns abouts its safety as a rutine fuel for daily public usage
- Thus, technical safety standards and practices that are widely known and routinely used like in self-service petrol stations or plug in electrical appliances may need to be strengthened and altered to increase public acceptance of hydrogen.
- Further, safety-related information about the handling and storage of gaseous and liquid hydrogen is also critical and should be readily available to the public.

Nonetheless, the hydrogen space is fast evolving through intense research and development aimed at addressing the numerous challenges concerning the novel hydrogen technologies and the public perceptions around the usage of hydrogen as a fuel. Government policy and regulatory support would be the critical pillars to facilitate and drive hydrogen infrastructure investments and its large-scale deployment in the energy mainstream economy.

4.3.4 Low-carbon and renewable gases development

Renewable and low-carbon gases are receiving attention as key assets to decarbonise the gas industry. Renewable gases comprise biogas, biomethane and green hydrogen produced from renewable electricity while blue hydrogen and electrolysis hydrogen produced from fossil-based electricity are referred to as low-carbon gas/hydrogen. These are alternative gases that are capable of substituting fossil gas in the variety of uses or applications.

> **Biogas**: A mixture of methane (typically 50-65%) and carbon dioxide gases that is produced via anaerobic digestion of biomass (typically agricultural waste, manure, municipal and sewage waste). Biogas is usually produced in rudimentary small-scale settings near the points of consumption either for electricity generation and heat or upgraded to biomethane for use as a transport fuel or injected into the natural gas grid.
>
> **Biomethane (also known as renewable natural gas):** methane from biogas which has been upgraded to remove CO_2 and other impurities such that it is comparable quality to natural gas. Biomethane can be used as a direct supplement/substitute for natural gas in existing infrastructure and equipment. Biomethane is referred to bioCNG and bioLNG when used in transportation.
>
> **Green hydrogen (also renewable hydrogen):** Hydrogen produced via water electrolysis (i.e. splitting water into hydrogen and oxygen) using renewable electricity. According to IRENA, green hydrogen is not yet produced at scale although available at pilot. Green hydrogen is regarded as a low-carbon gas if fossil-based electricity is used for the electrolysis process.
>
> **Blue hydrogen:** Hydrogen produced from natural gas via steam methane reforming coupled with Carbon Capture and Storage (CCS) to remove the CO_2 emissions from the production process. Blue hydrogen production currently negligible (0.36 Mtpa) compared to the 90 Mtpa of grey hydrogen produced globally.
>
> **Green ammonia:** Zero-carbon ammonia, produced from renewable electricity, water and air. It can be used as a fertiliser, fuel in transportation, and energy storage solution.
>
> *Sources: IGU (2021), Gas Naturally (2021)*

Biogas and biomethane potential

According to the IGU (2021), the combined global scale of biogas and biomethane production is around 40 bcm which is equivalent to 1% of global natural gas production. About 75% of this production occurs mostly in Europe (Germany, Denmark, Netherlands, France, Italy, UK) and China. Most of the biogas is produced near the points of consumption for combined heat and power in secluded areas away from the grid. Only 10% of the biogas production in Europe is upgraded to biomethane that is suitable for injection to the gas pipeline network.[28]

The IGU further estimates that biogas supply has the potential to rise to 20% of the global natural gas demand in the long-term. However, this would require a strong government policy

[28] International Gas Union, 2021. Global Renewable and Low-Carbon Gas Report

focus to facilitate significant investments and rapid increase of the biogas production. The availability of feedstock supply, high production costs and scale are highlighted as key potential impediments to the upscaling of biogas and biomethane production to match the current levels of natural gas demand. Contrary to hydrogen, infrastructure is not regarded a challenge for biomethane (i.e., biogas upgraded to natural gas quality) given that it can be blended with natural gas in existing gas grids for distribution without any modifications to end use appliances.

In the South African context, biogas is produced from waste material via anaerobic digestion in rural communities mostly for heating and electricity near the source of production. NERSA oversees the registration of biogas production activities in terms of section 28 of the Gas Act, 2001 (Act No.48 of 2001) and has since registered both large-scale and small-biogas projects across various provinces in the country (KwaZulu-Natal, Gauteng, Limpopo, Western Cape, and Mpumalanga). According to Southern African Biogas Industry Association (2021), biogas has a potential to displace about 2500 MW of grid electricity in South Africa. This potential could be high given the multitude (about 108 million tonnes) of landfill waste and agricultural waste (40 million tonnes) produced in this country every year.

Blue hydrogen and the CCS technology

Blue hydrogen is viewed as an intermediate solution to decarbonise fossil natural gas en route to the carbon neutral world. Blue hydrogen production only accounts for 0.5% of the current global hydrogen production (IGU, 2021). According to the IEA (2020), the CCS technology enabling blue hydrogen production offers significant strategic value in the transition to net zero in that it can be retrofitted to existing gas-fired power and industrial plants; used to tackle emissions in hard to abate industries (iron & steel, chemicals, cement, long-distance road transport and aviation); and combined with bioenergy or direct air capture for removal of CO_2 from the atmosphere.

CCUS/ CCS technologies

CCUS/CCS is an integrated chain of technologies comprising capture, transportation and geological storage or utilisation of CO_2.

Capture involves either the separation of CO_2 from other gases prior to combustion (pre-combustion) or post-combustion separation of CO_2 from other gases produced at industrial or power plants.

Transportation involves the transportation of compressed/liquefied CO2 from the capture location to the storage facility, typically underground geological formations. Pipelines, ships or road/rail tankers can be used as the transportation medium.

Storage involves the injection of CO_2 in dense or liquid form into sub-surface rock formations, typically depleted oil and gas fields or deep saline formations. CO_2 can be stored onshore or offshore

Utilisation (where applicable) involves recycling CO_2 and use it as feedstock to produce commercial products in the food & beverages sector, production of synthetic fuels, chemicals or building materials.

In 2021, the Global CCS Institute reported significant growth in the CCS project pipeline with 27 CCS facilities in full commercial operation (compared to the 19 reported in 2020), four under construction, 58 projects under advanced development, and 44 projects in early development. Most of the commercially operational projects are concentrated in the US (12), followed by Canada and China (4 each), Norway (2), with the remaining located in Brazil, United Arab Emirates, Australia, Qatar, Saudi Arabia, Hungary and Iceland. In its Sustainable Development Scenario, the IEA predicts that unabated CO_2 emissions would reduce to 10 Gigatonnes from 35 Gigatonnes of 2019 levels, with a 20% contribution by carbon capture and storage. [29][30][31]

CCUS in particular is not a new concept in South Africa. Since 2009, DMRE through SANEDI had been involved in the CCUS research programme that has recently been transferred to the Council for Geosciences. The learnings from this research programme could assist the country on the appropriate approach to reasonably integrate the use of this technology in the development of sustainable gas solutions.

Similarly, the green hydrogen solution (including green ammonia) is expected to play an important role to decarbonise hard to abate sectors (e.g., heavy duty transport, shipping, and

[29] International Energy Agency, 2020. Special Report on Carbon Capture Utilisation and Storage: CCUS in clean energy transition
[30] Global CCS Institute. 2021. Global Status of CCS 2021: CCS Accelerating to Net Zero
[31] International Energy Agency, 2021. Net Zero by 2050: A Roadmap for the Global Energy Sector

aviation) where alternatives are not readily available. Electrolyser costs and low design scales are the critical issues impeding the fast adoption of these green energy technology solutions.

Although the role of renewable and low-carbon gases appears certain as sustainable solutions for the gas market, biomethane, CCS and green hydrogen technologies have challenges that should be addressed. Blue and green hydrogen and biomethane are not available in large quantities today and need to be scaled up. Both the IEA and IGU agree that requisite policy support mechanisms, public funding for research and development as well as financial incentives would be key enablers to facilitate large-scale development as well as expedient deployment and uptake of the renewable and low-carbon gases as essential CO_2 emissions mitigation instruments in the gas industry.

