Frankl, Paolo (Ed.); Madeira, Rita (Ed.)

Book

Renewable energy opportunities for Namibia

Renewable Energy Opportunities for Namibia

International Energy Agency

INTERNATIONAL ENERGY AGENCY

The IEA examines the full spectrum of energy issues including oil, gas and coal supply and demand, renewable energy technologies, electricity markets, energy efficiency, access to energy, demand side management and much more. Through its work, the IEA advocates policies that will enhance the reliability, affordability and sustainability of energy in its 31 member countries, 13 association countries and beyond.

IEA member countries:

Australia
Austria
Belgium
Canada
Czech Republic
Denmark
Estonia
Finland
France
Germany
Greece
Hungary
Ireland
Italy
Japan
Korea
Lithuania
Luxembourg
Mexico
Netherlands
New Zealand
Norway
Poland
Portugal
Slovak Republic
Spain
Sweden
Switzerland
Republic of Türkiye
United Kingdom
United States

The European Commission also participates in the work of the IEA

IEA association countries:

Argentina
Brazil
China
Egypt
India
Indonesia
Kenya
Morocco
Senegal
Singapore
South Africa
Thailand
Ukraine

Source: IEA.
International Energy Agency
Website: www.iea.org

Abstract

Namibia's abundant world-class wind and solar resources present significant opportunities for the country. Backed by robust policies to help harness these resources, renewable energy could play a central role in advancing Namibia’s vision for sustainable development and economic growth – driving local value creation and industrialisation.

Renewables can reduce the country’s reliance on expensive electricity imports, improve energy security, and lower costs for consumers, thereby fostering a more resilient and sustainable power sector. Renewables can also help Namibia achieve universal electricity access, particularly in remote areas through off-grid solutions.

The mining industry, which plays a central role in the country’s economy, can also benefit from renewables. By reducing energy costs and lowering emissions, they can improve mining operations and enhance the global competitiveness of Namibian mineral products, as demand for sustainably sourced minerals is set to grow.

Thanks to high-quality renewable resources, combined with ample available land for large-scale project development, Namibia is well-positioned to produce renewable hydrogen and its derivatives and develop a new industry. These projects can help attract investment thanks to their large size and foreign offtake. Care should be taken to ensure that large-scale projects support – rather than compete with – key priorities of the country. If designed and managed well, they can offer multiple levers for sustainable development.

This new IEA report – the first focusing on Namibia – explores these opportunities and how they can support the country’s development vision by integrating socio-economic considerations to achieve broader development goals.

Acknowledgements, contributors and credits

This study was prepared by the Renewable Energy Division (RED) and the Division for Europe, Middle East, Africa and Latin America (EMAL) of the International Energy Agency (IEA). The study was designed and directed by Paolo Frankl, Head of RED and by Rita Madeira, Africa Programme Manager – West and Southern Africa. The analysis and production of the report were led and coordinated by Ilkka Hannula, Senior Analyst. The work benefitted from strategic guidance from Ali Al-Saffar, Head of EMAL.

Main IEA contributors were (in alphabetical order) Yasmina Abdelilah, Elisa Asmelash, Trevor Criswell, Gaia Guadagnini, Claire Lesieur, Martina Lyons, Rita Madeira, Youngsun Om. The report also benefitted from the input of Zuzana Dobrotkova, as an external consultant. Support of the IEA Energy Data Centre, in particular Riccardo Inverni, was fundamental to the report. Other IEA colleagues who contributed to this work include (in alphabetical order): Ali Al-Saffar, Nouhoun Diarra, Darlain Edeme, Francesco Pavan, Beatriz Piloto and Amalia Pizzaro.

The following IEA colleagues reviewed the report and/or provided feedback (in alphabetical order): Nadim Abillama, Jose Miguel Bermudez Menendez, Herib Blanco, Joel Couse, Carole Etienne, Javier Jorquera, Pablo-Hevia Koch, Martin Kueppers, Christophe McGlade, Jacob Messing, Uwe Remme, Gianluca Tonolo.

The IEA would like to thank the Ministry of Mines and Energy of Namibia, the Namibia Green Hydrogen Programme and the Namibia Investment and Promotion Development Board (NIPDB) for the support and consultations throughout the preparation of the work.

This study benefitted greatly from discussions with experts on key topics in Namibia: Venton Malango (Namibia Chambers of Mines), John Roos (B2Gold), Siegfried Huegemann (African Hydrogen Partnership), Jonathan Metcalfe (Enertrag), Shanta Barley, Brownyn Grieve and Edward Kalajzic (Fortescue), Sebastian Sahla, Fatma Nyambura and Gilbert Makore (Extractive Industries Transparency Initiative (EITI)), Carsten Mosch, Emmeric Angermund and Daniel Castelyn (Lodestone Namibia).

The IEA would also like to thank the following senior government officials and experts who reviewed and provided feedback on the report:

Countries: Belgium (Sam Wanwijnsberghe, Federal Ministry of the Economy), Germany (Sophie Frossard, Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ)), Japan (Masuda Kazuo, Japan Organization for Metals and Energy Security (JOGMEC)), Namibia (Abraham Hangula, Ministry of Energy and Mines; James Mnyupe, Namibia Green Hydrogen Programme, Office of President of Namibia; Hafeni Motsi, Namibia Investment Promotion and Development Board), Netherlands (Anton Wuis, Ministry of Foreign Affairs), South Africa (Marilize Nel, Desiree Otto and Dzunani Makgopa, IPP Office).

Organisations: Cédric Philibert (Institut Français des Relations Internationales), Daniel Frank (Chemische Technik und Biotechnologie (DECHEMA)), David Lecoque (Alliance for Rural Electrification), Dolf Gielen (World Bank), Jerome Namaseb (Daures Green Hydrogen Village), Karla Barron Cervantes (Climate Compatible Growth, University of Cambridge), Laurent Antoni (International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE)), Laurent Roche (TotalEnergies), Marco Raffinetti and Toni Beukes (Hyphen Hydrogen Energy), Mandy Ros (Port of Rotterdam), Nabeel Mancheri (former Rare Earth Industry Association), Nicolas Lecomte and Pierre Laboué (France Hydrogène), Sebastian Sahla (Extractive Industries Transparency Initiative (EITI)), Thierry Lepercq (Soladvent and Fonds e5t).

Thanks also to the IEA Communications and Digital Office (CDO) for their help in producing the publication, especially to Astrid Dumond, Merve Erdil, Liv Gaunt, Grace Gordon, Julia Horowitz, Jethro Mullen and Clara Vallois. We thank Nicola Clark for the copyediting of the manuscript.

The study benefitted from the outcomes of the discussions at the IEA Ministerial High-Level Dialogue on Renewable Energy for Sustainable Economic Development in Africa: Turning a Vision into Reality, held in February 2024.

This work was supported by the Clean Energy Transitions Programme, the IEA's flagship initiative to transform the world's energy system to achieve a secure and sustainable future for all.

Table of contents

Executive summary ... 7
Chapter 1. Namibia's vision: Renewables for accelerated structural development ... 10
Context ... 10
Namibia's untapped renewable energy potential ... 11
Policy drivers of Namibia's vision ... 12
Chapter 2. Overview of Namibia's energy system ... 18
Energy supply and demand ... 18
CO_2 emissions from the energy sector ... 21
Namibia's power sector ... 21
Chapter 3. Opportunities for renewables in mining ... 31
Mining sector ... 31
Energy use of the mining sector ... 33
From raw materials to value-added commodities ... 36
Four drivers for the uptake of renewables in mining and processing ... 38
Use of renewables in mining and processing ... 39
Electrification of mining operations ... 43
Chapter 4. Opportunities for renewable hydrogen ... 46
Renewables-based hydrogen and ammonia projects ... 46
Preparing for ammonia exports ... 49
Opportunities for domestic fertiliser production ... 53
Water needs for electrolytic hydrogen ... 55
Chapter 5. Socio-economic benefits through renewable energy ... 59
Incorporating socio-economic factors into renewable energy project design ... 59
Socio-economic elements of emerging renewable hydrogen projects ... 65
Examples of socio-economic benefits in the mining sector ... 67
Key enablers ... 69
Annex ... 71
Explanatory notes ... 71

Executive summary

Namibia's vast renewable energy potential holds significant opportunities for socio-economic development. Located on the Southwest Atlantic coast of Africa, with a small population of 3 million people, the country is endowed with world-class solar and wind resources. Solar photovoltaic (PV) systems in Namibia can generate twice as much electricity as comparable systems in central Europe. Meanwhile average wind speeds in its southern and coastal regions exceed 7 m/s and capacity factors can reach 50%. Backed by robust policies to help harness these resources, renewable energy could play a central role in advancing Namibia's vision for sustainable development and economic growth – driving local value creation and industrialisation.

Renewables can lower costs, reduce import dependency and increase energy security for Namibia's electricity sector. Namibia is highly dependent on imports to meet its electricity needs, with the share of imported electricity standing at 60%-70%. Meanwhile, Namibia's spending on purchased power jumped to USD 5 billion in 2023, up from USD 4 billion in 2019, due to the rising cost of imported electricity. As a result, Namibia currently has the highest electricity prices in Southern Africa. To increase electricity security and decrease costs to the consumer, the government has set a target to generate 80% of its electricity domestically by 2028. Current plans include deploying 170 MW of new renewable capacity, which would account for more than a third of that goal. Given the competitive prices that the government has been able to secure through public tenders, renewables are poised to become a cost-effective new source of domestic power.

The deployment of renewables can help Namibia reach its goal of providing universal electricity access by 2040. Despite significant progress over the past two decades, nearly 45% of Namibians still lack access to electricity. Most people without power live in sparsely populated rural areas across the country. Off-grid renewables are therefore particularly compelling as an access solution. Closing the gap will depend on sustained government efforts, support from development partners and active participation from the private sector.

Integrating renewable energy into the mining sector can enhance the competitiveness of Namibian products in global markets, while reducing emissions. Mining is Namibia's largest industrial sector (14% of GDP) and consumes 21% of the country's electricity. As Namibia develops its downstream industry to capture a greater share of the mineral value chain, electricity demand will continue to increase. Recent auction prices for solar PV and wind in Namibia were nearly 80% and 65% lower, respectively, than the retail price of USD 135/MWh that mines pay today for electricity. This is a strong indicator of the potential that renewables represent for lowering costs, reducing emissions and enhancing the competitiveness of the mining industry, including in markets that seek for more sustainable products. There are currently several renewables projects under development in Namibia – totalling 40 MW of capacity – that are associated with mining.

Electrifying mobile mining equipment can lower overall costs, enhance efficiency and provide environmental and health benefits for miners and local communities. Although most mines are connected to the electricity grid, mobile mining equipment such as haul trucks, excavators and loaders rely on fossil fuels for their operation. The electrification of these tools – either with large batteries or through high-voltage trailing cables – is progressing rapidly around the world, with Namibia's uranium mine emerging as one of the world's pioneers. Despite higher upfront investment needs, overall cost savings can be significant over the life of a mine, especially when accounting for the low cost of renewable electricity.

High-quality renewable resources, combined with ample available land for large-scale project development can facilitate competitive production of renewable hydrogen. Recognising Namibia's renewables potential, the country has set ambitious renewable hydrogen production targets of 1-2 Mt per year by 2030, rising to 5-7 Mt per year by 2040. Currently, however, Namibia lacks a domestic market for hydrogen – meaning that all production would initially need to be exported. Delivery to international markets would require shipping hydrogen in the form of ammonia, which would necessitate large-scale investments in port infrastructure and development of ammonia handling expertise. Moreover, neighbouring countries could be supplied with new or repurposed dedicated hydrogen pipelines. The country has already established strategic partnerships with prospective export markets to enable technology transfer, secure offtake agreements and attract the investment flows needed to unlock this potential.

Mitigating the risks associated with large-scale projects and lowering financing costs are essential for competitive ammonia production. The cost of capital – a measure of how investors and financiers price the risks associated with an investment project in a particular country – can be up to two to three times higher in emerging markets and developing countries than in advanced economies, making it much harder to finance new projects. This is especially relevant for renewable hydrogen and ammonia plants, which require a significant portion of upfront investment relative to the total project costs. Efforts to lower the cost of capital are not only crucial for attracting investors but also for the overall competitiveness of a project. For example, reduction in the cost of capital from 15% to 5% would slash the levelised cost of ammonia production in Namibia from nearly USD 1 400/tonne today to USD 740/tonne. Anticipated reductions in the cost of electrolysers and renewable electricity could lower the levelised cost of ammonia still further, to around USD 560/tonne by 2030.

Renewable hydrogen production requires significant amounts of purified water, which can be cost-effectively obtained through seawater desalination powered by renewables. To achieve Namibia's hydrogen production goals, the country would need between 10-20 million cubic metres (Mm^3) of purified water per year by 2030. Water demand would continue to increase in line with rising hydrogen production so that, by 2050, demand would exceed current municipal water needs. Such water requirements can be cost-effectively supplied for hydrogen production using seawater desalination powered by renewable energy – which would ensure that a thriving hydrogen industry does not jeopardise water security and that other associated environmental impacts are minimised. The cost of desalinated water has a marginal impact on the levelised cost of hydrogen, being in the range of 2%-5% depending on cost of hydrogen and cooling method.

All stakeholders must take close and coordinated action to ensure that large renewable investment projects provide tangible socio-economic benefits and support broader development goals. Incorporating socio-economic considerations in renewable project design can support job creation and skills development, lead to direct investments benefitting communities and attract fiscal revenues that can be deployed for infrastructure development and public services. It is important to draw from successful experiences and tailor actions to the Namibian context to ensure that these expectations are met in practice.

Care should be taken to ensure that large-scale projects support – rather than compete with – key priorities. It is critical to design and calibrate policies that ensure export-oriented industries like mining and renewable hydrogen are developed in a way that complements national electrification and water needs. The scale of these projects offers opportunities for leverage towards local economic development, including by de-risking investment and lowering costs of auxiliary energy sectors, such as distributed renewables. This could include initiatives to build skilled workforce and aggregate demand for the purpose of procurement, lowering costs for off-grid developers**.**

Namibia has the opportunity to leverage its renewable energy potential as a foundation for broader socio-economic development and industrialisation. By linking the country's world-leading renewable resources, vast areas of open land and strong and stable democratic institutions, Namibia is positioning itself at the forefront of catalytic change. A holistic approach that integrates renewable energy, industrialisation and development targets – informed by best practices in policy and governance – provides a solid foundation for advancing socio-economic progress. Establishing strong governance and fiscal frameworks to manage revenue inflows is equally critical, as it enhances transparency and accountability. This can enable the government to use these funds to mitigate risks for projects that cannot solely rely on commercial capital, such as off-grid access.

Chapter 1. Namibia's vision: Renewables for accelerated structural development

Context

Namibia's substantial land area includes a 1 572-kilometre coastline stretching along the South Atlantic Ocean. It is bordered to the north by Angola and Zambia, by Botswana to the east and to the south by South Africa. Namibia ranks among the driest countries in sub-Saharan Africa, dominated by the Namib Desert along its western coast and the Kalahari Desert in the southeast.

Namibia has a small population of about 3 million people (2023), mostly concentrated in the north. Rural communities represent half of the population. The midlands region of Khomas, which includes the capital Windhoek, is home to more than 15% of the country's inhabitants, followed by the northern regions of Ohangwena, Omusati, and Oshikoto.

Since gaining independence three decades ago, Namibia has emerged as one of the most stable and peaceful nations in Africa, achieving the status of an upper-middle-income country. In 2023, the country's gross domestic product (GDP) increased by more than 3%, totalling USD 12.3 billion, spearheaded by a recovery in the mining sector that has brought the economy back to pre-pandemic levels. Recovery of other sectors that were more directly impacted by the Covid-19 crisis, such as tourism, has been slower.

Namibia is rich in mineral resources – notably diamonds and uranium, but also copper, zinc, lithium and rare earth elements. The mining sector represents 10% of GDP and the country relies heavily on international trade, exporting almost all its primary resources, often in their raw and unprocessed form. It is also highly dependent on South Africa, from where it sources 45% of its imports. Import dependency affects nearly all consumer goods and a significant share of total final energy consumption. Although the country has not experienced large-scale power shortages, it relies heavily on imported electricity from South Africa, Zambia and Zimbabwe.

Reliance on international trade and vulnerability to fluctuations in commodity prices have influenced Namibia's macroeconomic outlook. Prudent government spending policies have enabled Namibia to sharply reduce its fiscal deficit from almost 9% of GDP in 2021/22 to just over 5% in 2022/23. However, public debt has continued to rise, reaching close to 70% of GDP in 2023. According to the International Monetary Fund (IMF), interest payments on that debt represented 4.5% of GDP that same year.

Despite its upper-middle-income status, Namibia continues to rank among the most unequal countries globally. Socio-economic inequality – a legacy of the apartheid system during South African rule – remains significant and was exacerbated by the Covid-19 pandemic. Vast regional disparities persist: large parts of the population still lack access to economic opportunities and basic services. In 2023, only 56% of Namibians had access to electricity while 48% had access to clean cooking solutions. (Both figures are still higher than the sub-Saharan African averages of 49% and 19%, respectively, excluding South Africa). Meanwhile, most communities – about 99% of urban households and 87% of the rural population – do have access to potable water. Although poverty has declined rapidly since the 1990s, it remains high for Namibia's level of economic development.

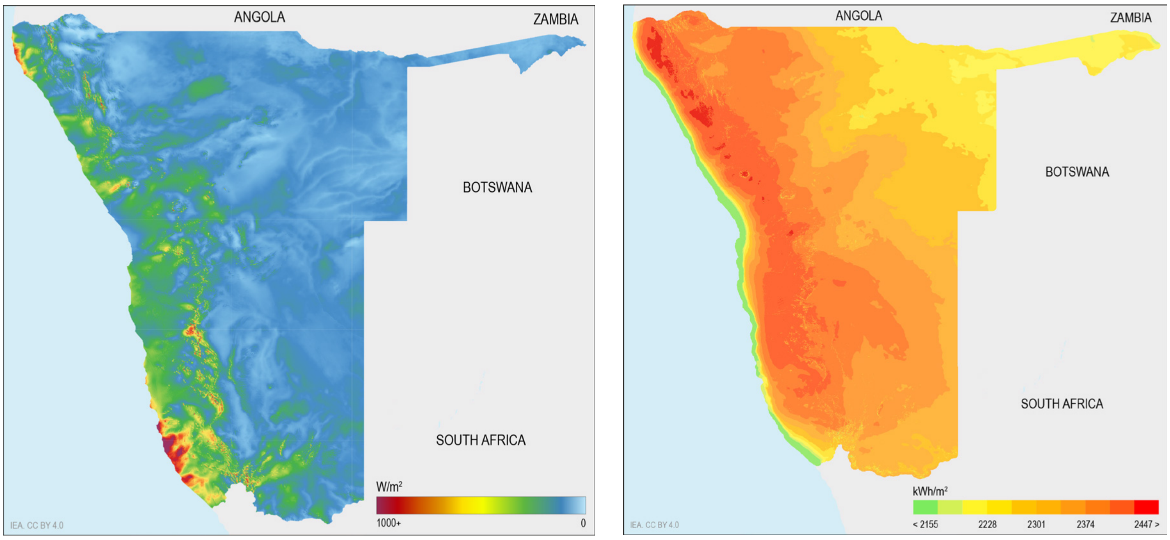
Unemployment is both a factor and a contributor to inequality and remains a major concern. In 2023, the unemployment rate stood close to 20%, according to the World Bank. Accurate figures are hard to come by, though, as large segments of the workforce operate outside the formal economy and depend on opportunities in the informal sector, which are not captured in official statistics. Unemployment is especially pronounced among Namibia's youth (defined as those aged 15 to 34). The most recent Labour Force Survey from 2018 reported a youth unemployment rate of 46%. This is a growing concern, particularly as youth now account for 71% of Namibia's population, according to the preliminary results of the 2023 census.

Namibia's untapped renewable energy potential

Namibia's climate is predominantly hot and dry, with irregular rainfall: 92% of its land is defined as either very arid, arid or semi-arid. These characteristics, while adversely affecting living conditions in some areas, also place Namibia among the countries with the best solar and wind resources in the world.