4.4 Gas, renewable and hydrogen- where is the interface?

4.4.1 Gas and renewable energy complementarities

Gas and renewables are often developed independently within a sphere of a dynamic and competitive energy environment that props one or the other as the preferred energy source to contribute to a country's energy mix. Gas is a primary energy resource that can be used directly as a feedstock or fuel in the variety of applications to meet energy demand, while renewable energy is a secondary energy source or carrier produced from primary renewable resources predominantly wind, solar and hydro. Gas and renewable energy are common in the global power generation mix as part of the many technology options available for electricity generation. Their relative positions in the power generation mix differ from country to country and influenced by various factors including resource availability, weather conditions, price (technology and fuel costs), and government policies that lately favours renewables over fossil fuels in response to climate change challenges.

Renewable energy, due to its clean carbon free characteristics, is among the green energy solutions leading the race to decarbonise and transform the global energy system to be carbon neutral. Renewable energy, has made significant in-roads in the electricity sector and is propped to become the mainstay of the energy system alongside electrification and renewable hydrogen in the carbon neutral world. Gas on the other hand is regarded as a bridging fuel between the current high emissions fossil based energy environment and the future net-zero emissions or carbon neutral energy system.

Conventional wisdom from literature suggests that a natural partnership exists between renewable energy and gas in the power generation sector. In this partnership, gas is casted as:

(i) a potential replacement for coal baseload power plants in the initial stages of the energy transition – gas to reduce carbon emissions relative to coal while efforts are being made to accelerate the high penetration of renewable energy into the energy system;

(ii) a conventional back-up for intermittent renewables where gas-fired power provides flexibility to electricity systems when variable renewable solar, wind and hydro plants fall short or unable to produce enough electricity to meet existing demand.

Although the growth of renewable energy is embraced across sectors, it comes with challenges i.e., the intermittency of the renewable resources (particularly, solar and wind) and their inability to be stored in physical infrastructure like conventional fuels - gas, coal & oil. As such, the high share of renewable energy in electricity systems is often complemented with a range of innovative solutions including − the use of peaking power plants (typically natural gas) when demand is high and renewable power supply is low; storage of excess energy in batteries; and sector-coupling (power-to-X solution which is currently a theoretic concept in the industry).

The debate around the coupling of renewable energy with gas peaking power plants or with battery energy storage technology in electricity systems still dominates the public discourse on energy policies given that neither option can be adopted as a one-size-fits all solution. Geographic specificities and different market conditions affect the choice of the technology solutions that can be employed in a single electricity supply system. In essence, battery energy storage appears to be a natural complement for renewable energy production and a preferable option to gas peaking power plants from an emissions standpoint. However, there are other key factors as summarised below that are likely to affect the investment decisions on renewable power + battery storage system or renewable power + gas peaking plants. Table 1 provides the relative key characteristics of gas peaking plants vs battery storage.

Table 1: Gas peaking power vs Battery energy storage

Gas peaking power	**Battery energy storage system (BESS)**
• Flexible, dispatchable power when needed that utilizes abundant natural gas or LNG fuel with carbon footprint although arguably lower than coal-fired power	• Storage system for preserving surplus renewable electricity typically from wind or solar resources with no carbon footprint. A large number of battery packs is required to provide grid-scale storage system to match high levels of variable renewable energy output.

• Competitive and Lowest CAPEX compared to other fossil based power but with very high operational costs due to the variable gas fuel cost	Wide range of battery storage capital costs exist in literature with no definitive international benchmarks. According to nrel, current capital cost projections of the most common grid-scale battery storage technology (i.e. lithium-ion battery) expected to decline by 28-58% by 2030.
• Mature, proven and modular technology; capable of capacity factors of 30% and can achieve more than 50-90% when needed for mid-merit or baseload	Maturing technology, currently exists at capacities below 100 MW
• Relatively small physical footprint, does not require vast amounts of land compared to combined renewables and battery storage systems.	Battery storage requires vast amount of land, preferably next to the renewable power generation plant to eliminate the need for high electricity transmission costs.
• Cost of gas-fired power is strongly tethered (tied) to the price of gas, which is often volatile. Gas price instability influences the utilisation rate of the gas power plant and the recurrent switch between gas and other available cheaper alternatives. • In some instances gas become more prevalent to use despite the price to provide energy security, especially when renewable production is low due to extreme weather conditions (cold winter or drought season) and alternative thermal coal and nuclear are not readily available to provide baseload power.	• No fuel cost applicable. • However, battery storage is arguably efficient for meeting short-term energy demand that cannot be served by renewables but cannot be easily relied on to provide a long-term energy storage solution to service high seasonal demands which are often difficult to predict accurately as they are influenced by unstable weather patterns. • Further, BESS are capable of self-discharging even when not in use thus reducing the amount of energy available for later use by the grid or customer when renewable energy supply is low. This further justifies the need for gas in the generation mix as a flexible and reliable technology to balance the energy system irrespective of the varying demands.

Sources: ge.com/gas-power; www.nerl.gov/publications

Figure 4 provides practical examples of the gas and renewable energy interplay in Brazil and California.

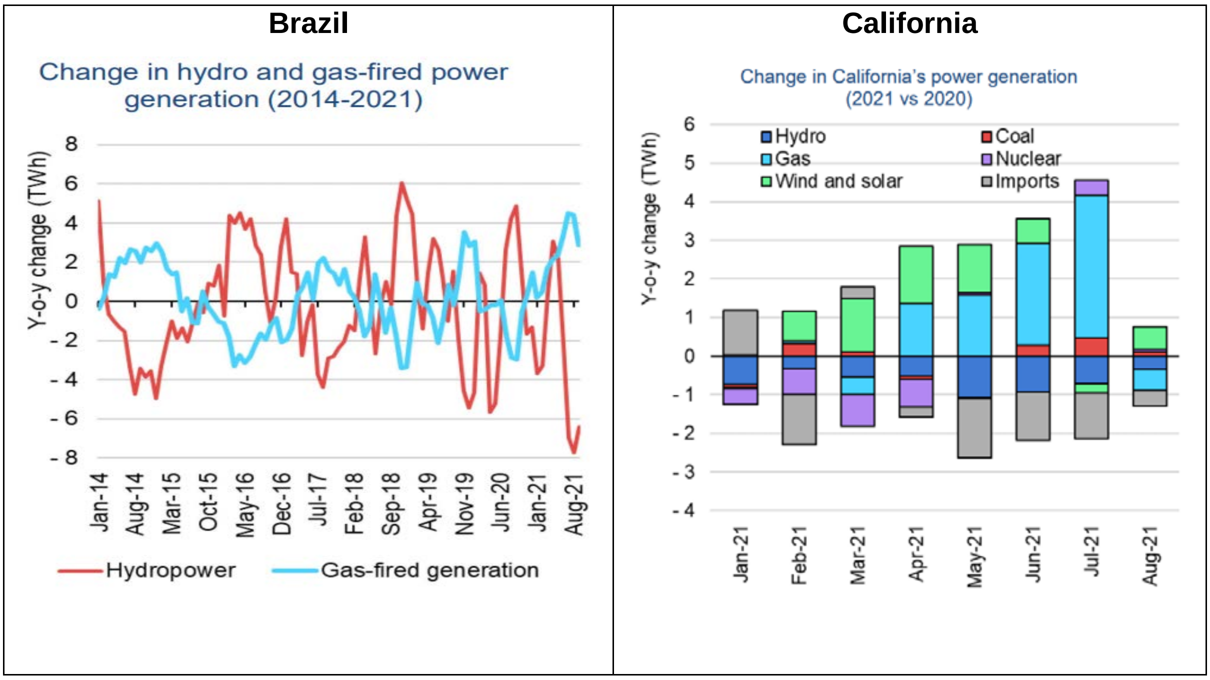

Figure 4: Gas and renewables interplay in Brazil and California

Source: IEA (2021c). Gas Market Report Q4: 2021

Brazil is a renewable energy-rich country known for its endowment in hydro, solar and wind resources. Hydropower usually dominates Brazil's power generation mix and provides for about 64% of the total generation capacity followed by a combined 14% of thermal power from gas, coal and nuclear. Gas contributes a relatively small amount with supplies mainly sourced from Bolivia, Argentina and the US through gas pipeline and LNG imports. However, Brazil (similar to its neighbouring Argentina and Chile) is prone to severe droughts which often result in significant decline in hydropower generation capacity thus increasing the need of more thermal dispatch, gas-fired power. [32][33]

The recent historic drought in 2021 caused hydro reservoirs to drop to 17% below the normal 5-year average thus resulting in low hydropower output and forcing the country to import more LNG to narrow the power supply gap. In 2021, Brazil imported about 7.5 Million tonnes of LNG mainly for power generation over and above the normal gas pipeline imports used for other various applications. However, a significant boost to hydropower reservoirs in January 2022 following a strong rainy season improved the country's hydroelectric power generation

[32] IEA, 2021d. Country Review – Brazil
[33] https://www.trade.gov/country-commercial-guides/brazil-energy

capacity thus reducing the demand for LNG imports significantly. This gas and renewable interplay in the Brazil power generation market is a common phenomenon as illustrated above in Figure 4.[34][35]

California is also known for its renewable energy-rich power generation mix– dominated by hydro, solar and wind. On average, solar and wind energy contributes above 25% of the power generation capacity while hydro alone is accounted for 15% over the last decade. Severe drought experienced in the summer of 2021 in the region led to a steep decline in hydropower output and increased use of gas-fired power to fill the power supply gap. The use thermal generation, particularly gas-fired power has become a common phenomenon in most jurisdictions due to variable weather and hydrology conditions that affect the availability of the wind, solar and hydro renewable resources.

The renewable energy-gas partnership is often viewed in the context of power generation, which involves the use of gas peaking plants to back-up the intermittent renewables when storing excess energy is not practical. However, this relationship has the potential to go beyond power generation in future. Power-to-gas is a distant realistic alternative solution where excess renewable power is converted to green hydrogen via electrolysis. The green hydrogen (which is regarded as a green or renewable gas) can be injected into existing natural gas grids or further processed to green ammonia or methanol for use in various industries or subsequently methanated to produce synthetic methane.

The transformation of surplus renewable power into green hydrogen gas by electrolysis is a promising prospect for gas as it signifies the useful role that gas would continue play in the global energy mix beyond 2050 although in a decarbonised form. Green hydrogen and other renewable gases (biogas, biomethane, bioLNG, bioCNG, bio synthetic natural gas) are deemed as the future of the global gas industry in a decarbonised world.

4.4.2 The hydrogen and gas nexus

Climate change actions and the growing interest on hydrogen as a pillar of decarbonisation for the global energy systems are creating shifts in the natural gas industry. Hydrogen is regarded as a potential replacement for natural gas in various energy markets as it can be transported, stored and used in the same way as natural gas. In various scenarios green

[34] IEA, 2021c. Gas Market Report Q4: 2021
[35] IGU. Global Gas Report 2022

hydrogen in particular is casted as a natural substitute for gas in the decarbonised world, thus the growing call for fossil gas to be completely phased out in the global energy mix.

However, proponents of natural gas argue that it has the ability to facilitate the energy transition as it can be easily decarbonised and the existing gas infrastructure can be repurposed to accommodate hydrogen. There are strong arguments for decarbonised gas and hydrogen to co-exist as complementary rather than competing fuels in the energy system. This complementary role is predicated on the following strategies that can be used to possibly integrate hydrogen in the mainstream economy:

- Blending hydrogen to existing natural gas pipelines to aid storage and transportation;
- Repurposing the existing natural gas network to transport pure hydrogen;
- Using existing SMR and CCUS/CCS technologies to reduce carbon emissions in gas-fired power plants or fossil fuelled operations;
- Scaling-up the production of biogas and biomethane (which are carbon neutral gases) to displace raw fossil natural gas in some markets;
- Sector coupling (power-to-X pathways), including renewable power-to-gas and renewable power-to-liquids (PowerFuels);

The following observations were made from literature regarding few of the strategies discussed above:

⇒ The blending of hydrogen to existing natural gas pipelines and repurposing the network to transport pure hydrogen are currently being piloted in few key markets around Europe including the UK and Netherlands.

⇒ The use of SMR and CCS technologies as well as the production and use of biogas and biomethane are common practices globally although the scale of their use may be limited compared to conventional natural gas and its derivatives.

⇒ Sector coupling is currently a theoretical concept but seen as a practical distant alternative solution where the hydrogen produced from renewable electrolysis is fed into the existing natural gas network for storage. This hydrogen could later be recovered or separated from the natural gas-hydrogen mixture using various technical methods such as pressure swing adsorption, the membrane process, or electrochemical gas separation. However, all separation processes require additional technical effort and energy input.

5. GAS, RENEWABLE ENERGY AND HYDROGEN STATUS IN SA

Gas and renewables in South Africa are currently developed independently from each other and within different sets of regulatory frameworks, while the position around the domestic hydrogen economy is still developing and requires explicit policies particularly concerning the role of hydrogen in the country's energy system. As this study seeks to explore the potential synergistic development of the gas, renewable energy and hydrogen markets in South Africa, it is important to provide a background of the related industries where these energy sources are utilised. This is intended to introduce their major features, including a review of pertinent statistics, historical development, and a brief analysis of the overarching problems faced by each sub-sector.

5.1 Overview of the SA Gas Industry

(a) Gas resources: conventional and unconventional

Gas is a scarce resource in South Africa and currently contributing less than 3% in the energy mix (DMRE, 2021). Domestic gas production is very limited and unlikely to increase substantially in the near future. South Africa currently does not have significant proven gas reserves. The extensive exploration efforts offshore conventional gas resources in the country's five main hydrocarbon basins namely–the Karoo Basin, Kalahari Basin, East Coast Basin, Outeniqua Basin and the Orange Basin – over a period of more than fifty years have only resulted in the discovery of the only producing offshore PetroSA F-A/E-M natural gas field which has since depleted. The Ibhubesi gas fields in the Orange Basin is yet to be developed or commercialised; while the potential for the Total Brulpradda natural gas exploration project is yet to be quantified. The onshore biogenic gas project by Renergen in the areas of Virginia and Theunissen of the Masilonyana Local Municipality of the Free State Province is very limited therefore inadequate to satisfy overall existing and future demand. The gas production from the Renergen project is currently targeted to small-scale LNG operations to refuel trucks and busses through 18 LNG stations across SA. However, there are expansion plans in place to increase production capacity in order to meet domestic and export demand.

Unconventional shale gas and coal bed methane resources have also been discovered in the Southern part and the North east of the Karoo basin, respectively. However, environmental activism and concerns regarding hydraulic fracturing hampered the prospects of the shale gas resource development. The Kalahari basin is less explored whilst the exploration work in the

East Coast Basin (including the Durban and Zululand sub-basins) is yet to yield to any positive gas discoveries.[36]

South Africa currently imports about 160 million gigajoules per annum of conventional natural gas from the Pande/Temane gas fields in Mozambique, and is likely to pursue additional supply from regional sources including, Rovuma Basin in Mozambique, Angola, Tanzania and Namibia as indigenous gas supply remains constrained. LNG imports from the region and international markets also remain a key and favourable alternative source of gas supply for SA.

According to the IGU (2022), global LNG trade reached 372.3 million tonnes in 2021 and is expected to increase by 200 million tonnes by 2030. This trade is facilitated through a niche and technologically advanced global supply chain involving waterborne and terrestrial natural gas liquefaction facilities, specially designed cryogenic LNG carries (ships or vessels), cryogenic pipelines, and LNG storage and regasification facilities (fixed or floating).