Namibia receives approximately 10 hours of sunlight per day throughout the year, and an average annual solar irradiation of 2 700 kWh/m^2. Solar photovoltaic (PV) systems in Namibia can generate double the annual electricity of comparable systems in Germany. Furthermore, limited seasonal variability makes it possible for Namibia to achieve over 75% of its maximum solar output during its lowest solar production months, in contrast to many countries in Europe and elsewhere. The country also happens to be one of the world's windiest places, with potential concentrated in the southern coast around Lüderitz, as well as along the border with Angola (Figure 1.1). In these areas, average wind speeds exceed 7 metres per second and capacity factors reach 50%. With a vast territory and extremely low population density – roughly three people per square kilometre – Namibia also offers vast potential for the development of large-scale renewable energy projects.

Figure 1.1 Wind power density (left) and total yearly solar horizontal irradiation (right) in Namibia



Source: IEA, based on data from Global Wind Atlas and Global Solar Atlas.

Policy drivers of Namibia's vision

Namibia has developed a series of policy documents to guide its vision for sustainable development, anchored by its seminal initiative, Namibia Vision 2030. This programme charts a pathway to development that "meets the needs of the present without limiting the ability of future generations to meet their own needs." Over the past two decades, Namibian policy makers have focused on balancing socio-economic progress and industrialisation with sustainable development. Their policies set long-term goals alongside short- and medium-term targets, with the aim of enhancing the wellbeing of all Namibians.

Vision 2030

Published in 2004 by the Office of Namibia's first President, Sam Nujoma, Namibia Vision 2030 (Vision 2030) was the country's first policy document to set out long-term goals and objectives, aiming "to improve the quality of life of the people of Namibia to the level of their counterparts in the developed world by 2030."

Intended as a framework or roadmap for achieving a set of long-term goals over a 30-year timeframe, Vision 2030 articulates the objective of "a prosperous and industrialised Namibia, developed by her human resources, enjoying peace, harmony and political stability." This long-term goal therefore guides the design of the country's national development plans, which tend to focus on shorter-term targets – typically for a period of five years. While Vision 2030 outlines the main principles, the national development plans specify quantifiable targets to be reached during each implementation period. The most recent, the 5th National Development Plan (NDP5) spanned the years 2017-2022 but remains applicable while the government finalises its 6th National Development Plan (NDP6). NDP5 focuses on several key priority areas, including economic diversification and industrialisation, investment in infrastructure development – particularly energy infrastructure – ensuring energy security and enhancing the value-added processes for natural resources, especially in the mining sector.

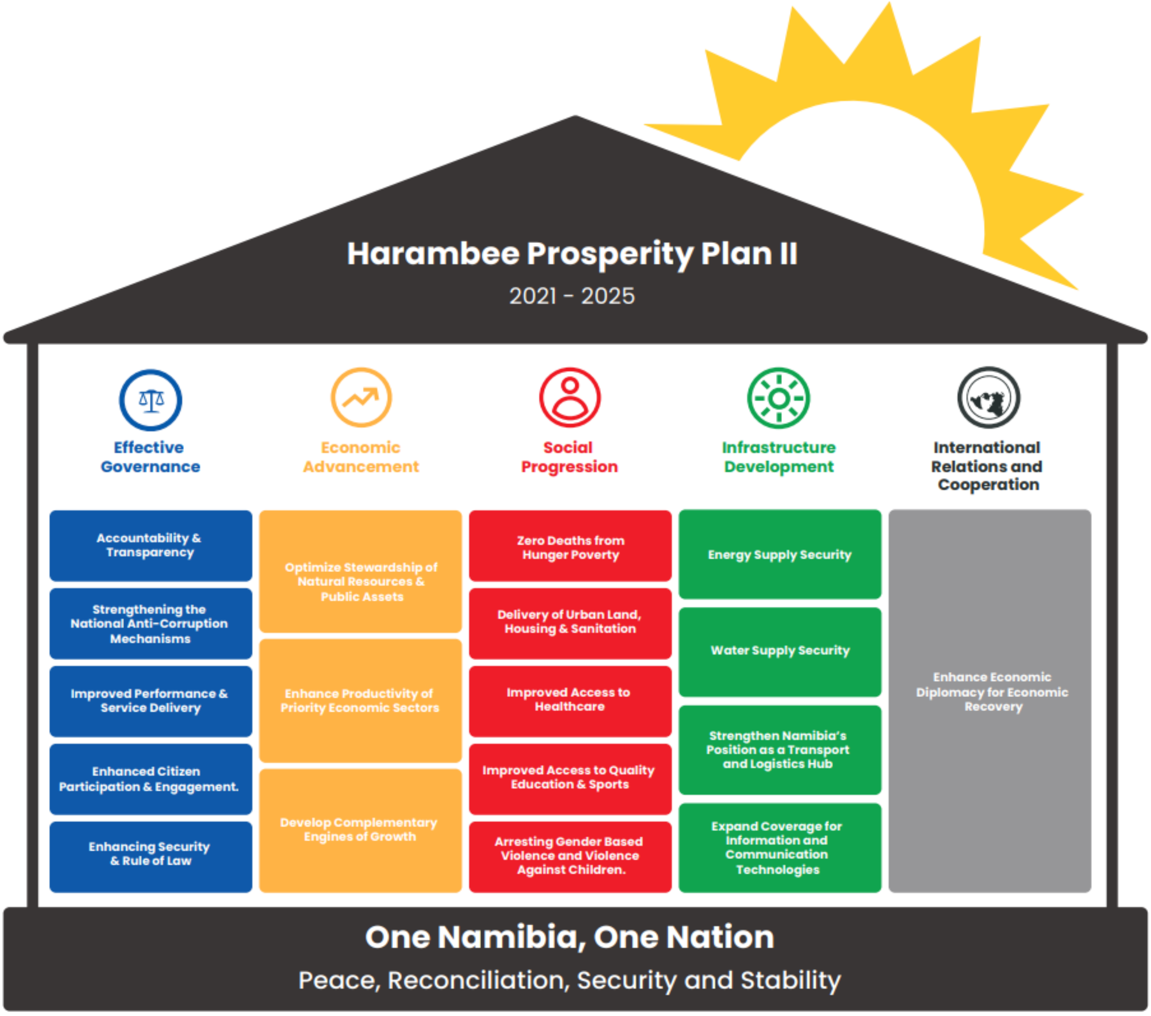
Although Vision 2030 presents a cross-sectoral and system-wide vision for the country, it acknowledges and prioritises the energy sector as an important enabler. The transformation of Namibia into an industrialised economy, anchored in sustainable development, hinges on a self-sufficient, reliable system that can provide stable and affordable energy. Central to this vision is ensuring that households and industry have universal access, unlocking the benefits of a skills-based industrial and services sector.

It also emphasises the commitment to sustainable development, socio-economic advancement of Namibians and investment in the energy sector that supports industrialisation while respecting the climate and the environment. These priorities will continue to influence future policy documents and are examined in closer detail in the following subsections.

Prosperity for all Namibians

Building on the foundation of Vision 2030 and addressing challenges emerged from formulating the NDP5, Namibia's late President, Hage G. Geingob, launched the Harambee Prosperity Plan I in 2016, with the goal of reducing poverty and improving quality of life. In 2021, in the aftermath of Covid-19, the Office of the President launched the Harambee Prosperity Plan II (2021-2025), defining strategic actions that will serve as targeted policy programmes to advance Vision 2030 in the short to medium term. The Harambee Prosperity Plan II (Prosperity Plan) outlines five pillars for government action, which are further broken down into specific goals and activities that support this vision (Figure 1.2).

Figure 1.2 Namibia's vision for prosperity



Source: Republic of Namibia (2021), Harambee Prosperity Plan II.

The Prosperity Plan emphasises the key themes of Vision 2030, including socio-economic advancement and infrastructure development, with a focus on skills and knowledge building – and employment – at its core. These priorities are articulated through five "pillars", with Pillar 2 (Economic Advancement) and Pillar 4 (Infrastructure Development) addressing topics of particular concern to the energy sector. They also dovetail with other policy documents targeting specific subsectors of economic activity.

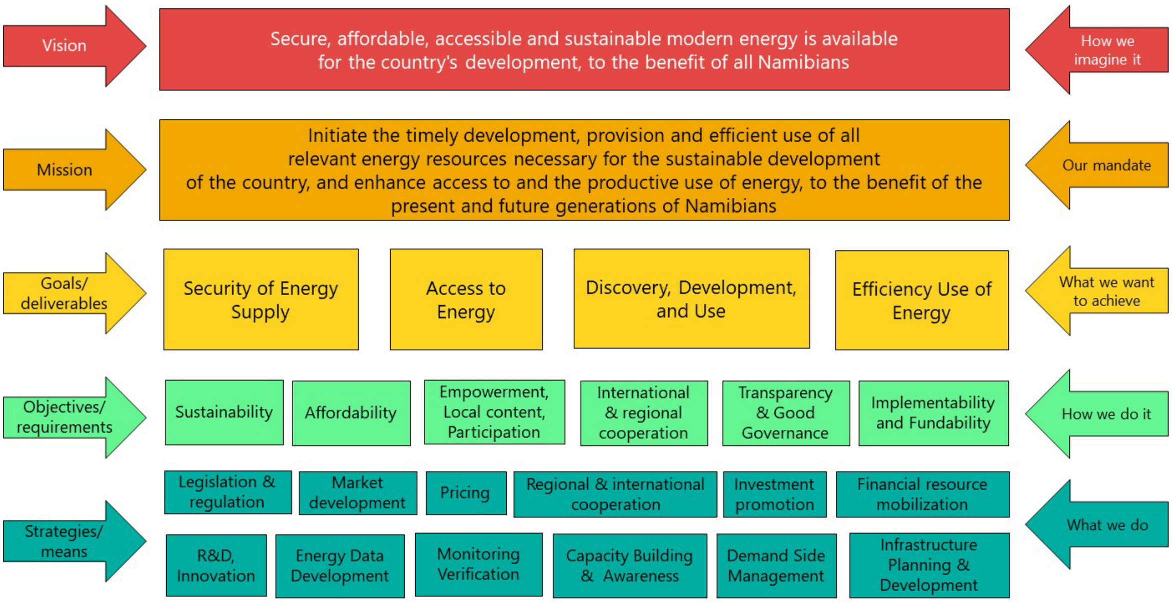
Among these key concerns, the Prosperity Plan highlights the primary goal of ensuring a cost-effective energy supply while also improving access to electricity in both rural and urban areas. Given the weight of the highly water-intensive mining sector in Namibia's economy and concerns around water stress, this plan seeks to optimise the use of natural resources and ensure water availability to households as well as other industries. It also underscores the importance of identifying and prioritising investment in projects that create significant employment opportunities, as well as the importance of attracting private sector capital to support infrastructure development. This is also Namibia's first policy document to recognise renewable hydrogen – hydrogen produced through electrolysis using solar PV and wind power – as a potential opportunity to drive socio-economic development through a "transformative strategic industry".

Sustainable development

Sustainable development is a core principle cited across Namibia's policy documents. It supports key focus areas, including energy, renewables, water availability and management, as well as mineral resource production. Namibia's National Energy Policy emphasises sustainability – as well as the United Nations Sustainable Development Goals (SDG) more broadly – and puts it at the centre of its vision for the country's energy sector.

Approved in 2017, the National Energy Policy "envisions a future in which secure, affordable, accessible and sustainable modern energy is available for the country's development, to the benefit of all Namibians."

Figure 1.3 Framework underpinning Namibia's National Energy Policy



Source: Republic of Namibia (2017), National Energy Policy.

The National Energy Policy outlines key concerns of Namibia's policy makers regarding the energy sector: (i) ensuring the security of energy supply across the country, (ii) providing cost-effective, affordable, reliable and equitable access to energy for all Namibians, (iii) promoting energy efficiency and (iv) incentivising the discovery, development and productive use of the country's diverse energy sources (Figure 1.3).

Sustainable development also underpins Namibia's vision and strategy for renewable energy deployment. Acknowledging the country's abundant, high-quality solar and wind resources, policy makers highlighted the strategic value of renewable energy in their first energy policy document, the White Paper on Energy Policy of 1998.

When the government revised its energy policy in 2017, it also released its first standalone National Renewable Energy Policy, signalling strong support for renewable energy as a crucial driver of development. This is evident in its mission statement to "enable access to modern, clean, environmentally sustainable, and affordable energy services for all Namibians."

The National Renewable Energy Policy emphasises several key objectives that confirm Namibia's commitment to renewable energy. These include creating an enabling environment for renewable energy development and accelerating renewable energy growth and value chain development, as well as fostering investor confidence in the sector as a critical step towards attracting investment. To accomplish this, the government adopted a modified single buyer (MSB) model (see Chapter 2) that permits the private sector to sell electricity to entities other than the national power company, thereby facilitating the deployment of renewables and enabling distributed generation.

Alongside renewables, the principle of sustainable development is key to the country's focus on water availability and management. This is highlighted in NDP5, which acknowledges that the combination of an arid climate and high rates of water evaporation makes Namibia one of the driest countries in the African continent. Water scarcity is therefore a preoccupation that impacts the availability of drinking water and freshwater resources for other economic activities, including agriculture and mining. This is seen as a significant constraint that could limit Namibia's development.

The latest National Development Plan estimates that water demand for domestic purposes and economic activities (including mining, industries and irrigation) is set to increase from around 334 million cubic metres (Mm^3) per year in 2015 to about 583 Mm^3 per year in 2025, reaching 772 Mm^3 per year in 2030. This policy document considers the availability and affordability of water as essential Namibia's goal of becoming an industrialised economy. It also highlights opportunities for desalination plants along the coast, including through public-private partnerships, as a viable solution to combat water scarcity.

Equitable socio-economic advancement

Alongside sustainable development, the goal of extracting greater value from the country's abundant natural resources has long been fundamental to its efforts to achieve towards equitable socio-economic progress. From Vision 2030 to

Harambee Prosperity Plan II, this key driver of Namibia's policy is tied to the goals of improving quality of life and transforming into an industrialised economy. It also focuses on building the necessary skills and knowledge to support this transformation, as well as on creating employment opportunities.

The Prosperity Plan identifies key "engines of growth" that can drive socio-economic progress. Policy makers are particularly focused on the mining sector and the potential for hydrogen production to support the country's industrial transformation.

Namibia's vast mineral wealth includes diamonds, uranium and gold, as well as critical minerals like copper, zinc, lithium and rare earth elements. Policy documents take particular note of the economic weight of the mining sector, including its importance as a source of foreign exchange earnings and its potential to contribute even more to Namibia's economic development.

The Prosperity Plan, the 5th National Development Plan and the Mineral Beneficiation Strategy for Namibia recognise that value addition in Namibia's mineral supply chains is still at an early stage. While Namibia has some experience in processing and refining certain well-established minerals and metals, expanding this expertise to cover other critical minerals poses new challenges. If these can be overcome, they could bring wider socio-economic benefits such as new local jobs and increased revenue through higher-value exports and the growth of supporting industries, such as renewable energy, which would, in turn, contribute to a more sustainable mining sector (see Chapter 3).

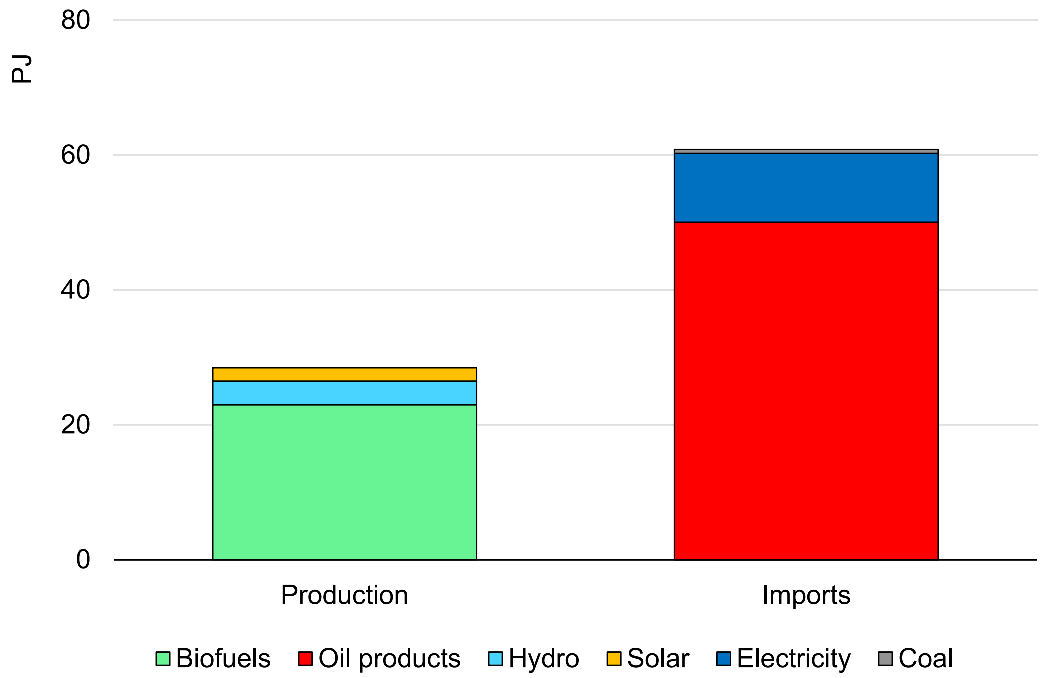
The Prosperity Plan also considers how Namibia could leverage the significant inflow of foreign investment to transform the country into a leader in the production of renewable hydrogen and ammonia. In pursuit of this vision, Namibia approved its Green Hydrogen and Derivatives Strategy in November 2022. This strategy lays out the country's ambitions to harness its world-class renewable resources to achieve its sustainable development and industrialisation goals. By producing renewable hydrogen at scale, Namibia aims to contribute to global decarbonisation efforts while also creating a potential source of funding that could accelerate both national and global objectives. This aligns with the country's second update to its Nationally Determined Contribution, submitted in 2023, which reaffirms Namibia's commitment to a climate-resilient and low-emission development path. In 2024, the government prepared a blueprint for Namibia's green industrialisation. This was followed by a study on the localisation of green industries in the country, which assesses the challenges and opportunities linked to renewable hydrogen and value addition in the mining sector. This study also highlights Namibia's commitment to anchoring sustainable development on energy-related industries. It also addresses the challenges that must be overcome to seize those opportunities, such as attracting a diverse range of industrial projects and ensuring they lead to final investment decisions.

Chapter 2. Overview of Namibia's energy system

Energy supply and demand

In 2021, Namibia's total net energy supply was around 80 petajoules (PJ). Domestic energy production contributed almost 30 PJ, with bioenergy accounting for 76%,[1] hydropower 19% and solar PV about 5%. Energy imports included 50 PJ of oil, 0.5 PJ of coal, and 10 PJ of electricity, mainly from the South African national power utility (ESKOM) and, to a lesser extent, the Southern Africa Power Pool (SAPP).

Figure 2.1 Overview of energy production and supply in Namibia, 2021



Note: Total production and imports accounted for 89.2 PJ, while total net energy supply was 80.5 PJ, after adjusting for energy exports and energy consumed by aircraft on international routes. Biofuels are primary solid biofuels, including traditional use of biofuels.
Source: IEA (2024), World Energy Balances.