In terms of geographic reach, LNG is traded between 21 exporting countries and 43 LNG importing countries across six IGU regions. The most recent IGU statistics reveal that global LNG liquefaction/export capacity is about 472.4 million tonnes per annum (Mtpa), while regasification capacity was recorded at 901.9.1 Mtpa by April 2022.[37]

As stated above, international LNG trade is facilitated through the massive existing LNG infrastructure network within the trading countries comprising – LNG liquefaction facilities (47), floating LNG facilities (5), landbase regasification facilities (116), 641 active LNG shipping vessels including floating regasification and storage units (45) and floating storage units (5).[38] This LNG network represents the traditional large-scale global LNG supply chain, which is largely about intercontinental movement of large quantities of the LNG product from gas production facilities to import terminals where the liquid gas is regasified and fed into the national pipeline system to the market. LNG can also be utilized directly via small-scale LNG operations without a need for regasification.

(b) Gas markets

Approximately 120 of the 160 million gigajoules of gas imported from Mozambique annually is consumed by Sasol internally for use in the GTL and chemicals plants in Secunda and

[36] www.petroleumagencysa.com

[37] IGU, 2022. World LNG Report

[38] GIINGL, 2021. The LNG Industry in 2020

Sasolburg and for power generation. The balance is distributed to the external market including industrial, commercial, residential customers and CNG markets via a pipeline network in the Free State, Gauteng, Mpumalanga and KwaZulu-Natal.

According to DMRE (2021), the industrial sector consumed about 51% of the total energy supplied in South Africa in 2018, with gas meeting about 29% of that energy demand. The chemical sub-sector is the biggest consumer of gas, followed by iron & steel, pulp & paper and food and tobacco. The use of gas in the transport and residential sector is negligible.

(c) Gas infrastructure

Figure 5 shows that South Africa has limited gas infrastructure comprising predominantly of pipelines, with a few compressed natural gas facilities mainly used for the refuelling of natural gas vehicles. The country has no LNG import infrastructure and is yet to realise the development of the small-scale LNG infrastructure recently licensed by NERSA.

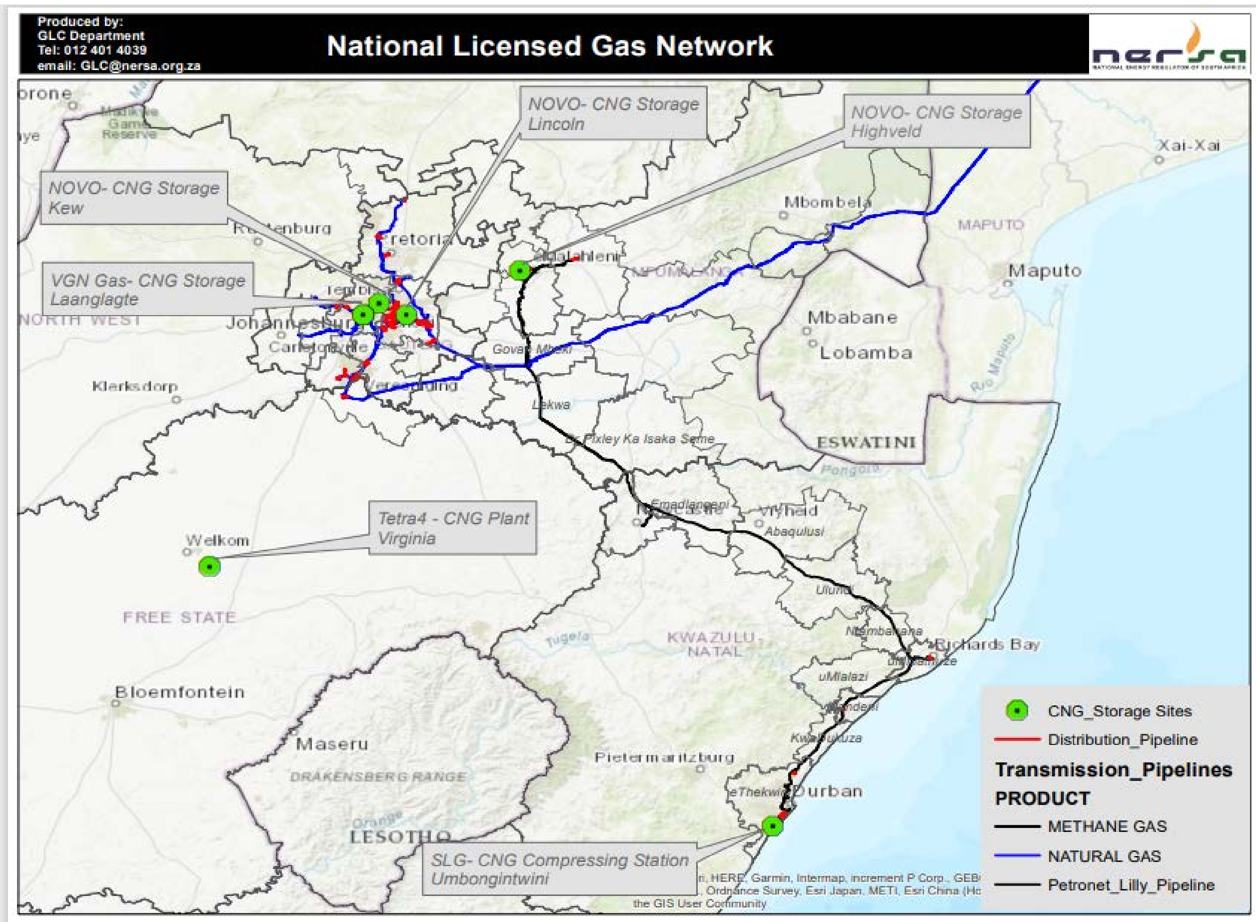

Figure 5: Existing gas pipeline and CNG infrastructure

Source: NERSA GIS System

(i) Pipeline infrastructure

As seen in Figure 5 the existing gas pipeline infrastructure in South Africa is concentrated mainly in the inland region, with some few parts of it located in Mpumalanga, KwaZulu-Natal and Free State provinces. Any other types of infrastructure such as gas storage and LNG regasification facilities are non-existent in South Africa now. The existing pipeline infrastructure comprises:

- An 865 km high pressure transmission pipeline traversing from the Pande/Temane gas fields in Mozambique to South Africa owned by ROMPCO;
- A 573 km transmission pipeline from the Sasol plant in Secunda to Durban owned by Transnet Pipelines;
- A network of about 1 500 km of gas transmission and distribution pipelines located in Mpumalanga, Gauteng, Free State and KwaZulu-Natal provinces predominately owned by Sasol Gas Limited; and some directly connected to customers for own use.
- A network of 1 200 km gas reticulation pipelines servicing small industrial and residential customers in the greater Johannesburg area owned by Egoli Gas (Pty) Ltd.

The combined total length of the existing gas pipeline network in SA is approximately 3 500 kilometres, excluding the portion of the ROMPCO pipeline situated in Mozambique. No major gas infrastructure development has taken place in South Africa since the Sasol Mozambique natural gas project in 2001. Various factors are attributed to this lack of development including limited access to gas supply, the existence of established cheaper energy carriers, and the inadequate demand for gas in the domestic market to justify investment required to further develop new gas infrastructure including gas import infrastructure to bring additional gas in the absence of domestic gas reserves (NERSA, 2012).

(ii) Small-scale LNG/CNG infrastructure

Since 2010, SA has experienced a growing trend and investment for virtual CNG and small-scale LNG operations. Both the virtual CNG and the small-scale LNG technologies involve the storage, transportation and delivery of gas to customers thus performs the same functions as the conventional pipelines without the physical footprint on the ground. These technologies are commonly used to distribute gas to places where the physical or economic conditions deem the installation of a conventional real pipeline unfeasible.