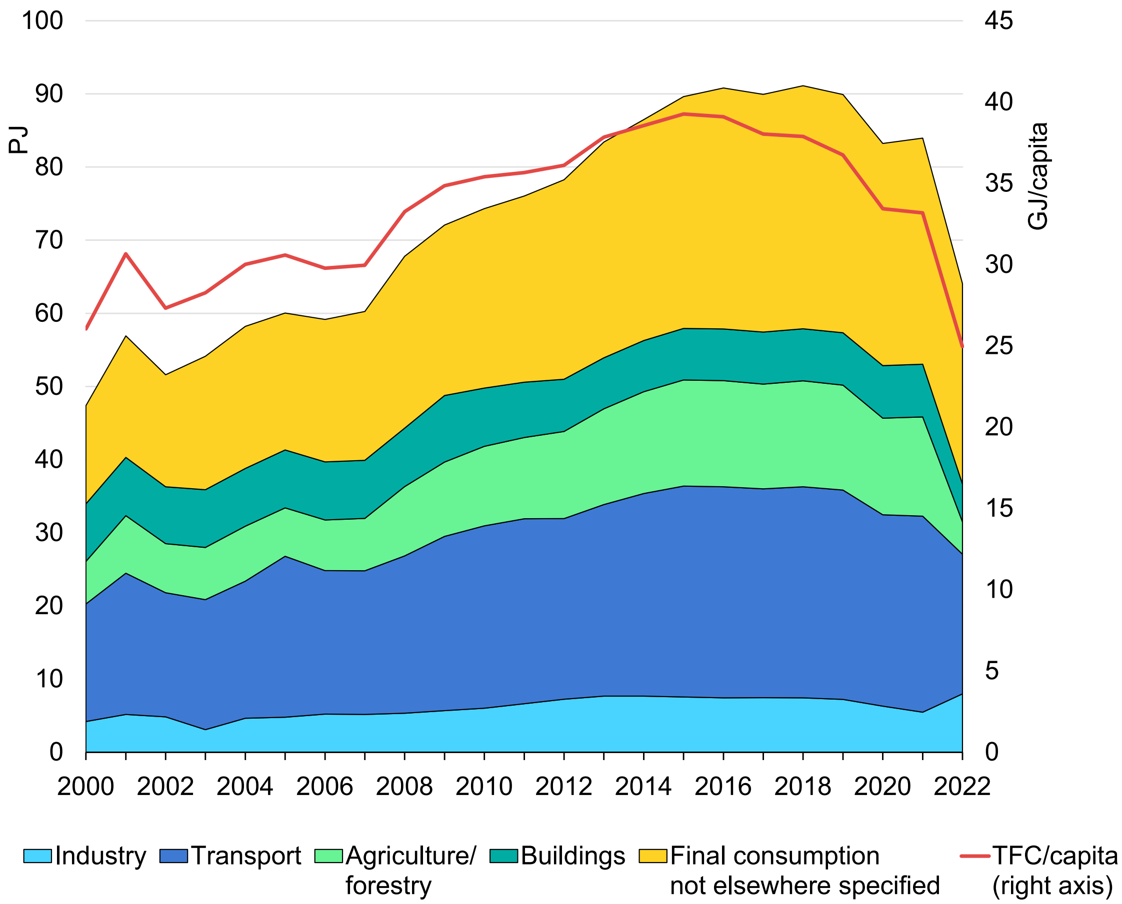
Namibia recently started diversifying its sources of imported power, engaging with utilities in Botswana, Zambia, Zimbabwe, the Democratic Republic of Congo (DRC) and Mozambique. But over the long term, Namibia's government and the Namibia

[1] The country produced approximately 22 PJ of primary solid biofuels, of which only 16 PJ went to energy supply.

Power Corporation (NamPower) aim to become energy self-sufficient, expand electricity access to the entire population (see access section below) and ultimately become a net exporter of power by developing new domestic generation capacity.

Total final energy consumption in 2022 was 60 PJ, or close to 28 gigajoules (GJ) per capita (Figure 2.2). Transport accounted for 30% of total final consumption, followed by industry (12%), agriculture and forestry (8%), and residential buildings (7%). The majority of total final consumption (43%) is attributed to energy and non-energy uses in other unspecified sectors. Namibia's energy consumption has increased by roughly 40% since 2000, a trend also reflected in the per-capita consumption. However, both figures remain very low by international standards, with Namibians consuming roughly half of the energy per capita compared to the world average. Nevertheless, final consumption per capita exceeds the average of 16 GJ for sub-Saharan Africa (excluding South Africa).

Figure 2.2 Namibia´s total final energy consumption by sector and per capita, 2000-2022



Source: IEA (2024), World Energy Balances.

Box 2.1 Namibia's oil and natural gas developments

The Namibian coast regions hold abundant oil and gas reserves. While initial discoveries were made 50 years ago, exploration activity has accelerated in recent years, positioning Namibia at the centre of an oil and gas exploration boom. To date, the country has four offshore and four onshore basins with estimated reserves of 21 billion barrels of oil and 2.2 trillion cubic feet of natural gas and around 24 exploration wells drilled in them today.

Namibia's first exploratory programme for gas started in the 1970s, following the discovery of the Kudu offshore gas field with proven reserves of around 1.3 trillion cubic feet. After encountering multiple challenges due to technical complexities, the Kudu Gas Project is now moving forward. It is being developed by BW Energy Ltd and the National Petroleum Corporation of Namibia (NAMCOR), with a final investment decision expected in 2025. Gas extracted from the Kudu field would be transported via a 170 km pipeline to an 885 MW combined-cycle gas power station set to be built near Oranjemund, in the south. NamPower could be a potential strategic off-taker for the electricity generated. Roughly half of the power generated would be used to cover domestic demand, while the remainder would be exported through power purchase agreements (PPAs) to Zambia and South Africa.

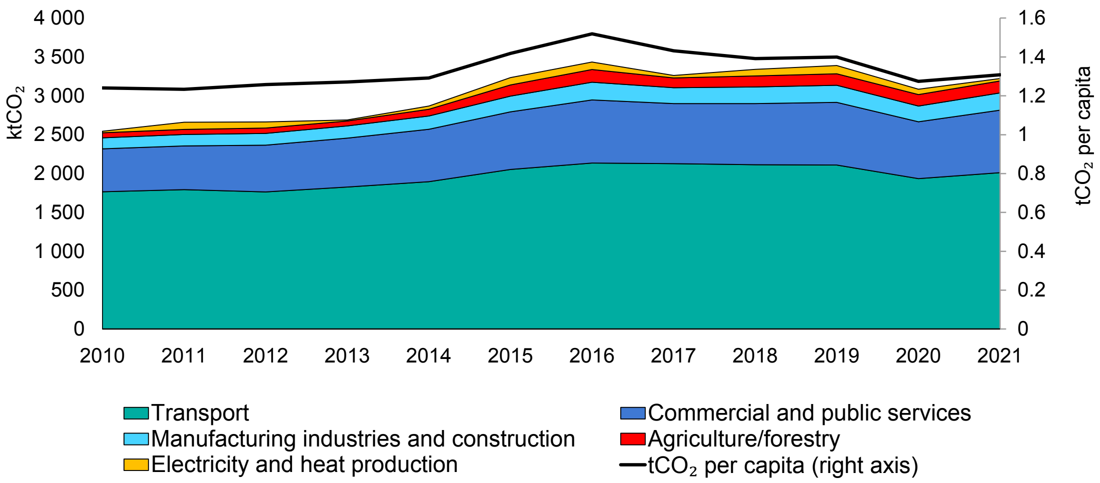
For oil, several new fields have recently been discovered by Galp as well as oil supermajors, namely TotalEnergies, Shell and Galp, while others are actively exploring (i.e., Chevron and ExxonMobil). TotalEnergies and Shell have estimated discoveries along the Namibian coast amounting to 2.6 billion barrels, and although production is still some years away, efforts to develop Namibia's resources are already underway. The latest exploration, of the Mopane field, was conducted by the Portuguese company Galp Energia in April 2024. This field is located in the Orange Basin, where most of Namibia's oil and gas discoveries have been made, with ''in place'' estimates for 10 billion barrels of oil.

Africa's industrialisation relies in part on expanding natural gas use. As seen in other African countries with large natural gas projects, such as Mozambique and Senegal, these developments could play a significant role in boosting Namibia's growth. Not only could they help the country meet its own growing energy demand – through increased electricity access and clean cooking via liquified petroleum gas (LPG) – but they could also increase national revenues. That said, near-term market opportunities must be weighed alongside the uncertain demand outlook, particularly if global efforts to reduce fossil fuel consumption succeed in achieving net zero emissions by mid-century. If Namibia is to successfully leverage its nascent hydrocarbons sector, careful planning will be essential – not just for the investments in resource extraction, but also for managing the potential revenue windfall from such sales.

CO_2 emissions from the energy sector

In 2021, Namibia's total energy-related CO_2 emissions were around 3.3 Mt (Figure 2.3), or roughly 1.3 t CO_2 per capita. By sector, transport accounted for roughly 60% of Namibia's total CO_2 emissions in 2021, with approx. one-fourth of emissions attributable to commercial and public services. Between 2010 and 2021, overall emissions increased by approximately 45%.

Figure 2.3 CO_2 emissions from fuel combustion in Namibia by sector, 2000-2021



Source: IEA (2024), World Energy Balances.

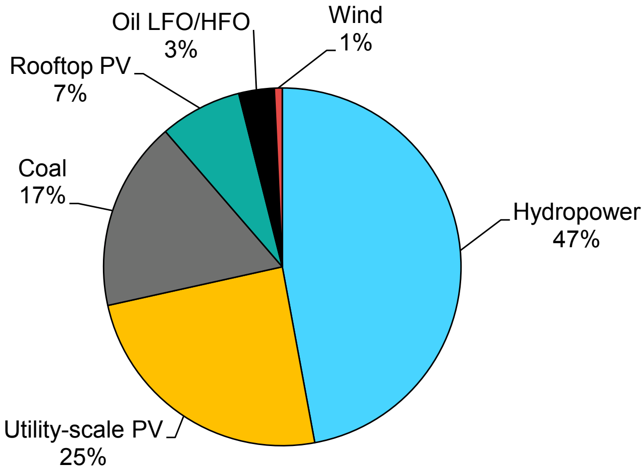
Namibia's 2030 climate policy goals include a target to reduce greenhouse gas (GHG) emissions by 91% compared to projected emissions if no action is taken (known as "business-as-usual"). These targets are included in Namibia's updated 2021 Nationally Determined Contributions (NDCs) under the Paris Agreement of the United Nations Framework Convention on Climate Change (UNFCCC).

Namibia's power sector

Electricity system overview

By the end of 2022, Namibia had 750 MW of installed generation capacity. The largest source of capacity was hydropower (347 MW), followed by utility-scale solar PV (171 MW), coal (120 MW), light/heavy fuel oil (23 MW), rooftop solar PV (52 MW) and wind (5 MW) (see Figure 2.4). Namibia Power Corporation (NamPower), the national electric power utility company, is responsible for the generation, transmission and some of the distribution of electricity (regional electricity distributors are the main entities distributing power). NamPower owns 70% of the country's generation capacity, with the remainder operated by independent power producers.

Figure 2.4 Installed domestic electricity capacity in Namibia by source, 2022



Notes: LFO/HFO: light fuel oil/heavy fuel oil.
Source: IEA (2024), World Energy Balances.

Namibia's electricity sector operates in a modified single buyer (MSB) market, allowing independent power producers (IPPs) and consumers to enter power purchase agreements (PPAs), with additional regulations for customers not connected to the grid. Enacted in 2019, the MSB was initially only available to NamPower transmission customers, before opening to additional customers in 2021. Customers with a peak demand of 1 mega-volt ampere (MVA) and above are eligible for the MSB and can source up to 30% of their demand from a supplier (generator).[2] NamPower remains the system and market operator, as well as the supplier of last resort. Customers who opt to purchase power from an alternate supplier can still purchase reliability and balancing services from NamPower. In addition, the NamPower tariff was unbundled to enable certain services such as wheeling to be charged separately, and to ensure that customers who generate their own electricity (known as "captive generation") still contribute to the maintenance of the grid.

To improve electricity security and lower costs to the consumer, the government has an ambition to have 80% of its power from domestic sources by 2028, as outlined in the National Integrated Resource Plan. To achieve this, NamPower aims to deploy 170 MW of new generation from renewable sources. The MSB

[2] The demand threshold and quantity are both applicable to Phase 1a of the MSB. In Phase 1b and 2, the Electricity Control Board (ECB) can change both customer eligibility and quantity.

model also allows for up to 30% of certain types of consumer demand to be met by third parties, with some capacity currently being developed outside of government-run procurement programmes. (At least one wind power project has signed a PPA with NamPower).

Prior to the introduction of the MSB structure, NamPower sourced generation from independent producers through REFIT, a feed-in tariff programme that was introduced in 2015. The programme added 70 MW of new generation derived from solar PV and wind power. As a follow-up to REFIT, the government has held tenders for additional solar PV and wind capacity. The tender programme, which began in 2018 as part of NamPower's 2019-2023 Corporate and Strategic Business Plan, has since procured 20 MW of solar PV and 40 MW of wind power. Final auction base prices were 65% and 17.5% lower than those seen in the REFIT programme for solar PV and wind, respectively.

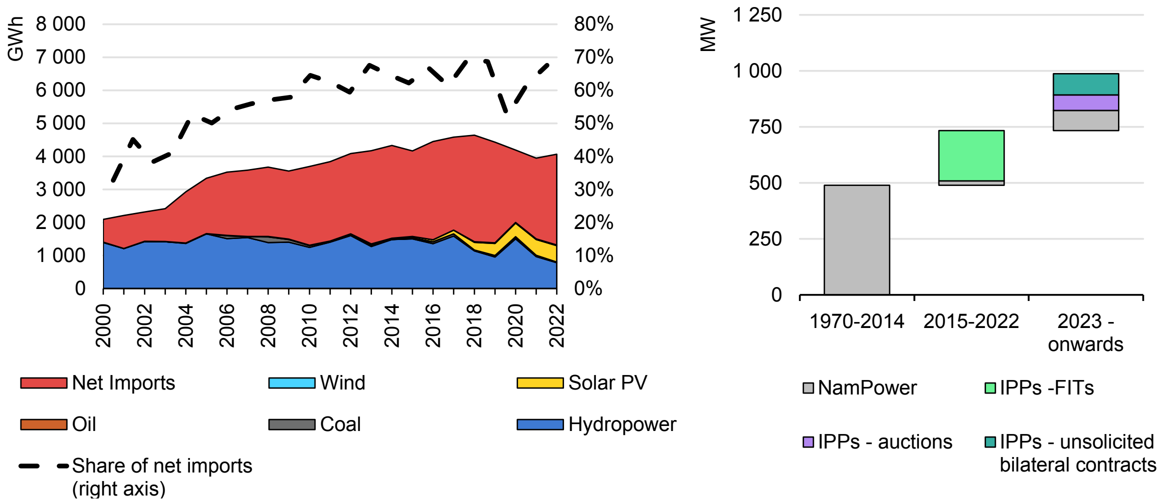
The latest Integrated Resource Plan estimates the levelised cost of electricity (LCOE) generation from solar PV in Namibia to be USD 43/MWh, while for wind power it is estimated at USD 63/MWh. Solar PV procurement elsewhere in the region aligns well with these estimates. For example, Zambia's GET FiT programme (2019) resulted in 120 MW of solar PV with a weighted average price of USD 44/MWh. South Africa's six renewables auction in 2022 awarded 860 MW of solar PV with a final average price of USD 30/kWh.[3] Given the resource potential and competitive costs, renewables could provide an additional, cost-effective source of domestic supply.

Electricity security concerns

Namibia today is among the African countries with the highest dependence on imported electricity. The country has imported electricity to meet power demand since the 1990s but imports still amounted to less than 40% of the country's needs. Since 2004, domestic demand began to outpace the ability to build new generating capacity and reliance on imports began to exceed 50% reaching 60-70% in recent years.

[3] Using the average exchange rate for 2022 of 1 USD = 16.3742 NAD (https://www.exchangerates.org.uk/USD-ZAR-spot-exchange-rates-history-2022.html).

Figure 2.5 Net imports as a share of Namibia's total power demand (2000-2022) and domestic electricity generation, by source (1970-2023)



Notes: IPPs = independent power producers; FITs = feed-in tariffs.
Source: IEA (2024), World Energy Balances (last accessed on 26 September 2024).

In 2021, Namibia imported more than 2 800 GWh of electricity (i.e. 62% of total power demand), the largest amount in sub-Saharan Africa after South Africa and Mozambique. Sources of imported power have fluctuated due to market conditions and infrastructure. For example, power imported from South Africa declined in 2023.

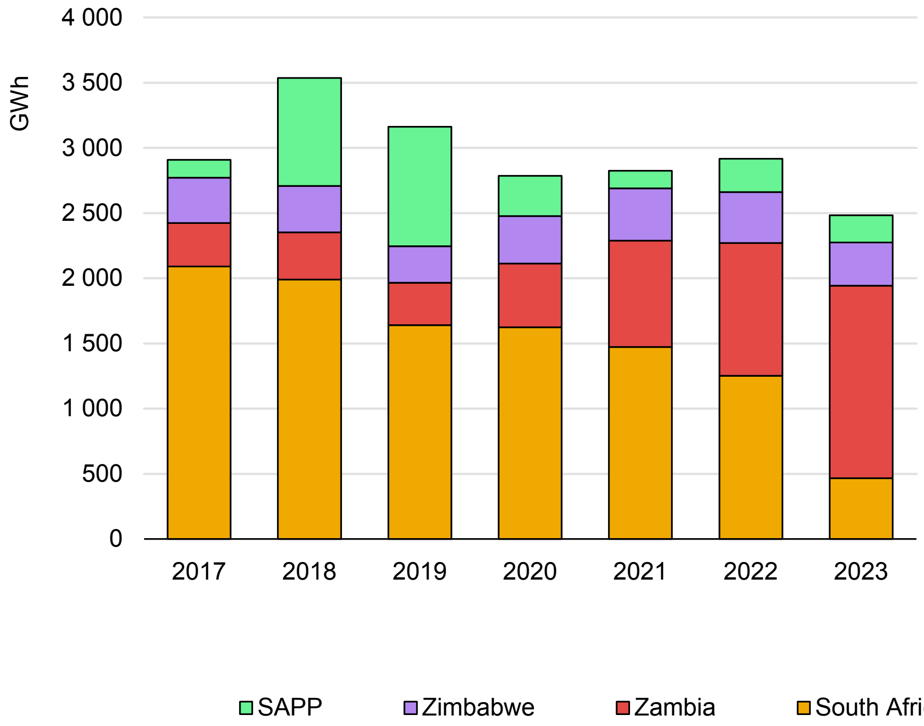
In recent years, Namibia's electricity system has experienced significant fluctuations. In 2022, generation from the Ruacana hydropower station dropped by 20% year-on-year to 781 GWh, its lowest level since 1997. The main reason for this was lower precipitation levels in the Cunene River catchment area in southern Angola, which feeds into the Ruacana power station. Another reason was water infrastructure development upstream in Angola. As a result, the utility had to increase electricity imports by 300 GWh to meet demand, through bilateral agreements with neighbouring countries and the Southern Africa Power Pool.

In addition, Namibia's expenditures on purchased power to meet customer demand increased by 25% from USD 4 billion in 2019 to USD 5 billion in 2023, due to the rising cost of electricity imports. Spending has more than doubled since 2019, from USD 800 million to over USD 1.8 billion in 2023 – despite a decline in the number of GWh imported over the period.

The increase can be attributed to two main factors. First, the Namibian dollar (NAD) has depreciated against the US dollar, which is the currency used for pricing power contracts. More than 80% of these imports were made through bilateral contracts with four countries, all of which were denominated in USD

(Figure 2.6). While imports decreased from 3 042 GWh in 2019 to 2 750 GWh in 2023, the US dollar appreciated by almost 20% over the same period, driving up expenditures for the utility in local currency. The second factor was a shift in imports from South Africa, where prices were lower, to Zambia, where prices are higher. In 2021, the TransCaprivi Interconnector was commissioned, increasing imports from Zambia and Zimbabwe.

Figure 2.6 Imported power and agreement capacity in Namibia, 2023



Notes: SAPP = South African Power Pool.
Source: IEA analysis based on NamPower Integrated Annual Reports: 2023, 2022, 2021, 2020, 2019 and 2018.