The virtual-pipeline allows for the transportation of natural gas in the form of compressed/ liquefied gas using modules coupled to mobile platforms, which are transported by trucks, shipping vessels or rail platforms. When the product reaches its destination, the module is connected to a decompression/regasification station for ready consumption. Gas is sourced from nearby conventional pipelines, compressed and transported at very high pressures in the case of CNG or liquefied and transported at very low temperatures in the case of LNG. The CNG or LNG is stored in specially designed modular containers and transported via specialised trucks to where it is needed. This allows the gas to reach consumers far removed from the physical pipeline network in an economically feasible way.

The virtual CNG and small-scale LNG technologies offer remote customers the possibility of using gas long before conventional pipelines are constructed. This in turn contributes tremendously to the development of gas markets by consolidating the gas consumption and prepares the market for the future utilization of conventional gas supply.

To date, NERSA has licensed five companies for small-scale LNG infrastructure projects comprising a small-scale LNG liquefaction plant, FSU and cryogenic ISO LNG storage containers, with a combined estimated project investment of R6.6 billion. Further four companies have been licensed for virtual CNG projects comprising mobile CNG storage and transportation trucks and NGV refuelling stations, with a combined estimated project investment of about R206 million. All these infrastructure projects are private sector initiatives relying on private funding. The small-scale LNG market, in particular is anticipated to grow faster than the conventional gas pipeline business in South Africa in view of the imminent development of LNG import infrastructure through the DMRE’s IPP procurement programme. This technology is quick and easy to set up and dismantle to be moved to a different location where needed, and transport relatively more volumes than CNG.

CNG and LNG fuels are potential substitutes for conventional liquid fuels in the transport sector. The potential demand for CNG/ LNG is typically investigated by assessing the current and future volumes of conventional fuels (e.g., HFO, LPG, petrol and diesel) in light passenger vehicles, buses, taxis or long-distance road trucks, marine bunkerships, mining heavy-duty trucks and diesel-fuelled power generation.

Both the small-scale LNG and CNG technologies provide low investment opportunities for new entrants in the gas market. Opportunities for historically disadvantaged South Africans exist in the competitive gas trading segment as development costs are relatively lower than in the distribution, transmission and upstream segments of the value chain. New entrants can supply the LNG or CNG via specially designed road trucks or tankers to industrial off-grid customers and sell the gas to NGV customers at CNG/LNG refuelling stations.

5.2 SA Renewable Energy Sector

South Africa is well endowed with renewable energy resources that currently contribute about 11% in the total primary energy mix (DMRE, 2021).[39] Banks and Schäffler (2006) reported that the potential for renewable energy resources in South Africa are theoretically assessed given the limitations of the amount of resource that can be extracted at any given time. Factors such as resource locations, resource intensities, timeframes for resource availability and physical constraints including land availability play a significant role in quantifying the potential of the contribution that the different forms of renewable resources can make in the energy system (Banks & Schäffler, 2006: 13).

Table 1 presents the varying estimates of theoretical potential for solar and wind renewable energy resources in South Africa as investigated by the International Renewable Energy agency (IRENA) in 2014.

Table 1: Estimates of theoretical potential for renewable energy in SA

Resource	**Energy potential (TWh/yr)**
Solar CSP	43 275
Solar PV	42 243
Wind	41 195

Source: Hermann, Miketa & Fichaux, 2014

Currently solar energy is the leading renewable energy resource in SA already harnessed through solar heating, solar power and solar cooking technologies, followed by wind for power generation and biomass mostly for household application including cooking and space heating in the country's energy poor rural areas.

South Africa enjoys an average of 2 500 of sunny hours per year, with its solar radiation levels estimated between 4.5 and 7 kWh/m^2 on daily average (Banks & Schäffler, 2006:14; DoE, 2015). The availability of solar energy is not a concern for South Africa however its intermittent nature is the only limiting factor particularly for power generation. Solar power can only be produced when the sun shines but technological innovations such as battery storage systems have advanced to enable the storage of excess renewable power for use during peak power demands when the solar power is unavailable.

[39] DMRE, 2021. The South African Energy Sector Report 2021

Wind is another abundant and favourable renewable energy resource in South Africa. DoE predecessor, the Department of Minerals and Energy (cited by Banks & Schäffler, 2006: 23) estimated the wind generation potential to be 60 TWh per annum. However, the availability of the wind resource and land are limiting factors likely to impede the realisation of the full potential of wind energy in South Africa.

South Africa is a water scarce country with limited potential for hydropower. SESSA (cited by Klunne, 2013: 20) estimated an aggregate of 1 100 MW of small-scale hydropower potential for South Africa. Nonetheless, imported hydropower from Mozambique and Democratic Republic of Congo has a growing potential as the country seek to fulfil its commitment to the Southern African Power Pool.

The penetration of renewable energy in the country's power generation mix is growing. Renewable solar and wind currently contributes 5 661 MW (IPPO, 2021). The IRP 2019 outlines a combined 20 409 MW of renewables power which accounts for 48% of the new total generation capacity envisaged to be added to the national electricity grid by 2030. Wind will contribute 22.7% (17 742 MW), followed by Solar PV with 10.6% (8 299MW), Concentrating Solar Power with 0.8% (600 MW), and imported hydro making up the remaining 5.9% (4 600 MW) of the renewable energy share envisaged in the IRP 2019. The requirements for battery energy storage are set at 5 000 MW in the IRP 2019 period. The availability of the renewable energy resources and the government support afforded to the REIPP programme are the main drivers of the increasing deployment of renewable energy technologies for power generation in the country. Renewable growth in the energy mix creates opportunities for "green hydrogen" development in the country, which is likely to send SA in the trajectory for the hydrogen export market in the near future because of its vast solar and wind renewable energy resources.

5.3 Hydrogen in South Africa

South Africa has a long history of grey hydrogen produced from coal and natural gas feedstocks mainly for limited use in the industrial sector. South Africa produces approximately 2% (2.5 million tonnes) of global hydrogen output, with Sasol being the leading producer through its Fischer-Tropsch (FT) CTL-fuel process (Sasol Climate Change Report, 2021).

In early 2022, South Africa set out its own ambitions to develop a hydrogen economy through the release of the Hydrogen Society Roadmap (HSRM)[40], which aim to serve as a national coordinating framework to facilitate the integration of hydrogen-related technologies in various sectors of the South African economy and stimulate economic recovery, in line with the

[40] Department of Higher Education, Science and Innovation, 2022. Hydrogen Society Roadmap for South Africa 2021

Economic Reconstruction and Recovery Plan. Key highlights and targets from the HSRM include:

- Green hydrogen set as a key priority to leverage on the SA's endowment of renewable solar and wind resources and platinum reserves.
- Target set for a minimum 1 MW electrolysis capacity by 2024 for green hydrogen, which would be scaled-up to 15 gigawatts (GW) by 2040.
- Green hydrogen targeted for use in the decarbonisation of heavy-duty transport sector, aviation, shipping and rail, energy-intensive industry (including steel, chemicals, mining, refineries and cement); greening of the power sector, and for creating an export market.
- HSRM also recognises the need for the production, storage and distribution of all forms of hydrogen to support its objectives while positioning the country to transition from grey, blue to green hydrogen to contribute to the achievement of climate change targets.
- No specific targets set for grey and blue hydrogen in the HSRM.

From the energy sector perspective, hydrogen is yet to be integrated in the SA energy policy framework. Government, through the Department of Mineral Resources and Energy is yet to clearly articulate the role that hydrogen would play in the country's energy system.

6. POLICY FRAMEWORK ANALYSIS

Figure 6 shows the structural design of policies and legislation governing South Africa's electricity and gas industries.