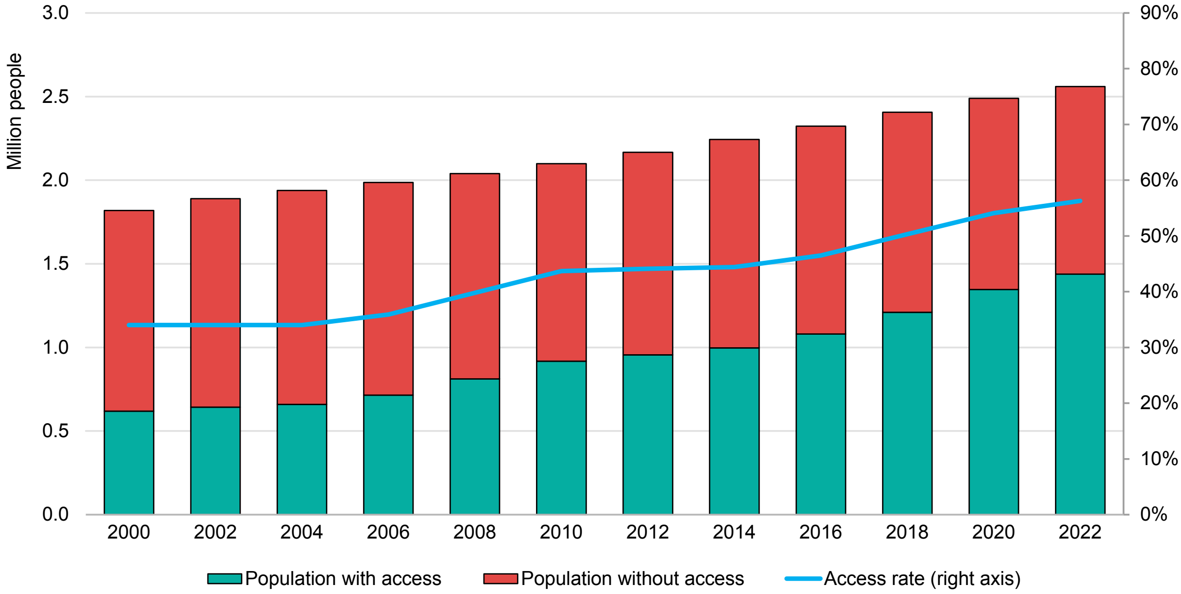
The reliance on imported electricity has implications for electricity security and affordability for consumers. Unlike most utilities in sub-Saharan Africa, NamPower has cost-reflective rates for all market segments, resulting in the highest electricity prices in southern Africa. Passing on the rising import costs to consumers has resulted in a 30% jump in end-user prices in Namibian dollar terms, from NAD 130 cents/kWh in 2016 (USD 0.088 cents/kWh)[4] to NAD 170 cents/kWh in 2022 (USD 0.104 cents/kWh).[5]

[4] Using the average exchange rate for 2016 of 1 USD = 14.70 NAD (https://www.exchangerates.org.uk/USD-NAD-spot-exchange-rates-history-2016.html).
[5] Using the average exchange rate for 2022 of 1 USD = 16.3 NAD (https://www.exchangerates.org.uk/USD-NAD-spot-exchange-rates-history-2016.html).

Electricity access

In 2023, half of Namibia's population had access to electricity through a grid connection, with another 5% to 6% supplied via off-grid, mostly solar PV-based systems. This is a significant improvement from 2000, when only one-third had access, thanks largely to a combination of government initiatives and relatively slow rates of population growth – but still means that close to 45% of Namibians live without electricity. Though short of the United Nations' Sustainable Development Goal (SDG) 7.1 – which targets universal access to secure, affordable, reliable, sustainable and modern energy – Namibians' access to power remains above the sub-Saharan African average (49% in 2023, excluding South Africa). But the dual impact of the Covid-19 pandemic and price surges triggered by the 2021 global energy crisis threaten to stall this momentum.

Figure 2.7 Trends in electricity access in Namibia, 2000-2023



Note: This analysis is based on the IEA official energy access database. Total population may differ from the results of the Namibia's 2023 Population and Housing Census.

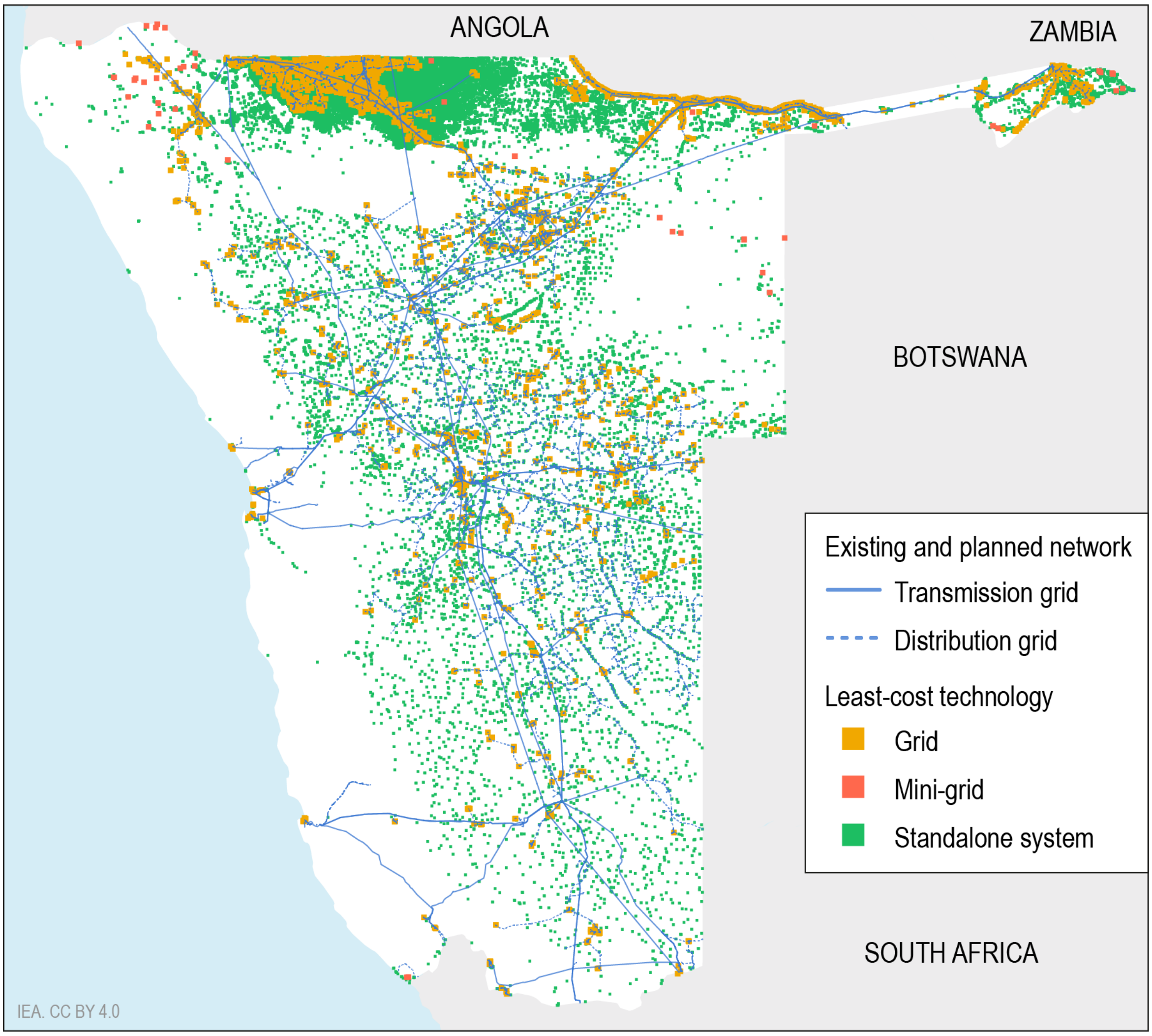
Geography has a significant impact on access to electricity. People living in urban areas have easier access to the national grid than those living in remote areas. Despite being in line with a broader access trends for sub-Saharan Africa, Namibia's geography poses specific challenges to the electrification of rural areas. Its vast territory, combined with a low-density, highly dispersed population pose challenges to extending national grid to remote areas in a cost-effective way.

Distributed solar PV systems play an essential role in reaching remote households and they are already providing power to around 5% of Namibians. Access to electricity through mini-grids remains negligible, with less than 10 000 people currently served by these solutions. Yet mini-grids offer significant potential for powering households and economic activity, especially when renewable resources such as solar and wind are coupled with battery storage technologies.

Namibia's National Electrification Policy, which remains under development, targets universal access to electricity by 2040. According to the IEA's Sustainable Africa Scenario (which sees Africa achieving universal electricity access by 2030 in line with SDG7), as many as 68% of Namibians could gain cost-effective access via a grid connection, with the rest (32%) connecting off-grid (Figure 2.8). Although small solar off-grid systems only provide basic access, they can be an efficient and cost-effective solution for reaching a large swath of the rural population – at least until access to larger Solar Home Systems (SHS), the national grid or mini-grids can be established.

With the support of development partners and participation from the private sector, Namibia would be able to provide first basic access for all by 2030 and full access by 2040, in line with current targets. This analysis focuses on the cost and manner of providing access to electricity for all Namibian citizens, particularly in the residential sector. However, for certain energy-intensive productive activities located far from the grid, there is significant potential for solar PV-based mini-grids combined with battery storage and solar mesh grid – and possibly a backup diesel generator for added reliability.

Figure 2.8 Namibia's least-cost analysis for universal power access by 2030



While NamPower is responsible for supplying electricity through grid expansion, the Ministry of Mines and Energy has focused on electrification through off-grid solutions. The 2007 Off-Grid Energy Master Plan was set up to improve affordable access to renewable energy services and accelerate market development for renewable energy technologies by addressing barriers such as institutional, information, human capacity, financial, technical and awareness-related challenges.

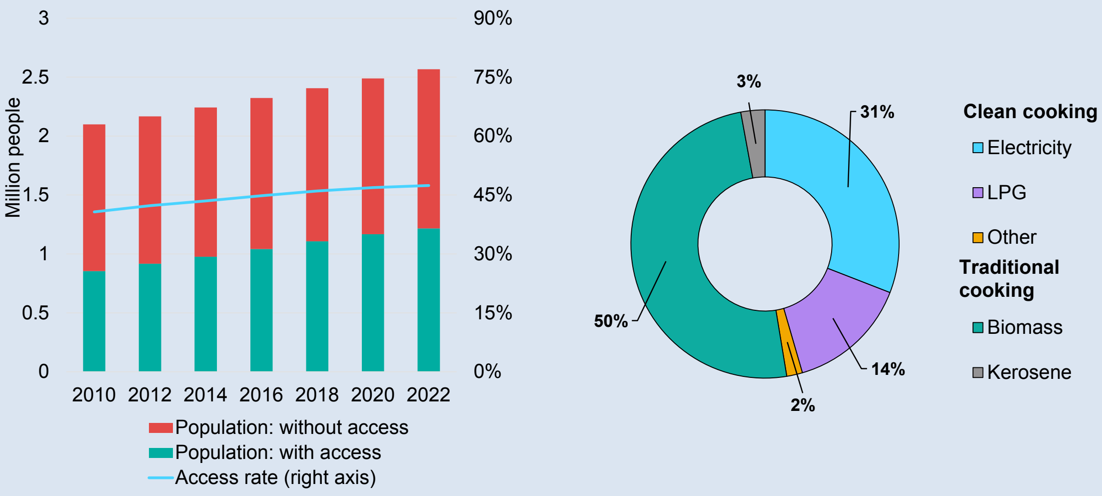
In 2010, the government adopted the Rural Electricity Distribution Master Plan, designed to accelerate electrification efforts in rural areas – where about 51% of the population lives – through both grid and off-grid solutions. This initiative particularly targets critical economic infrastructure such as schools, health facilities, government institutions and businesses. Given the challenges to providing affordable access to electricity to populations in peri-urban and rural areas, the Ministry of Mines and Energy and the Electricity Control Board – Namibia's power regulator – have created mechanisms to advance household electrification.

In 2019, the Ministry of Mines and Energy submitted a final draft of the Off-Grid Electrification Policy, which now awaits parliamentary approval. The Electricity Control Board is currently working on a draft Off-Grid Electrification Regulation, which could become Namibia's first off-grid framework document. The draft regulation aims to establish a flexible environment to encourage new off-grid projects that provide affordable and sustainable electricity access. Given the geographic challenges to rural electrification, these types of projects could help to expand access beyond urban areas.

Box 2.2 Access to clean cooking and socio-economic implications for Namibians

Today, nearly half (48%) of Namibia's population has access to clean cooking, one of the highest rates in sub-Saharan Africa. However, more than 1.37 million people – three-quarters (74%) of whom live in rural areas – rely entirely on firewood and charcoal to cook their meals. Initiatives to promote clean cooking have proven highly effective, particularly in urban areas. The National Energy Policy (2017) focused on the need to reduce reliance on biomass and promoted the use of more sustainable energy sources, such as LPG and electricity. Among its 2023 Nationally Determined Contribution (NDCs), Namibia includes clean cooking as a key lever for reducing GHG emissions.

Trends in clean cooking access 2010-2022 (left) and share of access by fuel in 2022 (right)



Note: This analysis is based on the IEA official energy access database. Total population might differ from the results of the Namibia's 2023 Population and Housing Census.

Source: IEA based on data from the World Health Organisation household database.

With just over 30% of its population preparing its meals with electricity in 2022, Namibia stands out for its high penetration rate. This share has been consistent for decades, although it has dipped slightly from a high of 33% in 2017. Liquified petroleum gas (LPG) is the second-most preferred solution, with 15% of Namibians using LPG for cooking in 2022. Use of LPG for cooking has almost doubled between 2010 and 2022.

As in most African countries, much of the population relies on traditional biomass for cooking, typically firewood or charcoal. In densely populated areas, where people tend to cook indoors and collect firewood, reliance on polluting fuels has important impacts on health, gender and economic development, including the effects of deforestation. Such impacts will differ in a country like Namibia, which is sparsely populated and where people can more easily cook outdoors, but still disproportionately affects women and children, particularly young girls. In Namibia, girls spend 1-2 hours per day collecting firewood, limiting their opportunities for education, employment and participation in community activities. Girls may forego education to help with these tasks, perpetuating cycles of poverty and limiting future economic opportunities.

Over the past two decades, Namibia has successfully been reducing its reliance on traditional biomass for clean cooking, mostly by switching to LPG. With the use of traditional biomass, it has adopted more sustainable practices that consider the country's unique conditions and challenging climate, where water is a scarce resource. Approximately 45 million hectares of Namibia's land are prone to the encroachment of an invasive bush species, which competes with the population and livestock for fresh water and grazing areas. The sustainable harvesting of biomass from the invasive bush to produce charcoal has been adopted as a strategy to tackle the threat of bush encroachment while also generating additional income for farmers.

Continued efforts are required to improve access to clean cooking, including the promotion of more efficient cookstoves, especially in remote communities. Expanding access through LPG and electricity could considerably reduce the number of people without access to clean cooking. Nonetheless, challenges remain, including high costs, insufficient infrastructure and cultural preferences for traditional cooking methods. In the context of Namibia, overcoming such obstacles is critical. Not only would it enhance access to clean cooking, but it could also empower women and girls by freeing up time for education and economic activities, thereby fostering broader socio-economic development.

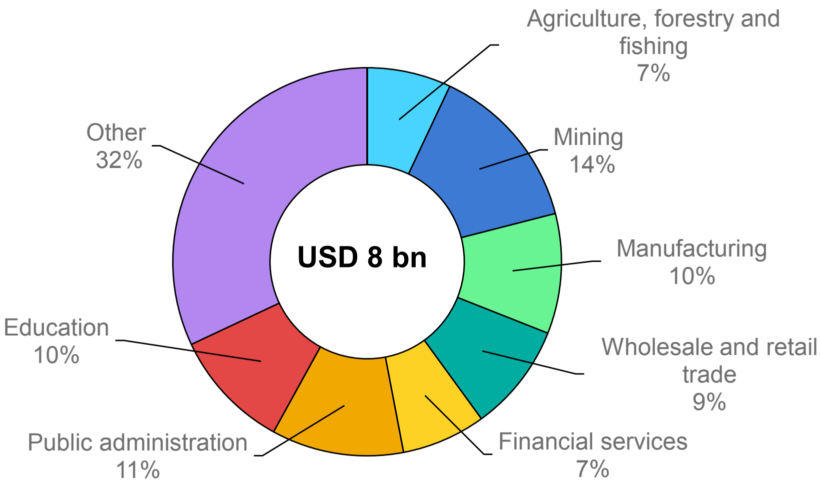
Note: For additional information on the topic see IEA (2023), A Vision for Clean Cooking for All.

Chapter 3. Opportunities for renewables in mining

Mining sector

Namibia's mining industry is diverse and plays the largest role in the country's export-driven economy. In 2023, mining accounted for over 14% of GDP or more than USD 1 billion (Figure 3.1). Over the past 10 years, mining's share of GDP has grown by almost 30%. Mined and refined minerals and metals are also Namibia's biggest exports, accounting for more than 50% of its foreign exchange earnings.

Figure 3.1 Activity as a share of Namibia's GDP, 2023



Source: IEA analysis based on data from Namibia Statistics Agency.

Namibia is the third-largest producer of uranium in the world, representing more than 11% of global output. Over the past decade, domestic production grew by 24% and reached over 7 million tonnes of refined uranium oxide (or yellowcake), which is exported to countries that are signatories to the Nuclear Non-Proliferation Treaty. Growth is anticipated to continue amid increasing demand for uranium oxide and as a result of the recent US ban on uranium imports from the Russian Federation (hereafter, "Russia").

Namibia is the sixth-largest producer of diamonds, accounting for almost 3% of global output. Over the past decade, domestic diamond production grew by 21% and reached 2.3 million carats – of which 80% was mined offshore due to rich alluvial deposits. Namibia also mines and processes other minerals – including copper, gold, silver, lead and zinc – many of which as by-products. In addition to mining, Namibia also refines copper and zinc – in fact, it is home to Africa's largest integrated zinc plant and its only zinc refinery. Although Namibia's production of copper, silver, lead and zinc has been declining over the past ten years, gold mining has jumped by 69%.

Recent exploration has revealed Namibia's significant potential as a source of critical materials used in clean energy technologies. This includes high-grade ores of rare earth elements (REEs) – particularly dysprosium and terbium, two of the most valuable and difficult to substitute REEs used in making permanent magnets for wind turbines and electric vehicle (EV) motors – as well as yttrium, which is used in lighting technologies and as an additive to wind turbines. Ongoing innovations are focused on reducing the use of REEs in permanent magnets or developing new chemistries that eliminate the need for REEs altogether. Namibia also has the potential to produce lithium, cobalt, graphite, manganese and offshore phosphate. All these minerals are used in battery production, while phosphate is also for fertiliser. In addition, Namibia possesses iron ore for steel production.

Driven by efforts to diversify global supply chains of materials critical for clean energy technologies and fuels (e.g. uranium), Namibia has partnered with countries and regions to become a key supplier (Table 3.1). Such partnerships could further benefit Namibia by attracting sustainable capital and securing technology transfer, as well as developing local capacities to mine, process and refine these materials and secure their offtake.

Table 3.1 Namibia's partnerships on materials with other countries/regions

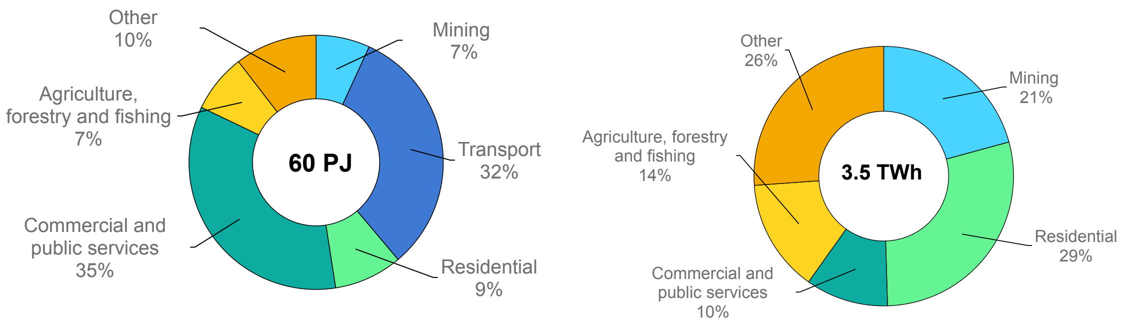
Date	Country/ Region	Details
April 2014	China	The joint venture between the Chinese (through its state-owned company Guangdong Nuclear Power Company Uranium Resources) and the Namibian government to develop and operate Husab Uranium Mine.
Since 2018	China	Strategic partnerships and agreements between the Government of Namibia and Chinese entities (as part of the Forum on China-Africa Cooperation within the Belt and Road initiative) beyond direct investment in uranium mining operations. This includes support for infrastructure development, mining technology transfer, skilled labour training, etc.