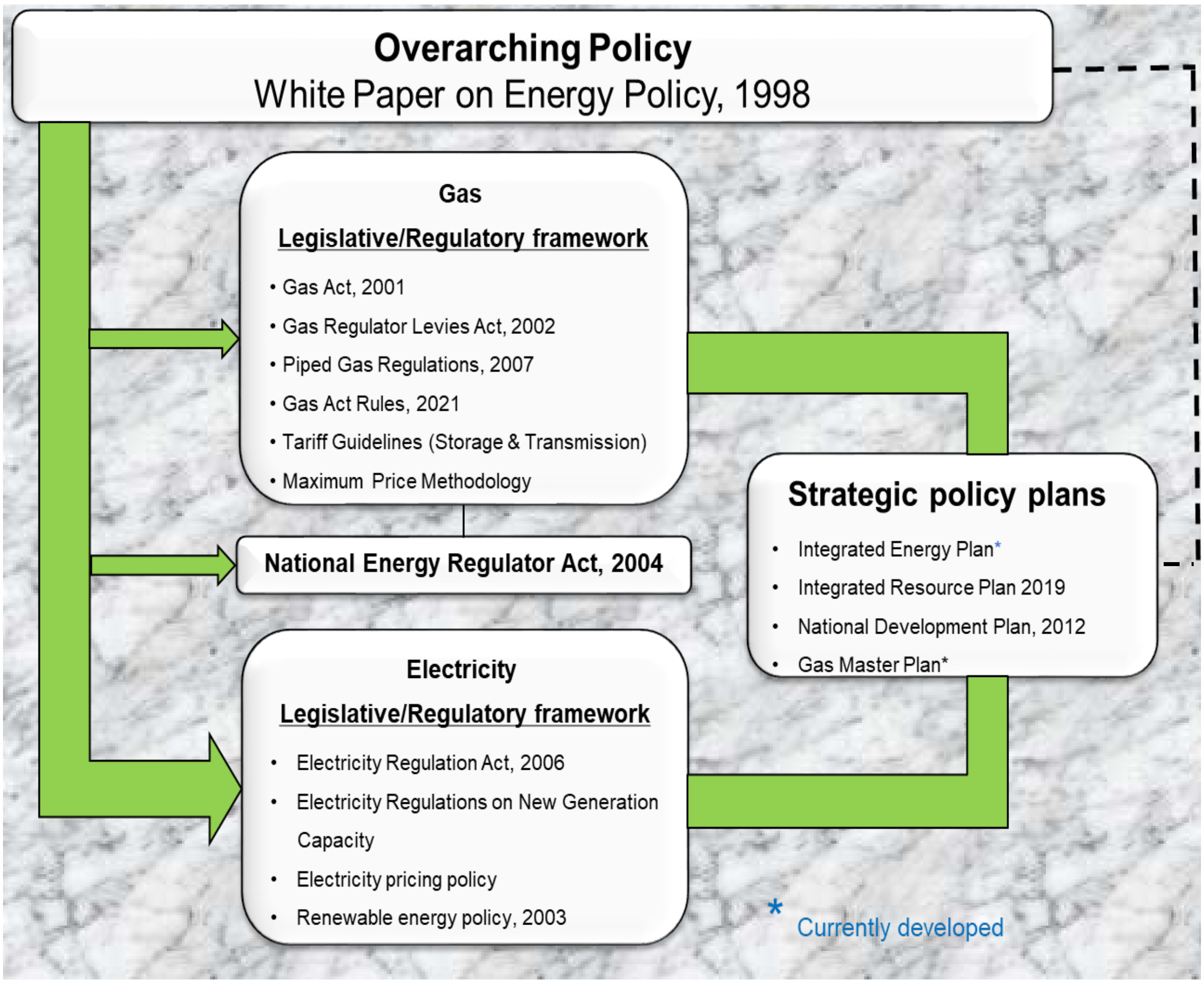

Figure 6: Schematic representation of key national energy policies and legislation

Source: Author's own synthesis

Overarching energy policy

The White Paper on the Energy Policy of the Republic of South Africa (Republic of South Africa, 1998) outlines the overarching policy objectives that government seeks to achieve in the energy sector. Government seeks to increase access to affordable energy services, improve energy governance, stimulate economic development, secure energy supply through diversification and manage energy-related environmental and health impacts. Government sets specific energy policy priorities aimed at achieving each policy objective. This White Paper on the Energy Policy of the Republic of South Africa of 1998 ("Energy White Paper") gave birth to the various acts, regulations and strategic plans that inform and drive the continuous developments realised in the South African energy sphere.

One of government's stated policy objectives in the Energy White Paper is to ensure security of supply through the diversification of both supply sources and primary energy carriers. Government undertakes to support the introduction of other primary energy carriers, including gas, in the national energy mix. South Africa is endowed with coal resources and renewable solar and wind resources but has limited domestic gas reserves. This is evidenced by the historic dominance of coal and the rapid increase of renewable energy in the national energy mix. Natural gas on the other hand only contributes about 3% in the energy mix, but there is an opportunity for this situation to change as the National Energy Act, 2008 advocates the optimal use of indigenous and regional energy resources. This implies that South Africa can import gas resources from neighbouring gas producing countries including Mozambique and Namibia.

Integrated energy planning considerations

The Energy White Paper considers the use of integrated energy planning to evaluate energy supply options periodically that are viable for meeting the country's energy needs. The purpose and objectives of integrated energy planning are anchored in the National Energy Act (Republic of South Africa, 2008) which seeks "to ensure that diverse energy resources are available, in sustainable quantities and affordable prices to the South African economy in support of economic growth and poverty alleviation, taking into account environmental management requirement and interactions amongst economic sectors…" The energy planning exercise is undertaken to determine the best way to meet the current and future energy service needs in the most efficient and socially beneficial manner. It is recognised that energy has a primary role in the development of the country's economy and that the energy sector is the pillar for the attainment of national social and economic imperatives. (DoE, 2013).

Further, the Energy White Paper discusses approaches to meet growth in electricity demand including the use of integrated energy planning, particularly integrated resource planning (IRP) methodologies to evaluate further electricity supply investments. IRP is a tool used widely used in most countries to plan for meeting new demand for electricity through a combination of supply-side and demand-side resources over a specified future period. The purpose of the IRP is to drive investment decisions in the electricity generation sector over a specified future period, usually a long-term planning horizon of about 20-30 years (International Rivers, 2013).

The spirit of any IRP is the balancing of the acquisition of least-cost energy resources with maintaining adequate, reliable, safe and environmentally sound energy services for all customers. The IRP creation process include forecasting future energy demand, identifying potential resource options to meet that demand, determining the optimal mix of resources for minimising future electric system costs (lower electricity cost, lower risks and lower social and environmental impacts) and the facilitation of public consultation in the planning process. This process considers a full range of technological, economic, environmental, and policy factors as well as the risks and uncertainties posed by different resource portfolios and external factors. Fuel price fluctuations and economic conditions are some of the key considerations in the IRP process (Energy White Paper (Republic of South Africa, 1998); Wilson & Biewald, 2013). The Electricity Regulation Act (Republic of South Africa, 2006) mandates the electricity regulations for the IRP development in South Africa.

Renewable energy sector specific policy objectives

South Africa's policy positions on renewable energy are articulated in the Energy White Paper of 1998 supplemented by the sector-specific White Paper on Renewable Energy Policy of the Republic of South Africa of 2003 (Renewable Energy White Paper). Both policy documents pledge *"Government support for the development, demonstration and implementation of renewable energy sources for both small and large-scale applications".* The Renewable Energy White Paper sets out the policy principles, goals and objectives for promoting and implementing renewable energy in South Africa. The overall vision of the policy is *for government to achieve "an energy economy in which modern renewable energy increases its share of energy consumed and provides affordable access to energy throughout South Africa, thus contributing to Sustainable development and environmental conservation* (Renewable Energy White Paper, 2003, page 1); whereas the main aim is to create favourable conditions for the development and commercial implementation of renewable technologies.