September 2019	United States	The Energy Resource Governance Initiative (ERGI), led by the Department of State, aims to share expertise to explore and develop critical minerals industry and advice on management and governance frameworks to help ensure the mining industries are attractive to international investors. Other ERGI members are Argentina, Australia, Botswana, Brazil, the Democratic Republic of the Congo, Namibia, Peru, the Philippines, the Holy See and Zambia.
January 2020	Japan	The joint venture between the Japan Organization for Metals and Energy Security (JOGMEC) and the Canadian company Namibia Critical Metals Inc. to jointly explore, develop, exploit and/or refine mineral produces from a Lofdal Heavy Rare Earth Project.
November 2022	European Union	The Memorandum of Understanding between the European Commission and the Ministry of Mines and Energy to establish a strategic partnership on Sustainable Raw Materials Value Chains and Renewable Hydrogen.
August 2023	Japan	The Ministry of Mines and Energy and JOGMEC agreed in the Joint Statement to formulate the Namibia Rare Earth Industry Master Plan and investigate the possibility of establishing a concentration and separation facility for rare earth elements.
October 2023	European Union	The EU-Namibia 2023-2025 Roadmap details actions to improve the sustainability of the mining industry and further develop processing, refining, recovery and recycling capacities in Namibia and includes aspects of trade and investment.
December 2023	Japan	A Memorandum of Understanding between Namibia's Ministry of Finance and Public Enterprises and the Japan Bank for International Cooperation aims to support the development of environmental preservation projects and business opportunities for Japanese companies, including those related to critical minerals.

Energy use of the mining sector

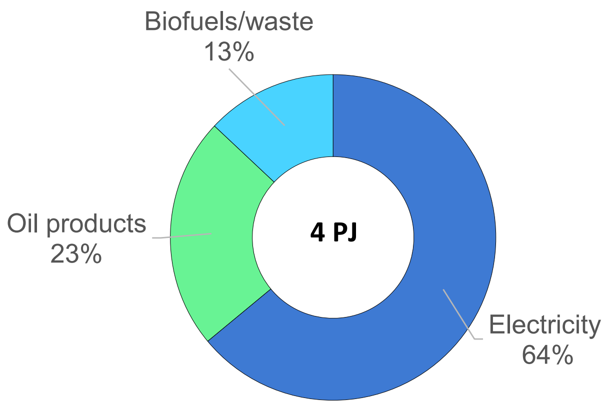
In 2022, the mining sector was responsible for 7% (4 PJ) of Namibia's total final energy consumption and 21% (700 GWh) of total electricity consumption (Figure 3.2). All Namibian land-based mines are connected directly to the transmission grid – mainly via NamPower, but a few are connected to the South African ESKOM grid. Around 70% of national electricity production is sourced from imports from neighbouring countries. The generation type (coal or hydropower) of the imported electricity varies by exporting country.

Figure 3.2 Total final energy consumption in Namibia (left) and total electricity consumption (right) by sector, 2022



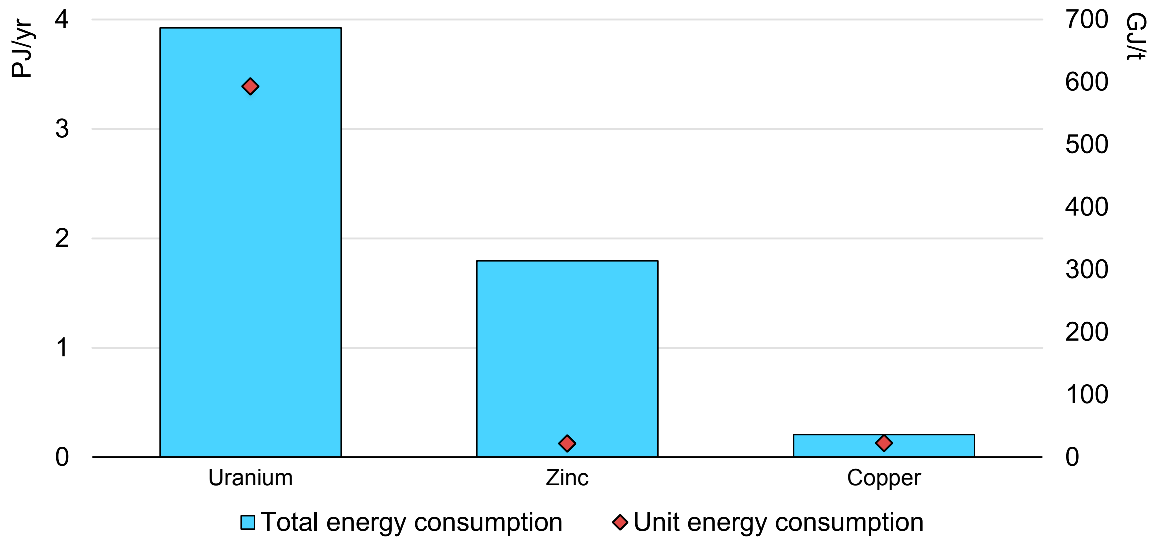
Mines consume energy in the form of electricity and fuels. Electricity is used for comminution (crushing and grinding) and processing of the mined ores, while fuels are used to operate mining equipment such as haul trucks, drills, excavators and loaders. Over the past decade, there has been a growing trend to electrify mining equipment, including in Namibia (see section below on the electrification of mining operations). In 2022, Namibian mines consumed 2.6 PJ (270 GWh) of electricity, 0.9 PJ of fossil fuels and 0.5 PJ of biofuels/waste (Figure 3.3).

Figure 3.3 Share of energy carriers in mining and processing in Namibia, 2022



Energy requirements vary significantly by mine as well as by the type of mineral and grade of the ore (Figure 3.4). Most mines in Namibia are open pits, although some are moving underground or offshore due to depletion. All land-based mines are connected directly to a transmission grid – mainly NamPower, but a few are connected to South African ESKOM.

Figure 3.4 Namibia's total annual and unit energy consumption by selected materials, 2022



Note: Energy consumption includes both mining and processing. A bottom-up analysis is based on the following average energy intensities: uranium 593 GJ/t, zinc 22 GJ/t and copper 23 GJ/t. These are multiplied by the level of production of those materials in 2022. Although diamonds (2000 GJ/kg) and gold (370 GJ/kg) are highly energy-intensive, their annual energy consumption is negligible compared to that of other minerals and metals.

Source: IEA analysis based on data from the Namibia Chamber of Mines, National Statistics Agency of Namibia, S&P Global, GREET 2023 and the International Atomic Energy Agency (IAEA).

Uranium mining and processing is energy-intensive. Almost 600 GJ of energy is required to produce a tonne of uranium oxide. Namibia has both open pit and underground uranium mining, with the latter requiring 20% more energy. Zinc and copper are the least energy-intensive metals to mine and process, requiring about 20 GJ per tonne, partially due to lower process heat requirements.

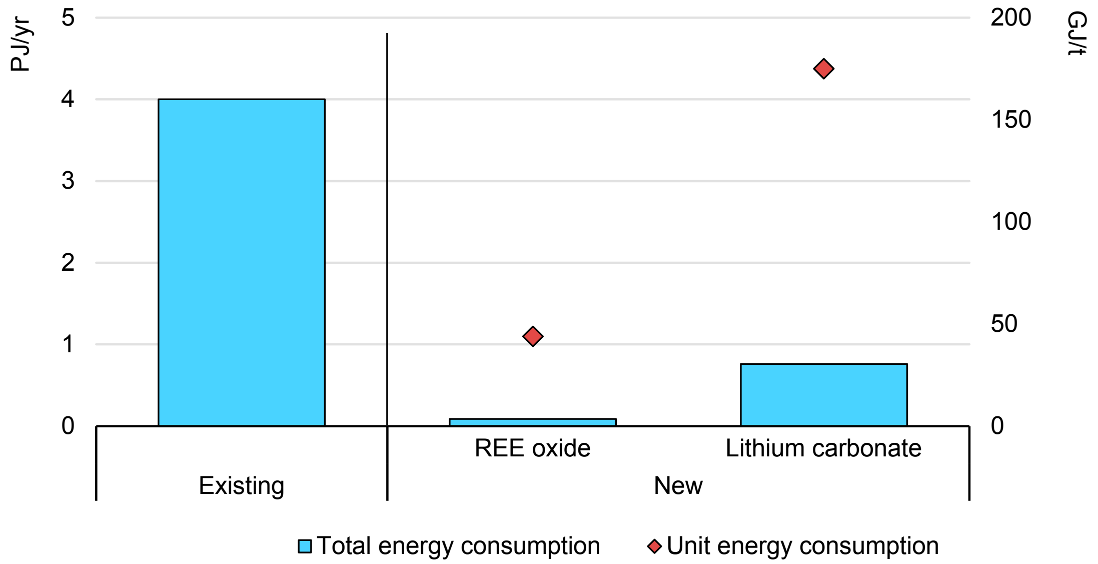
Diamonds are among the most energy-intensive minerals to mine and process, consuming approximately 2 000 GJ of energy per kilogramme. Depleting onshore resources have pushed diamond mining offshore, with currently 80% of the gems being mined in water depths of up to 150 metres. To increase efficiency and decrease fuel consumption, a major joint venture between De Beers Group and the Namibian government purchased mining vessels that suck up gravel from the seabed and sift it in an onboard treatment plant. The gravel is returned to the ocean, while the diamonds are brought ashore, often by helicopter. Such mining techniques raise environmental concerns, however, since they remove part of the seabed together with its habitat, contributing to its degradation and harming marine species and fisheries. Gold is also energy-intensive and requires approximately 370 GJ of energy per kilogramme. As miners move deeper underground in search of higher-grade ore, the energy intensity of this activity may increase further.

From raw materials to value-added commodities

Namibia aims to develop a downstream industry to capture a larger share of the mineral value chain and bring wider socio-economic benefits. Exporting processed and refined metals and minerals instead of unprocessed ores offers the advantage of higher and more stable prices. Namibia has already begun processing and refining several minerals and metals and can partly build on that experience. This includes refining zinc and copper and producing copper cathodes, uranium oxide from uranium ore, gold ingots, as well as cutting and polishing diamonds.

To encourage the development of mineral processing, Namibia introduced an export ban in 2023 on certain unprocessed critical materials such as lithium, graphite, cobalt, manganese and rare earth elements. To successfully implement its strategy and process all the minerals and metals it mines, however, Namibia will need to make significant investments in infrastructure, including water and transport. It must build up local skills and capacities, supported by enabling policies and laws. Critically, it will also need to invest in additional electricity supply, which offers an immense opportunity for Namibia to develop its world-class renewable resources.

Figure 3.5 Total and unit energy consumption related to the mining and processing of rare earth elements and lithium, and total mining industry energy consumption in Namibia



Note: A bottom-up analysis based on the following average energy intensities: REE oxides = 44 GJ/t and lithium carbonate = 175 GJ/t. These are multiplied by the level of potential production of those materials, as indicated in the feasibility studies. New total energy consumption is a sum of the current 4 PJ energy consumption of the mining sector and additional energy consumption from mining and processing of REE oxide and lithium carbonate in 2026, when the production of mining of both REEs and lithium carbonate is due to start.

Source: IEA analysis based on data from GREET (2023), Mines' feasibility study reports, Namibia Chamber of Mines.

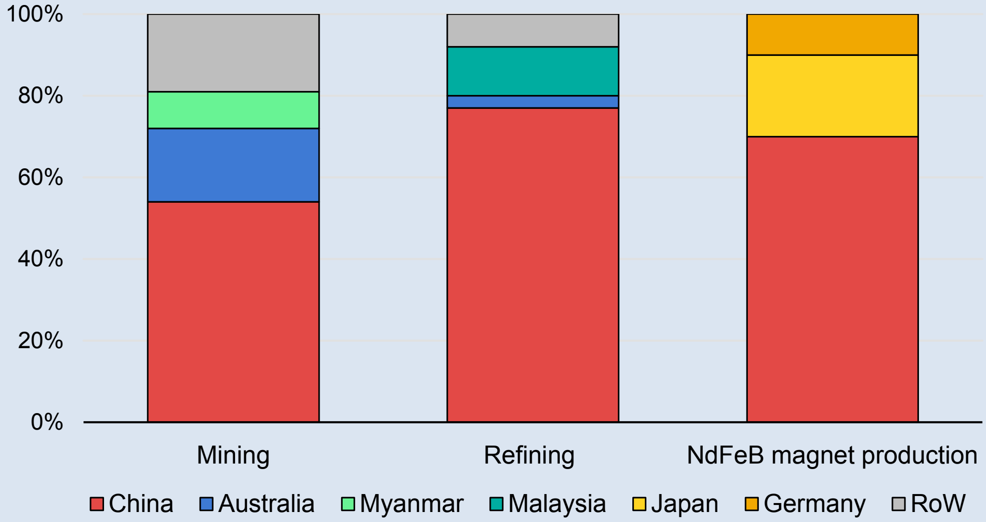
For example, producing rare earth oxide and lithium carbonate in Namibia would require an additional energy demand of 0.85 PJ, equivalent to more than 20% of the mining industry's current energy consumption (4 PJ) and a negligible addition (1.1%) to overall total final energy consumption (Figure 3.5).

Box 3.1 Increasing in-country value addition through rare earth elements beneficiation

Rare earth elements (REEs) are key to producing permanent magnets for wind turbines and EV motors. The mining and beneficiation of REEs and the production of permanent magnets are among the most concentrated globally. The People's Republic of China (hereafter, "China") dominates the global supply chain due to its large REE deposits and the early adoption of enabling policy frameworks and investments including in developing a downstream industry and imposing various restrictions on foreign investment, export taxes, etc. China mines almost 60% of the world's REEs and processes almost 90% of them. It also produces more than 70% of all NdFeB (neodymium-iron-boron) permanent magnets, which are the most relevant for wind turbines and EV motors due to their high magnetic properties and productivity (see figure below).

Such a high degree of concentration is seen as a significant risk for markets seeking to scale up the production and deployment of wind energy and EVs.

Share of countries mining and refining rare earth elements and producing Neodymium permanent magnets



Note: NdFeB = neodymium-iron-boron. RoW = Rest of the world.

Source: IEA analysis based on data from the IEA and Alliance Organisation.

Namibia could play a strategic role in diversifying the global REE supply chain, as seen by the collaboration and support from Japan and the European Union (Table 3.1). Its three advanced REE projects in northwestern and central Namibia contain high-grade deposits of dysprosium and terbium, difficult to substitute REEs that are used to produce permanent magnets. The projects have also agreed to jointly explore and evaluate the technical potential and viability of developing an REE-separation facility, a project that could help create jobs in Namibia and improve skill sets.

Four drivers for the uptake of renewables in mining and processing

Mining companies cite energy security as a key factor driving the accelerated adoption of renewable energy sources. Namibia currently imports 100% of its fuel and 60-70% of its electricity. Domestically produced electricity comes primarily from hydropower, making it vulnerable to frequent droughts. While renewables can diversify the electricity mix, their success depends on a coordinated effort to expand and upgrade grid infrastructure to enhance both its flexibility and resilience.

Another factor steering companies toward renewables is their ability to serve as a hedge against electricity price volatility. In Namibia, mining cost increases have been primarily driven by the rising price of imported energy. In 2023, the country spent more than USD 1.8 billion (NAD 32 billion at current prices) on imported fossil fuels and electricity, of which more than USD 100 million was spent by the mining industry. Given Namibia's world-class solar and wind resources, a shift toward renewables offers a path to both cheaper and more predictable electricity prices.

Decarbonisation targets for mining operations could help to further accelerate renewables deployment. While Namibia aims to make mineral mining and processing more sustainable, its government has not defined any specific decarbonisation or renewable energy targets. Currently, these are being set by mining companies, which due to their sizeable environmental and carbon footprints, have come under increased scrutiny from governments, consumers and investors. Access to sustainable finance is tied to the level of ambition in these voluntary targets (See Table 3.2 for some examples).

Using renewables to power mining and processing operations would enhance the value of these commodities, thereby boosting their competitiveness in certain export markets. The European Union, for example, has imposed rules[6] on

[6] EU Battery Regulation and Battery Passport, EU Critical Minerals Act, EU Corporate Sustainability Due Diligence Directive.

companies and their final products that are designed to encourage companies to produce cleaner and more sustainable products across their global value chains. (Though as of now, minerals and metals are not included in the EU Carbon Border Adjustment Mechanism.) The World Bank's Climate-Smart Mining initiative and the OECD Due Diligence Guidance for Responsible Supply Chains of Minerals – adopted by the London Metal Exchange – are additional initiatives designed to reinforce sustainable mining practices.

Use of renewables in mining and processing

According to the government's latest National Integrated Resource Plan, the estimated levelised cost of electricity (LCOE) generated from solar PV is USD 43/MWh, and for onshore wind it is USD 63/MWh, both assuming a 10% cost of capital. These figures are significantly lower than the costs for new gas plants (as there are no existing gas plants), which range from USD 131 to USD 265/MWh, and for heavy fuel oil plants, which are around USD 188/MWh.

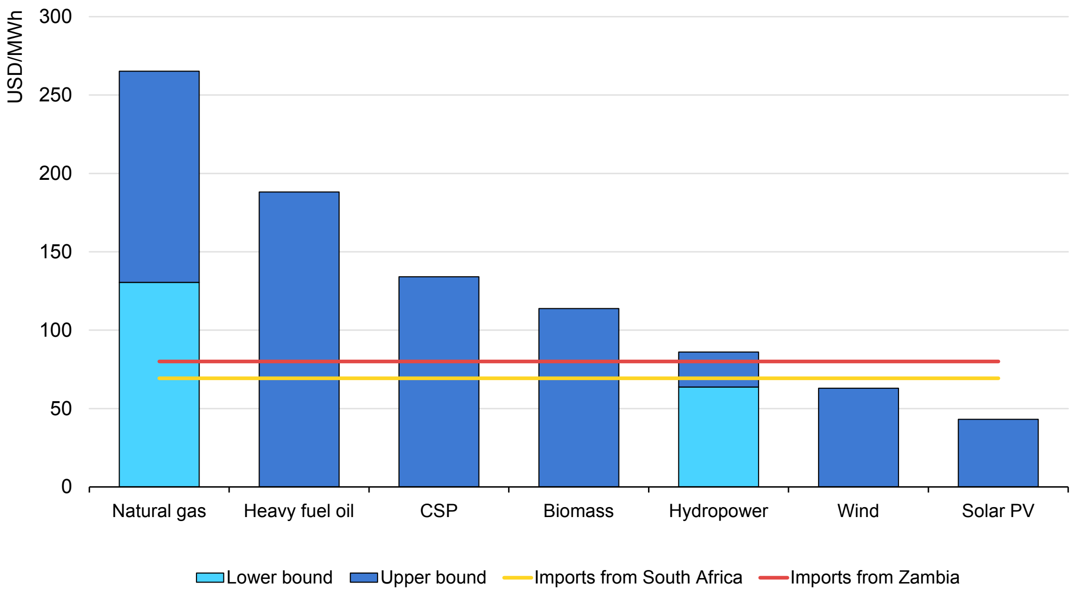
These renewables costs estimates are also below Namibia's contract prices for power imports from South Africa (USD 69/MWh) and Zambia (USD 80/MWh) (see Figure 3.6). While the opportunities presented by cost-competitive renewable energy are promising, there are significant barriers that need to be addressed. The most notable is the high cost of capital, since renewable energy projects require substantial upfront investments.

The cost of capital is driven by several factors, including both actual and perceived risks at the country, project and technology levels. In Namibia, the cost of capital can be significantly higher for utility-scale energy projects than they are in advanced economies or in China. Costs can be even higher for smaller projects that can only access debt from local commercial banks. In its National Integrated Resource Plan, the government assumes a 10% cost of capital. Despite the relatively low technology risk associated with mature and commercially viable wind and solar technologies, and access to some of the world's highest-quality renewable resources, project developers in Namibia still encounter challenges typical of utility-scale projects. These include transmission and land access risks stemming from underinvestment in infrastructure and a shortage of specialised skills, in addition to macroeconomic risks (e.g. high external debt and currency volatility). Although lower than in other parts of the continent, political and regulatory risks (e.g. income inequality, structural unemployment, etc.) can also play a role in project structuring. All these risks require tailored and balanced mitigation strategies that take into account local conditions as well as widely accepted risk allocation principles.