The Renewable Energy Policy recognises the meaningful contribution of renewable energy in the power generation and non-electric technologies such as solar water heating and bio-fuels. According to DMRE (2021), renewable energy contributed about 11% of the country's primary energy supply in 2018 with onshore wind power and photovoltaic solar power dominating the renewables contributions in electricity generation. Electricity supply is considered one of the key enablers of economic development in the country. Four of the country's key economic sectors i.e., industrial, agriculture, commerce & public service and residential are largely dependent on electricity as an energy source. Electricity contributes about 22% of the total energy consumed in the industrial sector, 76% in the residential sector, 31% in the agricultural sector and 34% in the agricultural sector (DMRE energy balances, 2021). This highlights the need for the development of sufficient energy resources, electricity production and transmission infrastructure capable of meeting demand at any given time. The increasing contributions of renewable energy in meeting the country's energy need is set to assist government to achieve its goals for ensuring secure, reliable and sustainable energy supply. As such, the IRP 2019 promulgated by the Minister of Energy (now Mineral Resources and Energy) projects the development of 20 409 MW renewable energy capacity by 2030, complemented by 5 000 MW of battery storage.

Gas sector specific policy objectives

South Africa currently does have a gas sector specific policy document, its policy positions on gas are expressed in various government instruments providing a comprehensive policy framework for the energy sector. The Energy White Paper recognises that gas is an attractive option for South Africa and that government is committed to the development of this industry. A strong potential for significant growth of the SA gas industry based largely on regional gas trade is envisaged. Further, the National development (2012) envisions that gas would play a critical role as a transition fuel to decarbonise the SA economy; and provides as one of the infrastructure priorities, the construction of infrastructure to import LNG and increasing exploration to find domestic gas feedstock.

From the IRP 2019, which sets out a long-term plan for the diversification of the power generation mix by 2030, gas/diesel is also expected to contribute 6 380 MW (8.1% of the total installed capacity). The planned large share of intermittent renewable generation from wind, solar photo-voltaic (SPV) and concentrating solar power (CSP) presents the opportunity for gas (vs battery energy storage) to increase the demand for gas-fired power in the generation mix because gas can provide flexible backup capacity quickly compared to thermal coal and nuclear when the sun does not shine and the wind is not blowing.

The considerations for gas in the electricity generation mix presents an opportunity for further growth in the gas industry, which largely hinges on inter-dependent development of more gas supplies and corresponding demand for the gas. The development of gas infrastructure, notwithstanding its importance, becomes relevant once there is assured supply and demand for the gas downstream. Conventional wisdom suggests that large gas volume offtakes by gas-fired power plants provide the critical mass that is sufficient to anchor developments of new capital-intense gas infrastructure projects. Gas on the other hand has proven to be a reliable technology for managing power systems loads. This is observable in countries with an increasing trend of high renewable energy penetration in their power generation mix.

Given the country's limited gas resources and notwithstanding the prospects of indigenous production in the long-term, South Africa is likely to depend on regional gas supply and/or liquefied natural gas (LNG) imports from the international markets including LNG producing countries in Africa in the short to medium-term. This would require investment in large capital-intensive cross-border gas transportation infrastructure including physical pipelines and LNG import facilities. Sound and supportive regulatory policies would be a pre-requisite for realising this goal.

The Gas Act, 2001 establishes the national regulatory framework for gas with the primary objective to promote orderly development of the piped gas industry and the development of competitive gas markets. It further sets out the functions and powers of the Energy Regulatory in relation the licensing of gas activities, regulation of tariffs and maximum prices for gas, compliance monitoring and enforcement, investigations of complaints and dispute resolution, amongst others. The Gas Act is supplemented by the Piped Gas Regulations of 2007 and a string of flexible and appropriate regulatory tools that are designed to improve regulatory effectiveness and efficiency. The regulatory tools include the Gas Act Rules, methodology for approving maximum prices for gas, guidelines for the approval of gas storage and transmission tariffs, regulatory processes and procedures that can be adapted to respond to the changing market conditions and needs.

On the overall, it should be noted that all energy projects are subject to compliance with Environmental laws and policies which are not the subject of this report. Key considerations should be given to the environmental factors affecting the development of gas projects. In South Africa specifically, gas is currently facing more resistance from an environmental standpoint than the clean renewable energy alternatives.

7. SUMMARY OF KEY ISSUES, IMPLICATIONS AND NEXT STEPS

It is clear that the global energy sector is evolving from the fossil-based energy system and that decarbonisation is gradually occurring to tackle climate change. High renewable energy scenarios and the green hydrogen solution are envisioned as the long-term sustainable future for the global energy system. However, it is recognised that this green transition is a complex endeavour that would not occur in a short period. It requires a set of multi-layered solutions proved overtime to achieve the decarbonisation goals while balancing the need for energy security. The IEA (2019) attests that the net-zero emissions pathway requires multiple approaches, policies, and technologies at different times; emphasising that there is no single solution to the energy transition.[41]

[41] International Energy Agency, 2019. The Role of Gas in Today's Energy Transitions

While renewables and hydrogen are expected to dominate the net-zero emissions pathway, coal/oil to gas switching is likely to play an important role in power generation and other sectors within certain timeframes during the transition. If anything, the events of 2021 that led to the energy crisis currently experienced globally and driven by the geopolitical events in Europe show the importance of striking a balance between maintaining well developed energy sources such as coal, oil and gas for energy security while gradually adapting the energy system for its green future.

The IGU and other reputable sources envisage that gas would remain part of the solution in the transformation of the energy sector. It is also acknowledged that gas needs to gradually decarbonise for it to continue to play a prominent role in the sustainable energy future. Renewable gases such as biomethane and renewable hydrogen as well as low-carbon gases such as blue hydrogen and the CCS technology are receiving attention as key assets to decarbonise the gas sector. As such, gas is expected to deliver a substantial decrease in CO_2 emissions mainly in power generation through coal to gas switching and serving as a complementary fuel to support the vast expansion of renewable energy production.

Nonetheless, the role of gas transcends beyond power generation as it can be used in a variety of sectors in its decarbonised form, e,g, biomethane as bioCNG and bioLNG in transportation; blue hydrogen and CCS, biomethane, green hydrogen & green ammonia for industry; and biogas, biomethane and blue hydrogen for commercial and residential buildings.

The literature analysis revealed that gas, renewable energy and hydrogen can co-exist to complement each other in the energy system. A graphic summary of this gas, renewable energy and hydrogen interface is provided in Figure 7 below.

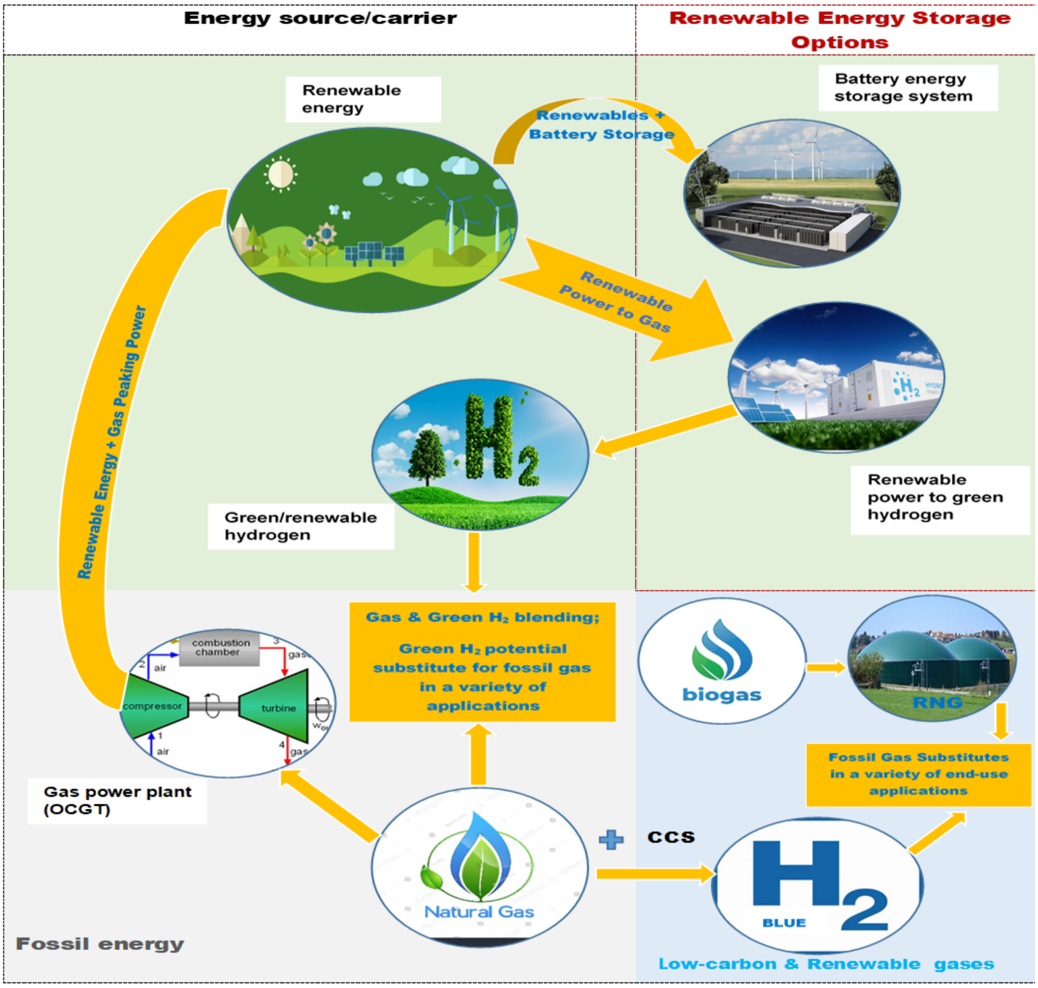

Figure 7: Graphic Illustration of the Gas, Renewable Energy and Hydrogen Interface

The existing complementarities between these energy sources present opportunities for the related industries to be developed in a coordinated fashion. However, the reality is that:

(i) The gas and electricity industries in South Africa are currently developed independently from each other and operate within different regulatory frameworks.

(ii) The position around hydrogen is still developing and requires explicit policies especially concerning its role in the energy system beyond what is envisaged in the HSRM 2021.

(iii) While gas has featured prominently in key national policies as an option to diversify the country's energy mix since 1998, the industry remains nascent as characterised by minimal domestic gas production, lack of diversification of gas supply sources, limited geographic scope of existing gas market concentrated in 4of 9 provinces in the country, lack of infrastructure, overdependence on a single source of imported gas, amongst others.

Nonetheless from the local perspective, the structure of the energy transition is yet to take shape in South Africa. The intent to transition to a low-carbon economy features in key government policy documents including the NDP 2012 and Energy White Paper of 1998, and set to be pragmatised through the implementation of the Renewable Energy Policy and the IRP2019 (currently reviewed by DMRE). Further, goals to exploit the renewable energy and green hydrogen interface are set out in the HSRM. However, there are no explicit policy plans to exploit the gas and renewables interface as well as the gas and hydrogen interface explored in this report.

The analysis in this report shows that whereas the interplay between gas and renewable energy is already a reality in the global power generation sector, gas and hydrogen on the other hand have no guaranteed markets as they have to compete individually with conventional fuels for their place in various energy demand markets, including industry, transportation, residential and commercial buildings and power generation. Thus the large-scale adoption of hydrogen and gas as suitable substitutes rests on government policy support and premised on displacing the conventional fuels in order to thrive. Therefore, a practical reality of a gas, renewables and hydrogen interface may be complex than what is perceived achievable in theory.

In order to understand the related practicalities, NERSA will undertake further assessments to seek quantitative and qualitative insights that would assist the Regulator to propose a pragmatic policy strategy for the coordinated development of gas, renewable energy and hydrogen in South Africa. The main objective is to highlight the possible futures for the role of gas in the envisioned energy transition environment, characterised by increased renewable energy penetration and hydrogen as preferred sustainable energy sources for the future.

NERSA intends to conclude this exercise by December 2023 and will continue to engage with key industry experts on specific issues emanating from this project throughout the process.

REFERENCES

Banks, D. & Schaffler, J. 2006. *The potential contribution of renewable energy in South Africa*, 2nd Edition. Johannesburg: RAPS Consulting & Nano Energy, SECCP.

Department of Higher Education, Science and Innovation. 2022. *Hydrogen Society Roadmap for South Africa 2021* [Online] Available: www.dst.gov.za

Department of Energy (DoE).2013. *Draft integrated energy planning report*

Department of Energy (DoE).2015. *2015/16 Policy and Budget Speech.* Speech delivered at the National Assembly, Parliament, Cape Town, South Africa, 19 May 2015

Department of Mineral Resources and Energy. 2019. *Integrated Resource Plan for electricity 2019 -2030* [Online] Available:*www.energy.gov.za*

Department of Mineral Resources and Energy, 2021. *The South African Energy Sector Report 2021* [Online] Available:www.energy.gov.za

GIINGL. 2021. *The LNG Industry in 2020*

Global CCS Institute. 2021. *Global Status of CCS 2021: CCS Accelerating to Net Zero*

Goldman Sachs. 2020. *The Rise of Clean Hydrogen*

Hydrogen Council. 2017

Hermann, S., Miketa, A. & Fichaux, N. 2014. *Estimating the renewable energy potential in Africa*. IRENA-KTH working paper. Abu Dhabi: International Renewable Energy Agency

International Energy Agency. 2020. *Special Report on Carbon Capture Utilisation and Storage: CCUS in clean energy transition*

International Energy Agency. 2021. *Net Zero by 2050: A Roadmap for the Global Energy Sector*

International Energy Agency. 2019. *The Role of Gas in Today's Energy Transitions*

International Energy Agency. 2019. *The Future of Hydrogen – seizing today's opportunities*

International Energy Agency. 2021a. *World Energy Outlook 21*

International Energy Agency. 2021b. *Renewables 2021 – Analysis and Forecasts 2026*

International Energy Agency. 2021c. *Gas Market Report Q4: 2021*

International Energy Agency. 2021d. *Country Review – Brazil*

International Renewable Energy Agency.2022. *Renewable Energy Statistics 2022*

International Gas Union. 2022. *World LNG Report 2022*
International Gas Union. 2021. *Global Renewable and Low-Carbon Gas Report*

International Gas Union. 2022. *Global Gas Report 2022*

International Rivers.2013. *An introduction to integrated resource planning*. [Online] Available:http://www.internationalrivers.org

Klunne, W. 2013. *Small hydropower in Sothern Africa- an overview of five countries in the region*. Journal of Energy in Southern Africa, 24 (3), 14-25

National Energy Regulator of South Africa. 2012. *Report on the NERSA dialogue on gas infrastructure investment*

Sasol. 2021. *Sasol Climate Change Report 2021* [Online] Available: www.sasol.com

Shell LNG Outlook 2022

World Energy Council. 2020. *Hydrogen Economy- Hype or Hope?*

World Energy Council. 2020. *International Hydrogen Strategies*

IEA.2020. Global Energy Review 2020: *The impacts of Covid-19 crisis on global energy demand and* CO_2 *emissions*

IPCC.2020. *A Special Report on the Impacts of Global Warming of 1.5°C above pre-industrial levels*

Li, T 2008. *Interdependency of natural gas network and power system security. IEEE Transactions on Power Systems*

Peter, G. 2012. *Gas and electric infrastructure interdependency analysis*

Republic of South Africa. 1998. *White Paper on Energy Policy of the Republic of South Africa, 1998*

South African National Planning Commission. 2012. *National Development Plan: Vision for 2030*

U.S. Energy Information Administration (EIA).2022. Annual Energy Outlook 2022

www.unfccc.int

www.eia.org/energyexplained/electricity/data-and-statistics

http://www.iangv.org/current-ngv-stats/

www.petroleumagencysa.com

www.sabia.org.za