In the context of the mining sector, renewables could be deployed through corporate purchase power agreements (CPPAs),[7] which are bilateral contracts concluded between the electricity producer and the consumer. CPPAs can be physical, where both contracting parties are located in the same grid or bidding area, requiring a direct connection for delivery. They can also be financial in nature, involving parties located in different grids or bidding areas – potentially even in different countries – where location independence is advantageous but not a requirement.

CPPAs offer several advantages to both contracting parties. In some markets, consumers can benefit from electricity prices that are lower than the retail electricity rates. When producing renewable electricity, CPPAs help to decarbonise the offtakers' operations. This makes them attractive for electricity-intensive industries such as mining.

Figure 3.6 Estimated levelised cost of new power generation in Namibia's National Integrated Resource Plan (2020 prices)



Note: CSP = concentrated solar power. The cost of capital is 10% for all technologies. The lower and upper bound for hydropower refers to different locations, while for natural gas it refers to power plant technology (open or combined-cycle),with the World Bank data to project natural gas prices forward to 2030. Import prices for South Africa and Zimbabwe are from the National Integrated Resource Plan (source below) representing the year 2020.

Source: IEA analysis based on data from Namibia, Ministry of Mines and Energy (2022), National Integrated Resource Plan.

[7] PPAs are the general term for power purchase agreements between a producer and a consumer. They vary mostly by the type of producer (a utility or IPP) and how the contract is awarded (competitively through a tender or bilaterally negotiated). For this report, corporate PPAs (CPPAs) are defined as a PPA between an IPP and the industrial consumer (either competitively awarded or bilaterally negotiated). This definition is in line with the policy and market definitions outlined in Renewables 2023.

Recently awarded bid prices for utility-scale solar and wind power from NamPower's auctions suggest that CPPAs could lead to lower electricity costs for mining companies in Namibia. Final auction prices were USD 26/MWh for solar PV in 2020 and USD 47/MWh for wind in 2022, representing reductions of nearly 80% and 65%, respectively, compared to the current retail price of USD 135/MWh that mines pay for electricity. These auction prices also need to reflect grid connection fees, which can be substantial. At least five solar PV projects, totalling 40 MW, are currently under development and contracted by the mining sites (see Table 3.2).

In addition to their economic attractiveness, CPPAs also give consumers long-term visibility over electricity prices, ensuring more stable and predictable energy costs. They also serve as a hedge against price volatility. Moreover, financial CPPAs enable consumers to access high-quality renewable electricity from distant locations through a process known as "wheeling" which allows both parties to use the transmission network.

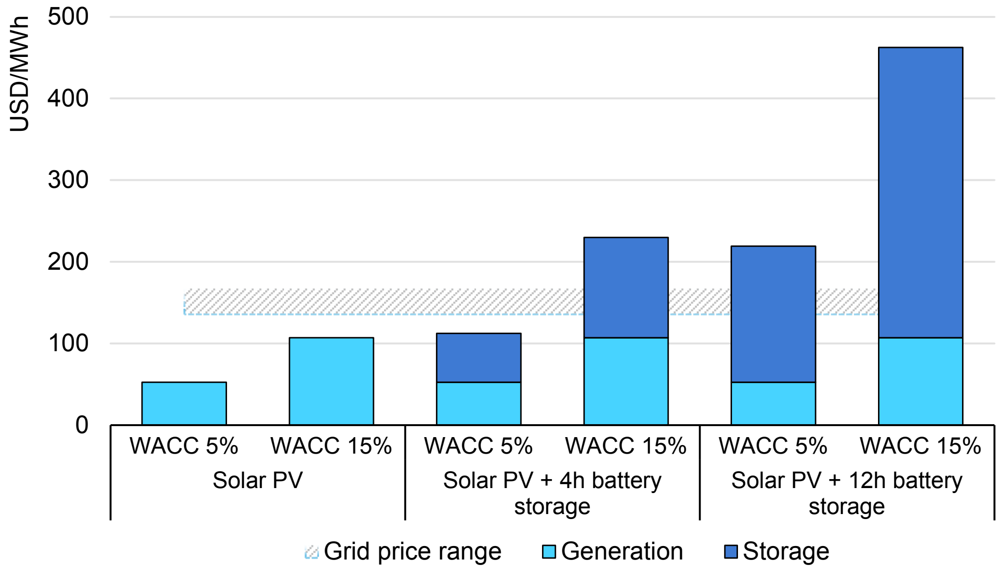
One potential challenge for CPPAs is that, under Namibia's modified single buyer (MSB) framework (see Chapter 2), only up to 30% of a customer's demand can be met by a third party. This limitation could impact the business case for both renewable developers and mines. Relaxing this requirement and allowing independent power producers (IPPs) to deliver more than 30% of power to Namibian mines (and other individual consumers) could attract more IPPs and speed the deployment of renewables. Such an approach might allow IPPs to focus on deploying renewables while NamPower focuses on strengthening the national grid through the construction of new transmission lines and energy storage systems.

Table 3.2 Selected renewable projects among Namibia's mines and smelters

Mine	Mineral	Plant	Operational	Comments
Otjikoto	Gold	10 MW solar plant	End of 2024	B2Gold aims to reduce GHG emissions by 30% by 2030 and become net-zero by 2050. The plant will be connected to the NamPower grid and generate more than 26 GWh of electricity per year. The plant is located 300 km from the mine. Once operational, it will "wheel" the electricity to the mine and then allocate it under the MSB to the B2Gold mine.
Trekkopje	Uranium	5 MW solar plant	End of 2024	Orano aims to reduce its GHG emissions by 15% by 2025. In pursuit of this target, it signed a 10-year CPPA to build a solar plant at its Trekkopje site to supply a desalination plant as part of its care and maintenance activities. The plant supplies desalinated water to the uranium mine and NamWater for further distribution to the city of Swakopmund, the nearby mines, and other areas of the Erongo Region.
Rossing	Uranium	15 MW AC solar plant	End of 2024	Rossing Uranium has called for bids from IPPs to build a solar plant to provide over 50 GWh of renewable electricity per year to its mine. The decision to move to renewable energy is driven by the desire to reduce import dependency.
Tsumeb smelter	Zinc/ Copper	5 MW solar plant	2024	Dundee Precious signed a five-year CPPA to cover 30% of its total electricity consumption at the smelter.
Rosh Pinah	Zinc	5.7 MW solar plant	2024	Rosh Pinah signed a 15-year CPPA to replace 30% of the energy procured from the grid under MSB.

Off-grid solar PV and storage systems could potentially offer another cost-competitive option for mining companies (Figure 3.7). However, the energy demand patterns of mining operations do not match well with the daily cycle of solar PV output. While battery storage can help to smooth out supply fluctuations, it remains a costly option today. For example, four-hour battery storage with a 5% cost of capital more than doubles the LCOE from USD 52/MWh to USD 112/MWh. With 12-hour battery storage, the LCOE increases to USD 219/MWh, making it uncompetitive compared to average grid electricity prices of USD 135/MWh. Assuming a high 15% cost of capital, the LCOE rises sharply to USD 230/MWh for the four-hour battery storage and USD 463/MWh for the 12-hour battery. Costs for individual utility-scale battery storage projects can vary widely depending on site conditions, technology choices and regulatory regimes.

Figure 3.7 Estimated levelised costs of electricity for solar PV in Namibia, with and without battery storage



Note: WACC = weighted average cost of capital. Costs for stationary battery storage projects are set at 290 USD/MWh.
Source: IEA analysis based on data from NamPower and IEA (2024), Batteries and Secure Energy Transitions.

Although grids and CPPAs currently provide economically attractive options, rapid innovations in battery chemistry and the growing availability of second-life batteries will likely continue to drive down battery costs, making off-grid solutions more viable in the future.

Electrification of mining operations

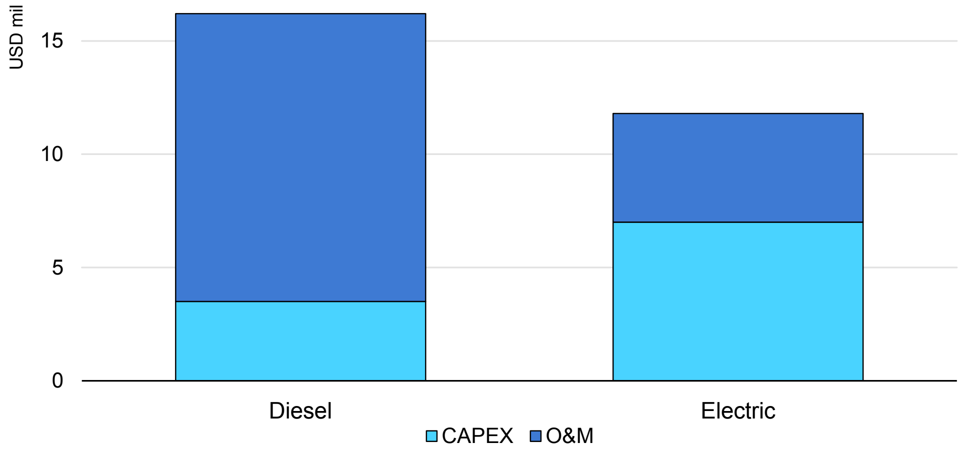
Mining companies have seized the initiative to electrify equipment, mostly through retrofits. Original equipment manufacturers have only recently started to enter the market with new electric tools and vehicles.

An electrified mining haul truck, for example, can either be plugged into a high-voltage (6 kV) trailing cable or powered by 1 000 to 2 000 kWh packs of lithium-ion batteries. The batteries required are significantly larger than those used for most electric vehicles (the average passenger EV has a battery pack of around 50 kWh, while a heavy-duty truck battery is around 500 kWh.) Currently, about 80% of electric mining equipment uses lithium-iron-phosphate (LFP) batteries, which are favoured because of their longer cycle life, fire safety and cost, despite having a lower energy density. The rest use nickel-manganese-cobalt (NMC) batteries. Advancements in battery chemistry and falling battery prices could reduce costs even further. Recently, trailing cables have been introduced in several mines, with a Namibian uranium mine being among the first in the world to use them.

Electric mining equipment offers a range of benefits beyond just improving efficiency and lowering fuel and maintenance costs. Workers' health and safety improves with reduced air and noise pollution, especially in underground mines. Electric equipment also cuts back on maintenance costs by eliminating the need for underground ventilation and cooling systems and generally reducing the number of moving parts. Electric mining equipment also delivers greater speed and acceleration.

For example, the cost savings over the lifecycle of an electric haul truck are substantial, even after factoring in multiple battery replacements and the cost of charging infrastructure. At current Namibian energy prices, opting for an electric truck over a diesel truck can result in savings of more than USD 4 million in total ownership costs. (Figure 3.8). This is largely due to energy cost savings, which are nearly three times greater for the electric truck. Fuel costs can be significant, with a single 150-tonne haul truck consuming around USD 850 000 of fuel per year. Additional cost savings could be realised through lower electricity prices, eliminating the need for expensive charging infrastructure around the mine and reducing charging times. Some companies have addressed this by implementing battery swap systems.

Figure 3.8 Total cost of ownership of mining haul truck using diesel versus electric drivetrain with battery



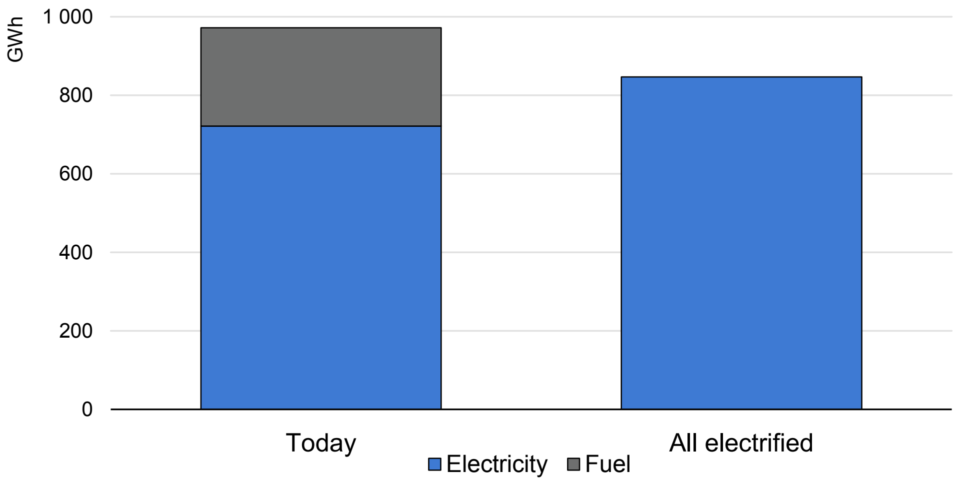
IEA CC BY 4.0.

Note: Comparisons based on a 150-tonne haul truck, a diesel price of USD 1.21/L and electricity price of USD 0.14/kWh. Operational and maintenance costs (O&M) include energy costs, while the electric haul truck's capital expenses (CAPEX) include battery replacement.

Source: IEA analysis based on data from mining.com and IDTech Research.

Electrifying mining equipment in all currently operating mines in Namibia could increase electricity demand by around 125 GWh per year. However, total final energy demand would decrease due to improvements in energy efficiency (Figure 3.9).

Figure 3.9 Mining sector energy consumption in Namibia, with and without electrification



IEA CC BY 4.0.

Note: Efficiency of diesel-based trucks = 40%. Efficiency of electric trucks= 80%.

Chapter 4. Opportunities for renewable hydrogen

Namibia benefits from abundant solar and wind resources, along with vast amounts of government-owned land. This facilitates project development and centralised planning of so-called hydrogen valleys – dedicated zones for producing and distributing hydrogen on a large scale. Namibia's Green Hydrogen and Derivatives Strategy, published in November 2022, sets production targets for renewable hydrogen and its derivatives, aiming for 1-2 Mt per year by 2030, 5-7 Mt per year by 2040 and 10-15 Mt per year by 2050. The strategy identifies three regions (southern, central and northern) with excellent wind and solar resources to power large-scale production of ammonia, hydrogen and other low-emission fuels. By 2050, the southern region could produce 5 Mt per year of hydrogen equivalent through a project called Hyphen that is currently being developed by Hyphen Hydrogen Energy. This project includes the necessary infrastructure to expand and transform the Port of Lüderitz for ammonia export. The central region could produce a further 3 Mt per year of hydrogen equivalent by 2050 and has also been identified as a potential "synthetic fuel hub" due to existing infrastructure at Walvis Bay Port. The northern region is expected to produce 5 Mt per year of hydrogen equivalent by 2050 and has been identified as a hub for both low-emission fuels and hydrogen production.

Renewables-based hydrogen and ammonia projects

Several projects based on electrolytic hydrogen and ammonia powered by renewables have already been announced and are under development. (Table 4.1).

Table 4.1 Renewables-based hydrogen and ammonia projects in Namibia

Name of project	Status	Location	Project developer	Size
Hyphen Hydrogen Energy	Feasibility study	Tsau IIKhaeb National Park in the Namib Desert	Joint venture between Nicholas Holdings Limited and ENERTRAG SE	Production: Phase I: 175 kt H_2/yr or 1 Mt NH_3/yr (2028) Phase II: 175 kt H_2/yr or 1 Mt NH_3/yr (Q4 2030)

Daures Green Hydrogen Village	Under constructi on	Erongo Region	Daures Green Hydrogen Consortium	Production: Phase 1: 18 t of H_2/yr or 100 t of NH_3/yr (2024) Phase 2: 602 t of H_2/yr or 3 500 t NH_3/yr (Q4 2026) Phase 3: 64 kt of H_2/yr or 360 kt of NH_3/yr (Q4 2027) Phase 4: 191 kt of H_2/yr or 1.1 Mt of NH_3/yr (Q4 2027)
O&L group – CMB.TECH hydrogen hub	Under constructi on	Walvis Bay	Ohlthaver & List (O&L) Group and CMB.TE CH	Production: 200 t H_2/yr (2024)
Renewstable Swakopmund	Develop-ment/ planning	Swakopmund	HDF Energy Namibia	Production: 1 400 t H_2/yr (2026)
Zhero	FID in 2026	Walvis Bay	Zhero	Production: 500 kt NH_3/yr (2029)
HyIron (Oshivela project)	Under construc-tion	Erongo Region	HyIron (Nambia) and CO2Grab, TS Elino and LSF (Germany)	Production: 15 kt of DRI/yr (Q4 2024)
PV₂Fuel	Feasibility study	Walvis Bay	CMB.TECH	Production: 250 kt NH_3/yr (Q4 2026)
Elof Hansson	Develop-ment/ planning	Walvis Bay	Elof Hansson	Production: 430 kt NH_3/yr

Hyphen Hydrogen Energy (Hyphen project) is the first large-scale renewable hydrogen facility under development in Namibia and the largest in sub-Saharan Africa. Pending a final investment decision (FID), the project is planning to produce 0.35 Mt of hydrogen or 2 Mt of ammonia by 2030. The construction of Phase I is slated to start at the end of 2026 and deliver the first half of the total supply by end of 2028. Phase II is planned to start construction in 2029 and deliver the remaining half of supply. The Hyphen project was selected as the preferred bidder for the first giga-scale green hydrogen project and secured a 40-year concession for more than 4 000 km^2 of land. This USD 10 billion project is comparable in size to Namibia's entire GDP (USD 12.2 billion in 2021).

In late 2023, the Government of Namibia exercised its right to acquire a 24% stake (USD 25 million) in the Hyphen project via the SDG Namibia One Fund. This fund serves as Namibia's blended finance vehicle for green hydrogen and was established through a EUR 40 million grant from Dutch Invest International. As part of this investment, SDG Namibia One Fund will be responsible for funding its share of the development costs, amounting to EUR 23 million, until final investment decision.

The **Daures Green Hydrogen Village project** (DGHV), located in the heart of Namibia's Erongo Region, aims to become Africa's first 100% Net Zero green community. The project seeks to integrate advanced technologies for various applications of green hydrogen, including agriculture, ammonium nitrate production and cleaning detergents. It also aims to generate socio-economic benefits for the region by actively creating value within local communities (see Chapter 5).

DGHV is set to start operations in Q4 2024, with a pilot phase to produce 18 tonnes of H_2 or 100 tonnes of NH_3 per year that will be used for making ammonium sulphate fertilisers to support crop growth in a co-located greenhouse. The project plans to gradually scale up production in four phases for regional and international exports, with final production of 191 000 tonnes of H_2/yr or 1.1 Mt of NH_3 by 2027.

The **O&L group – CMB.TECH hydrogen hub** plans to establish an ammonia factory along with the necessary export facilities at the Port of Walvis Bay. The site will be connected to a 10-hectare solar park with a hydrogen production facility powered by a 5 MW electrolyser and a 5 MWh battery. The pilot will test technologies for offtake applications within the transport and mining sectors (i.e. trucks, port equipment, and railway applications) to lay the groundwork for a second phase that involves a larger commercial plant for ammonia production. The project is under construction and could be operational by Q4 2024.

The **Renewstable Swakopmund project** aims to develop a hydrogen-to-power plant that will operate 24/7 and provide a baseload of 30 MW of electricity during the day and 6 MW at night. The plant would produce 1 400 tonnes of renewable hydrogen annually and have storage capacity of 230 MWh. The project has the potential to use desalinated water from the Erongo desalination plant for hydrogen production and for maintenance of PV panels. FID is expected in late 2024 and construction is slated to begin in 2026.

The **Zhero project** aims to produce 500 000 tonnes of renewable ammonia annually from 2029. Final investment decision is expected by 2026. The project, located 70 km from Walvis Bay, has secured private farmland and signed lease agreements for two additional parcels (for an industrial park and for storage).

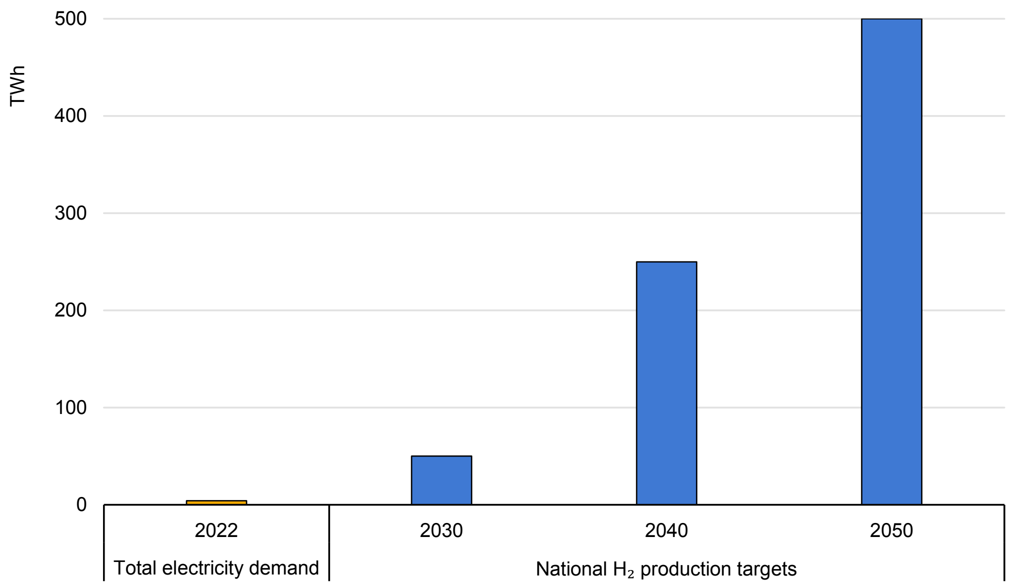
Namibia is also looking into increasing domestic production of refined products through hydrogen and renewable energy, namely renewable direct reduced iron (DRI) and hot briquetted iron (HBI). A consortium of Namibian and German companies has developed a process called **HyIron**, for reducing iron ore in a rotary kiln through the use of hydrogen. The technology is currently being developed in the context of the Oshivela project and will enable the production of 15 000 tonnes of DRI annually with a planned start in Q4 2024. A key feature of the HyIron process is its modularity, allowing for rapid expansion of production capacities. As such, the project developers are already conducting a feasibility study to expand production in the medium term to 1 Mt of green iron per year.

The **PV_2Fuel project** aims at producing 250 000 tonnes of NH_3 near the town of Arandis, approx. 100 km from the Port of Walvis Bay from the end of 2026. The developer (Belgian company CMB.TECH) is already making progress towards achieving its production goal and started construction of a USD 30 million integrated hydrogen production and refuelling system at the Port of Walvis Bay, to commence operation by the end of 2024.

Preparing for ammonia exports

Namibia's ambitions for renewable hydrogen production would require an unprecedented investment in renewable electricity. Meeting the 2030 hydrogen production target of 1 Mt would require around 50 TWh of dedicated electricity generation to run the electrolysers – five times more than current total power demand. Long-term hydrogen production targets would need to be supported with even larger investments. Approximately 250 TWh of electricity will be needed to meet the 2040 target and around 500 TWh to meet the 2050 target. This is a hundred times larger than today's power market. (Figure 4.1).

Figure 4.1 Current electricity demand and electricity needed to produce electrolytic hydrogen for meeting national production targets



Note: Current demand figures based on 2022 data. Forecast electricity needs are based on the lower end of the national hydrogen targets (i.e. 1 Mt in 2030, 5 Mt in 2040 and 10 Mt in 2050).

Currently, Namibia has no domestic market for renewable hydrogen, but the country is actively exploring ways to allocate a part of the production for future domestic use. In the meantime, all production would need to be exported.

Within the African continent, Namibia could consider transporting hydrogen to neighbouring countries, such as South Africa, via pipeline. This would give Namibia a cost advantage compared to other possible exporters outside the continent that would need to rely on more expensive transport in the form of shipping. Pipeline transport of hydrogen is a mature technology, with roughly 4 600 km of hydrogen pipelines currently in operation, over 90% of which are in Europe and the United States. However, in the context of Namibia, its applicability and feasibility would hinge on several factors. Firstly, on mobilising significant upfront investment, not only for building the infrastructure, but also for workforce training. Then, the development of a pipeline crossing national borders requires taking into account various geopolitical aspects, carefully co-ordinating all the various entities and stakeholders involved (i.e., regulatory authorities and communities), and it would also require considerable time for implementation.

Outside the continent, Namibia is actively engaged in the development of strategic international partnerships to facilitate the technology transfers and investment flows it needs to scale up its hydrogen economy. At COP26, Namibia and the Netherlands signed a Letter of Intent (LoI) to collaborate in the field of energy, and "green hydrogen" in particular. A similar agreement was also signed with Belgium. In March 2022, Namibia and Germany signed a Joint Declaration of Intent (JDI) to cooperate in the production, application and transport of green hydrogen and synthetic fuels. At COP27, Namibia and the European Union signed a Memorandum of Understanding (MoU) to develop a secure and sustainable supply of raw materials, refined materials and renewable hydrogen. Following this MoU, the European Union set up the Global Gateway initiative, a roadmap with concrete actions and goals for the development of a partnership on sustainable raw materials and green hydrogen with Namibia. Finally, in August 2023, Japan's Itochu company signed an agreement to cooperate on developing value chains for low-emission ammonia.

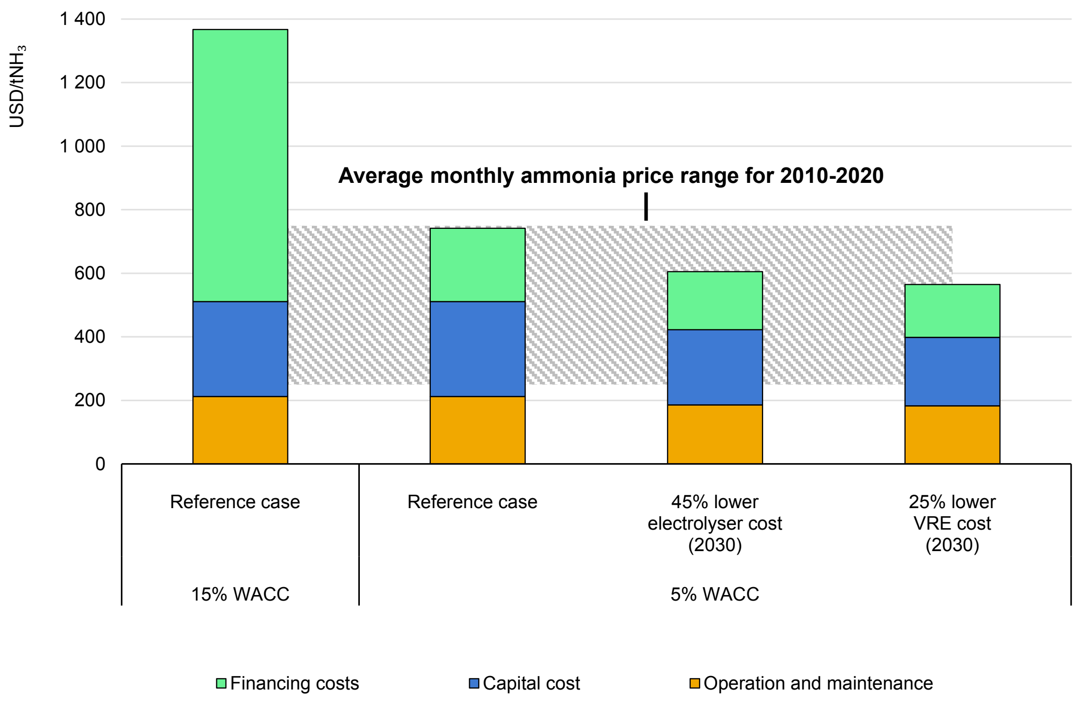
Although different options are technically available to ship hydrogen to global markets, doing so in the form of ammonia is considered the most viable. While the cost of converting hydrogen to ammonia is high, the overall seabound supply cost for ammonia is lower than for liquid hydrogen. This means ammonia will likely remain the preferred option for transporting hydrogen over long distances, at least in this decade. If Namibia's renewable hydrogen production targets were to be exported as ammonia, they could amount to the equivalent of 6-12 Mt of ammonia by 2030, raising to 30-35 Mt by 2040 and 60-90 Mt by 2050. (For comparison, the current global trade in ammonia amounts to 20 Mt per year.) Significant investments in ammonia infrastructure would be needed to accommodate these very significant production levels. Currently, Namibia does not produce ammonia. However, to achieve its long-term hydrogen targets, the country is actively investing in the necessary ammonia infrastructure and developing expertise in ammonia handling. The country has two main industrial ports – the Port of Walvis Bay and the Port of Lüderitz – which are both managed by the Namibian Ports Authority (Namport). Walvis Bay, Namibia's principal and largest port, is located in the Erongo Region in the south-west of the country. Lüderitz is its second largest port and is used mainly for mining and fishing industries. It is located in the ǁKaras region, in the southern part of the country. Both ports have been identified by Namport as primary export hubs for hydrogen-derived fuels. In June 2022, Namport signed an MoU with the Port of Antwerp Bruges (POABI) and Antwerp/Flanders Port Training Centre (APEC) (collectively referred to as POABI/APEC). In June 2023, Dutch and Namibian state-owned enterprises and authorities signed an MoU to develop hydrogen-related infrastructure to support trade between Namibia and the Netherlands. In addition, Namport has already set aside 350 hectares at the Port of Walvis Bay for hydrogen-related industries, including the infrastructure necessary to turn the port into a "green ammonia bunkering hub" to refuel ships passing the Cape of Good Hope. The Port of Lüderitz is also undergoing a new development plan as part of an MoU between Namport, Hyphen and the Port of Rotterdam for the design of infrastructure for delivering on Namibia's green hydrogen ambitions. In May 2024, Namport and POAB signed a new MoU to co-develop a new port situated north of Walvis Bay, on the southern Atlantic coast.

The economic feasibility of transforming Namibia into a supplier of renewable ammonia relies on its capacity to produce it at the lowest possible cost, along with the necessary infrastructure to supply to international markets. The levelised cost of renewable ammonia depends on both the level of capital expenditure (including investments in electrolysers and in electricity supply) and on the cost of capital. Cost of capital is particularly important for renewable hydrogen and ammonia projects because they are capital-intensive, involving significant upfront expenditures, while operating expenses are a relatively small part of overall project costs. For developing countries like Namibia, the cost of capital can be high, reflecting the greater risks – both real and perceived – at country, sectoral and project levels. High financing costs can significantly inflate the levelised cost of ammonia. This makes lowering the cost of capital crucial not just for investors, but for the overall competitiveness of a project.

In the case of Namibia, with a 15% cost of capital, a large-scale plant using an optimal mix of wind and solar PV could produce renewable ammonia at a cost of nearly USD 1 400/tonne (Figure 4.2). Securing affordable financing is key to the overall attractiveness of clean energy projects in emerging countries and economies, as it directly impacts the affordability of such investments. De-risking strategies are essential for maintaining low capital costs, enabling competitive pricing of renewable hydrogen and its derivatives. Examples of de-risking instruments include political risk insurance from multilateral banks; foreign exchange hedges and interest-rate swaps; and long-term offtake agreements with reputable and creditworthy counterparties. Using a mix of instruments helps to minimise risk and lower the cost of capital. If the cost of capital were successfully lowered to 5% (from 15% currently), it could cut the levelised cost of ammonia production in Namibia to USD 740/tonne.

Still further reductions could be achieved by lowering the cost of electrolysers and renewable electricity. Today, the capital cost for an installed electrolyser (including equipment, gas treatment, plant balancing, engineering, procurement and construction) ranges between USD 2 000/kW and USD 2 450/kW. Costs could be significantly reduced through economies of scale and mass production. Based on the capacity deployment of announced projects (excluding early-stage initiatives), the cost of an installed electrolyser could fall by 45% by 2030 compared to 2023 levels, reaching about USD 1 100/kW. Given such a significant drop in electrolyser costs, renewable ammonia prices might drop by another 20%, reaching USD 570/tonne. Assuming further a 25% reduction in the cost of renewable electricity, the levelised cost of renewable ammonia could reach USD 560/tonne.

Figure 4.2 Levelised cost of ammonia by potential cost-reduction measures



Notes: WACC = weighted average cost of capital. VRE = variable renewable energy. Performance assumptions (in LHV): electrolyser efficiency 66% (today), 69% (2030), H_2 to ammonia efficiency 88%. NH_3 synthesis electricity demand: 4kWh/kgH_2. Capital expenditure (CAPEX) assumptions: solar PV USD 1 110/kW (today), wind onshore USD 1 500/kW (today), electrolyser USD 2 000/kWe (today), H_2 storage USD 400/kg. Operating expenditure (OPEX) assumptions: onshore wind USD 10/MWh (today), solar PV USD 10/MWh (today). Consumables: water USD 2/m^3.

Opportunities for domestic fertiliser production

About 70% of ammonia is used to produce nitrogen-based fertilisers. The production of urea accounts for around 55% of ammonia demand, and most of it (75%) is used directly as a fertiliser. The other major use of ammonia is for nitric acid and ammonium nitrate production. Around 80% of nitric acid is used to produce ammonium nitrate and two-thirds is used for fertiliser. Urea is dominant today due to its high nitrogen content and convenience for storage, transport and application. However, the production of urea requires CO_2 feedstock, and the sourcing of low-cost, non-fossil CO_2 can become a bottleneck for producing low-emission fertilisers. Since ammonium nitrate production does not require CO_2, it is viewed as a potential alternative to urea for the transition toward low-emission fertilisers. However, ammonium nitrate is also the main component in many types of explosives, so it needs to be handled, transported and stored in accordance with strict safety standards.

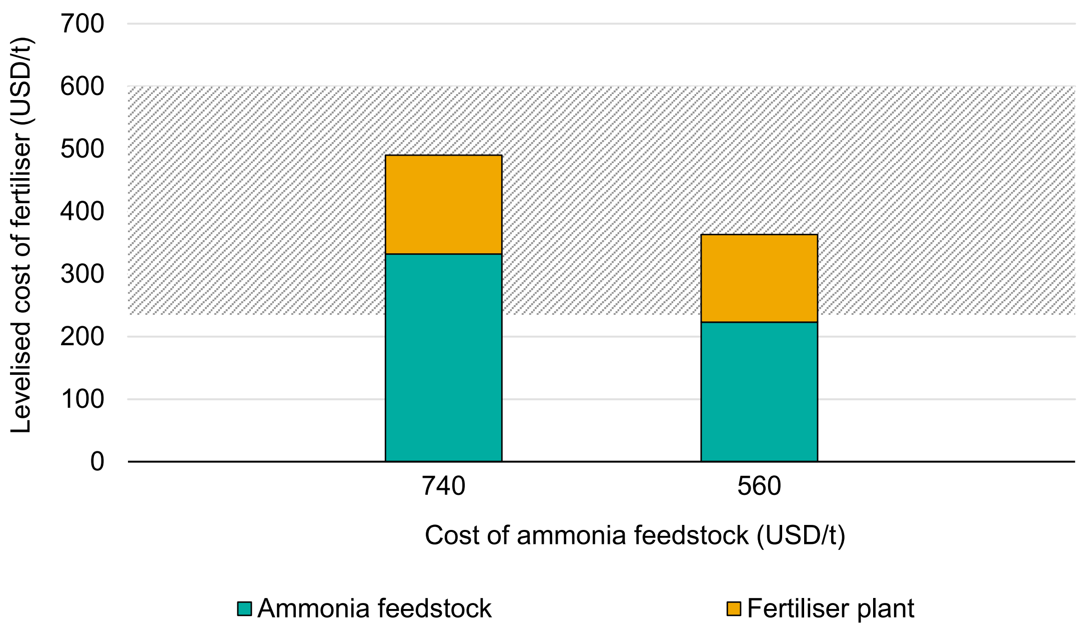
Africa is only responsible for 5% of global nitrogen-based fertiliser production, and approximately 90% of the fertiliser used in sub-Saharan Africa is imported. In 2020, South Africa was the largest consumer of fertilisers in the region, using 0.7 Mt (53% of total regional consumption). It was followed by Zambia with 0.3 Mt (21%) and Zimbabwe with 0.1 Mt (9%). The cost of producing fertilisers is closely linked to energy prices. Natural gas is currently the main feedstock for nitrogen-based fertilisers and accounts for around 70% to 80% of operating costs. The surge in fertiliser prices from 2020 to 2022 closely tracked a spike in natural gas prices that was driven by the disruptions linked to the Covid-19 pandemic and Russia's war in Ukraine. This has significantly impacted crop yields and food security in many parts of the world, including Namibia.

Namibia imports around 90% of its fertiliser from South Africa, with the remainder sourced from Russia, Chile, China and Malaysia. However, the country is taking steps to produce fertiliser domestically from renewable ammonia. Ammonia produced by the Daures Green Hydrogen Village project will be used in part for making ammonia sulphate fertiliser for local consumption as well as export. In 2023, an agreement was signed with the World Food Programme (WFP) Namibia to support the production of green ammonia-based fertiliser to improve the country's food production. Another MoU was signed with Sable Chemicals, a Zimbabwean fertiliser manufacturer, for ammonia offtake.

By 2030, the levelised cost of renewable ammonia in Namibia could fall to a range of USD 740-560/tonne, leading to a cost for fertiliser of USD 490-360/tonne. Such production cost levels would have positioned Namibia as a competitive supplier of fertilisers during the price surge from 2020-2022 (which was driven by rising natural gas prices and trade restrictions). Conditions have since returned to normal, but typically, market prices for fertilisers made from renewable ammonia would still be higher than for fossil-derived fertilisers (Figure 4.3). The fertiliser industry is highly price-sensitive, and most subsistence farmers in developing countries cannot afford to pay a premium for low-emission fertiliser. However, there are still several compelling reasons for Namibia to produce fertilisers domestically.

First, it could reduce dependence on food imports and improve agricultural yields. In the event of global supply shortages and rising prices, Namibia is among the countries that will feel the effects earliest and most severely. Farmers may respond to a supply shock by purchasing and using less fertiliser, which could have a negative impact for the next harvest. Although higher, the costs of the renewable route are more predictable and can help to mitigate against possible disruptions in the supply of natural gas. It also minimises the influence of commodity price fluctuations that affect fossil fuel-based routes. Secondly, if produced on a large scale, a domestic fertiliser industry could also generate opportunities for export to neighbouring countries, creating a new source of revenue.

Figure 4.3 Supply costs for renewable-based fertilisers in Namibia in 2030



Note: The example features a calcium ammonium nitrate (CAN) plant based in South America. Capital expenditure (CAPEX): USD 365 million. Operating expenditure: 4% of CAPEX. Plant output: 270 000 t per year.

Box 4.1 Infrastructure needs for marine transport of ammonia

The current global ammonia trade is approximately 20 Mt/yr and represents approximately 10% of global ammonia production. The transport of pure ammonia requires liquification as it is a gas at ambient conditions. In addition, specific safety issues need to be taken into consideration. Ammonia is used to produce nitrogen-based fertilisers, which are solids that can be transported in bulk. For example, 16% of global ammonia production is traded in the form of urea.

Based on export-oriented hydrogen projects, ammonia is currently the preferred carrier molecule. Transporting hydrogen in the form of ammonia would require suitable infrastructure for its production and handling, which Namibia does not currently have. For illustrative purposes, 1 Mt of ammonia (about 0.2 Mt of H_2 equivalent corresponding to about half of the planned production by 2030 in Namibia from Table 4.1) would require around 60 000 tonnes of ammonia storage[8] and the construction of several large storage tanks (the world's largest ammonia storage tanks have a capacity of 50 000 tonnes).

New hydrogen projects should consider the proximity to a deepwater port that could host an ammonia export terminal and dedicated jetties for the liquefied ammonia tankers, or the construction of hydrogen or ammonia pipelines to a deepwater port that could host this terminal. For Namibia, it would be necessary to build new or expand existing deepwater port facilities, such as planned around Port Lüderitz to allow large-scale ammonia exports. As with any large infrastructure project, these often have long lead times, so early planning is required. For example, just the completion of ammonia storage tanks takes usually more than three years, so port infrastructure planning needs to start well ahead of the planned start of production.

Exporting 1 Mt of ammonia would be equivalent to around 5% of today's global ammonia trade and would require around 2 very large ammonia tankers dedicated year-round to transporting ammonia. As shipbuilding may take a few years, orders need to be placed well in advance to reserve capacity at the yard.

Water needs for electrolytic hydrogen

Around 10 litres of water is needed to produce 1 kg of hydrogen through electrolysis. In addition to serving as a feedstock, water might also be needed for cooling. Three main types of cooling systems can be applied, each associated with very different water requirements.

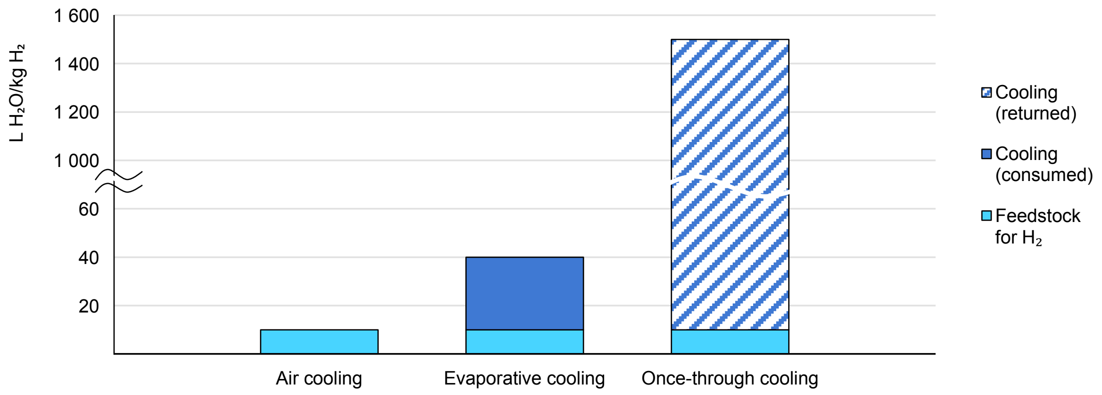
[8] Assuming that the ammonia storage tanks are loaded and unloaded between 15 and 20 times per year.

Air cooling does not consume any water, since byproduct heat from electrolysis is transferred to ambient air by moving fans. Air cooling offers flexibility in site selection, as location is not dependent on proximity to a major body of water. However, a large surface area for heat exchangers and fans that move considerable amounts of air is required. Also, efficiency is low, especially in hot and arid climates, since cooling temperatures are limited by the ambient dry-bulb temperature.

Evaporative cooling systems discharge heat through controlled evaporation in a cooling tower. Given the high amount of energy required to evaporate water, relatively small volumes of water are needed. However, water that is used for evaporative cooling cannot be returned to its source because it is permanently lost as vapour. Net water consumption can vary between 30 and 80 litres/kgH_2 depending on the design of the cooling system and climatic conditions.

Once-through cooling relies on liquid water that can be returned to its source after use. Heat from electrolysis is transferred to the water, increasing its temperature by about 10°C. Relatively large volumes of water are needed – between 1 500 and 3 000 litres per kilogramme of hydrogen. For this reason, such a system is only feasible for electrolysers that are located close to an abundant water source. Aside from filtering out foreign materials, no treatment of the raw water is needed for cooling purposes. However, regular maintenance is required to prevent corrosion, scaling and fouling in the cooling system.

Figure 4.4 Water requirements for electrolytic hydrogen production by cooling method



Source: IEA (2023), Renewable Energy Opportunities for Mauritania.

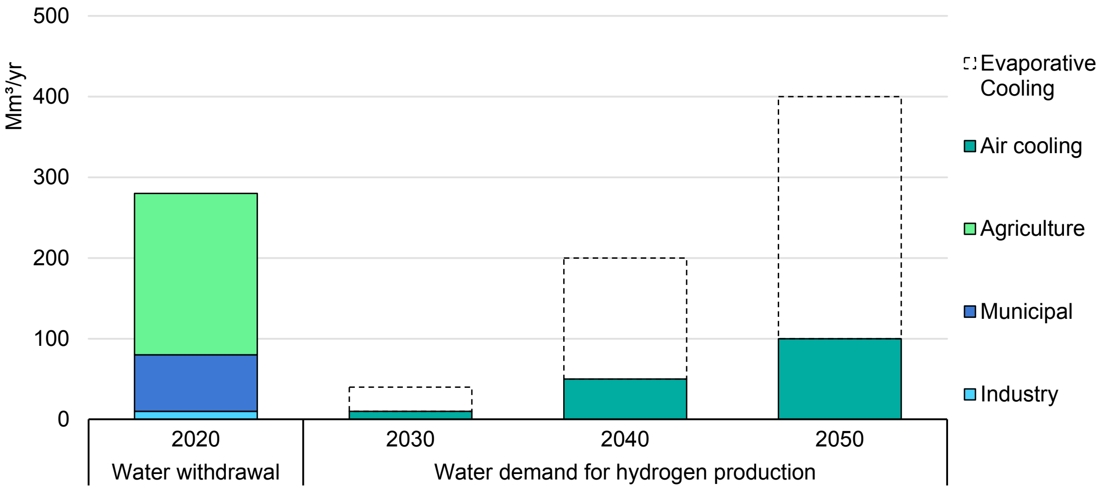
If the produced hydrogen is not used on site, it is likely pressurised to reduce its volume for storage and transport. Pressurisation can be achieved using multi-stage compressors with intercooling, which further increases the water needs associated with large-scale hydrogen production.

In terms of water quality, electrolysers require ultrapure water, which needs additional deionisation to reach the conductivity range of 0.1 to 1 µSv/cm. Cooling water does not need to be as pure as electrolyser feedwater, but it must be treated for evaporative cooling purposes to meet certain quality standards to minimise corrosion and prevent fouling in the system. In coastal areas, once-through cooling with seawater can be a good alternative to evaporative cooling, as it does not require desalinated water. Several large-scale power plants use this method.

Innovative configurations can help decrease water requirements. Some companies are exploring the potential to use waste heat from electrolysers in membrane distillation desalination units to produce clean water, thereby reducing the need for cooling water for electrolysis. Waste heat can also be used for district heating, as electrolysers produce around 45-65 MJ of byproduct heat per kilogramme of hydrogen, but this has rather limited potential in hot climates.

To meet Namibia's hydrogen production targets, the clean water requirements would be expected to range between 10-20 Mm^3 by 2030 (40-80 Mm^3 with evaporative cooling), 50-130 Mm^3 by 2040 (200-280 Mm^3), and 100-300 Mm^3 by 2050 (400-600 Mm^3). If implemented, the hydrogen sector would become the largest water consumer in Namibia. With air cooling, water demand would exceed current municipal water needs by 2050. If evaporative cooling is considered, water demand would exceed current municipal water needs already by 2040 – and by 2050, it would exceed current total water needs, including for agriculture.

Figure 4.5 Water withdrawal in Namibia by sector and water requirements for hydrogen production



Notes: Water consumption: for hydrogen production is 10 litres per 1kg of H_2, with evaporative cooling net water consumption is 30-80 litres/kgH_2.
Source: IEA analysis based on data from FAO Aquastat.

Hydrogen projects are now incorporating water supply into their planning. For example, the Southern Corridor Development Initiative (SCDI) announced a portfolio of green hydrogen and ammonia plants including a seawater desalination plant, which will be oversized to provide water capacity to Lüderitz. The Daures Green Hydrogen Consortium (DGHC) developed a plan consisting of four phases, each having distinct water and energy requirements, aiming at supplying water from a desalination plant.

Seawater desalination

Seawater desalination is a commercially mature technology: over the past 20 years, global desalination capacity has increased six-fold, reaching over 120 Mm^3/d. With more than 21 000 desalination plants around the world, desalination is increasingly becoming a conventional method to provide freshwater to meet the diverse needs of countries with limited water resources. Dry and high-income economies in the Middle East and North Africa (e.g. Saudi Arabia, United Arab Emirates and Israel) have the largest desalination capacities installed, followed by East Asia and North America. With increasing capacity and technological learning, the cost of desalination has dropped significantly to around USD 0.5-3/m^3. However, local costs vary according to technology, plant size and configuration, energy cost, feedwater and product water quality, and environmental regulations, most of which are site-specific. The cost of water has a marginal impact on the levelised cost of hydrogen, being in the range of 2%-5% depending on cost of hydrogen and cooling method.

State-of-the-art desalination plants currently enable large-scale production of renewable hydrogen, without adding to the competition for existing water. For example, an electrolyser plant that produces 1 Mt of H_2 per year would require a minimum desalination capacity of 110 000 m^3/d (assuming evaporative cooling). This would still be an average operating condition for desalination plants in countries such as Kuwait, Israel and South Korea, and well below the capacity of the Jebel Ali Desalination Plant in the United Arab Emirates, which is the world's largest seawater desalination plant at a capacity of 2 Mm^3 per day.

Desalination plants play a crucial role in addressing water scarcity issues around the world. However, large-scale implementation can have important environmental impacts that need to be carefully evaluated. When desalination plants draw in the large amounts of seawater required for the purification process, marine organisms can get trapped in the plant's filtration systems and potentially disrupt marine life. Another concern is the disposal of reject brine, a concentrated byproduct with roughly twice the salinity of seawater and containing a minor concentration of chemicals, such as anti-scalants, which are necessary to maintain the operation of a reverse-osmosis plant. When released back into the marine environment, this brine can disrupt the balance of local ecosystems due to its altered composition. Every day, desalination plants around the world produce 140 Mm^3 of reject brine, requiring proper brine management strategies to protect aquatic life and sensitive coastal habitats.

Chapter 5. Socio-economic benefits through renewable energy

Namibia's vision of socio-economic development, spurred by infrastructure development and industrialisation, is articulated in its key policy documents, including Vision 2030, the Harambee Prosperity Plan II (2021-2025), the National Development Plan 5, the Mineral Beneficiation Strategy for Namibia, and the Green Hydrogen and Derivatives Strategy (see Chapter 1).

There is a firm expectation that large-scale, capital-intensive investment projects will generate opportunities not only for local communities but also for the nation as a whole. Thanks to large, diversified and labour-intensive supply chains, renewable energy projects can create more jobs per unit of energy compared to conventional energy sources. They offer opportunities for domestic value creation linked to activities such as project operation and maintenance or manufacturing and distribution of equipment, especially in countries where renewable energy systems are still in the early stages of development and integration. However, without effective sustainability safeguards, these projects may also pose risks, including environmental degradation, displacement and unequal distribution of economic benefits. All stakeholders – the government, project developers, capital providers and others in the international community – must work closely and collaboratively to ensure that large-scale clean energy projects mitigate risks while delivering tangible socio-economic benefits. These efforts should align with broader development goals, including Namibia's industrialisation plans.

This chapter explores policy design, practices and new mechanisms aimed at enhancing and promoting broader socio-economic impacts from clean energy developments across the energy system, with a focus on renewable energy, the emerging renewable hydrogen industry and the mining sector.

Incorporating socio-economic factors into renewable energy project design

Large-scale renewable energy projects in Namibia offer significant opportunities to generate socio-economic benefits, from inception to operation. These benefits can be grouped into three main categories: **direct benefits** such as the participation of local suppliers of materials, services or labour; **community benefits** funded by the projects that address specific local needs; and **fiscal benefits** resulting from increased government revenues through taxes or fiscal contributions by the participating companies.

Direct benefits bolster local company revenues, provide a source of hard currency and support job creation. In the most successful of cases, companies that start as local suppliers of goods and services eventually become exporters, thereby expanding their clientele. However, when the industrial base of the country is small, coordinated efforts are needed to strengthen local firms to ensure they are prepared to engage with and capitalise on opportunities in the renewable energy sector.

Community benefits involve direct financial flows or actions taken by the project companies that address the needs of the communities impacted by a project or living in proximity to it. Such initiatives can take the form of electrification (e.g. through Solar Home Systems), development of water supply and sanitation, support to local agriculture or financing local schools and medical centres. They are often part of a broader transformation of the communities where projects are located. When these investments consider actual community needs identified through evidence-based assessments, they can deliver a socio-economic boost to local communities by enhancing skills and reducing inequalities related to gender and other forms of exclusion.

In some cases, communities can benefit from revenue- and ownership-sharing arrangements, such as payments into – or equity stakes in – community entities like trusts, cooperatives, or nonprofits (This excludes land purchases, which are mandatory compensatory mechanisms). Private sector developers often make corporate social responsibility commitments to finance local development projects to secure and maintain a "social licence to operate" and gain public acceptance.

Finally, there are the potential benefits to the public purse that arise from increased tax revenues, royalties and other income streams. These additional revenues can help finance public services, infrastructure and healthcare for the benefit of the wider population. As outlined in the Harambee Prosperity Plan II, large-scale energy and infrastructure projects can serve as anchors for fiscal growth, fostering a more resilient economy and reducing reliance on foreign aid and external borrowing.

This section discusses how policy design that incorporates socio-economic concerns into renewable energy project procurement and implementation can support the host country's development objectives and enhance quality of life for its citizens.

Namibia's experience with renewables auctions

Namibia's renewable energy auction programme was launched by NamPower as part of a strategic shift toward competitive procurement. Over the years, the system has evolved, starting with feed-in tariffs (FIT), tenders and direct negotiations and eventually moving to auctions. Since 2018, Namibia has been a leader in sub-Saharan Africa for the procurement of independent power producers (IPPs), with 20 currently operating in the country. In addition to FITs, NamPower has also held tenders for renewable capacity. A 2016 tender resulted in the Hardap Solar PV IPP project which secured one of the cheapest solar PV power purchase agreements in Africa, with a price of NADc 49/kWh (USDc 2.9/kWh). That success proved that FITs and tenders were driving down prices and accelerating project timelines, prompting a shift in Namibia's energy policies and power market.

As of 2019, market reforms overseen by the Electricity Control Board introduced a modified single buyer model (see Chapter 2) to accelerate investment and diversify the market. Tenders began incorporating socio-economic criteria, including requirements for local ownership, local content and employment, and spending on socio-economic development. For example, the Khan IPP mandated at least 45% Namibian ownership, and all operations and maintenance functions were required to be performed by Namibians. Meanwhile, reforms bolstered NamPower's reputation as a reliable, creditworthy off-taker, which helped attract international bidders through cost-reflective end-user tariffs and clear, standardised procurement processes.

Namibia's experience demonstrates that competitive and transparent procurement, combined with socio-economic development goals, can yield positive results in renewable energy deployment. Currently, 196 MW of solar PV and wind are installed in Namibia, demonstrating the potential for additional renewable capacity to be deployed. However, in regions with a limited industrial base and a shortage of skilled workers, job creation and local content targets must be supported by capacity-building initiatives, including skills development programs for individuals and enterprise development for local businesses. Robust mechanisms for reporting, monitoring and evaluation should also be implemented to ensure accountability. With these parameters in mind, targeted use of socio-economic criteria in renewable auctions can be an effective tool for ensuring that clean energy projects contribute to broader development objectives, as attested by the South African experience presented in the next section.

Findings from the South African Renewable Energy Independent Power Producer Programme

The South African Independent Power Producer Procurement Programme (IPPPP) pioneered an innovative approach to address socio-economic inequalities by making socio-economic development a central component of its design. Valuable insights can be drawn from this case study from South Africa, which over the years has resulted in 141 selected IPPs across various renewable and non-renewable bid windows, including seven renewable windows, the Risk Mitigation Independent Power Producer Procurement Programme (RMIPPPP), one Battery Energy Storage window, and the Peaker procurement. Of these, 95 IPPs were operational by the end of March 2024, contributing a substantial 7.3 GW to the county's national grid.

Launched in 2011, the Renewable Energy Independent Power Producer Procurement Programme (REIPPPP) is a competitive auction-based initiative aimed at attracting private sector investment in grid-connected renewable energy generation in South Africa. Through this programme, private companies submit bids to secure fixed-tariff offtake contracts for the development and operation of renewable energy projects, with the goal of expanding the country's clean energy capacity and diversifying its energy mix. In addition to driving economic investments, the REIPPPP aims to deliver broader socio-economic benefits by creating opportunities for individuals previously disadvantaged under the apartheid system to gain access to the formal economy. Bid obligations and minimum thresholds are implemented to ensure that a portion of the value and benefits generated by the scheme is directed to South Africans and local communities.

Between 2011 and 2024, seven rounds of renewable energy "bid windows" (i.e. rounds of procurement) were completed, allowing for adjustment and refining of the evaluation of socio-economic criteria over time. Economic development criteria are imposed on two levels. First, bidders must comply with specific qualification criteria to be eligible for final evaluation. This includes a requirement of a minimum of 40% South African citizens in the project company and a Broad-Based Black Economic Empowerment (B-BBEE) contributor status of at least level 5[9]. Secondly, bidders must be assessed against the evaluation criteria subject to a comparative evaluation.

Table 5.1 Inclusion of non-price evaluation criteria in South Africa's Renewable Energy Independent Power Producer Procurement Programme

Bid windows	Basis for evaluation of socio-economic benefits
1 - 4	Evaluation based on 70% price and 30% economic development commitment
5	90% price and 10% contributor status level (CSL) assessment
6	Evaluation based on 90% price and 10% economic development commitment

Source: IEA analysis based on data from the Independent Power Producers Office (2024), IPPPP Quarterly Report | Quarter 4 2023/24.

[9] B-BBEE contributor status level (CSL) is a rating comprising various components aimed at increasing the numbers of Black people who manage, own and control the country's economy and decreasing racially based income inequalities.

During bid windows 1 to 4, the scoring of bid submissions was split between price (70%) and economic development commitment assessment (30%) (Table 5.1). In bid window 5, the criteria for evaluation were limited to price and contributor status level (CSL) assessment. Therefore, bidders only needed to comply with economic development thresholds as part of the qualification criteria. According to the Ministry of Mineral Resources and Energy, this approach resulted in much lower economic development commitments in bidders' proposals compared to previous bid windows. Therefore, the basis for the socio-economic benefits' evaluation reverted to 10% of the economic development commitment assessment in bid window 6. Economic development commitment is assessed through seven non-price categories: job creation, local content, ownership, management control, skills development, enterprise and supplier development, and socio-economic development, each assigned different weightings.

The REIPPPP programme exemplifies successful innovative policy and ongoing regulatory design calibration in South Africa. Fuelled by strong political will, participation from key stakeholders and frequent adjustments to the programme, it has garnered widespread recognition for its achievements in capacity, investment and price outcomes.

From 2011 up to the end of March 2024, the REIPPPP projects generated nearly 109 TWh of energy through 90 renewable IPPs, created 78 075 jobs, contributed ZAR 2.8 billion (USD 152.3 million)[10] for socio-economic and enterprise development and ZAR 0.8 billion (USD 43 million) [11] – 49% of total project value – has been spent on local content. The REIPPPP has significantly boosted the renewable energy industry by attracting investment, fostering job creation, and promoting industrial and community development. It has also increased local ownership and enabled the procurement of renewable energy at increasingly competitive prices.

While the implementation of socio-economic development initiatives yielded impressive results in South Africa, it also faced challenges, particularly in establishing local content thresholds and employment requirements in a context where readily available skills are sometimes limited. To address these dynamics, other jurisdictions may consider taking a gradual approach to local content commitments, initially targeting accessible short-term opportunities while simultaneously working to develop the ecosystem needed for sustainable long-term growth.

[10] Using the average exchange rate for 2024 of 1 USD = 18.4 NAD (https://www.exchangerates.org.uk/USD-NAD-spot-exchange-rates-history-2024.html).

[11] Using the average exchange rate for 2024 of 1 USD = 18.4 NAD (https://www.exchangerates.org.uk/USD-NAD-spot-exchange-rates-history-2024.html).

Box 5.1 Leveraging the Noor Ouarzazate complex in Morocco to maximise socio-economic benefits

The Noor Ouarzazate Solar Complex – one of the world's largest solar parks, with more than 500 MW of installed capacity from Concentrated Solar Power technology – has prioritised socio-economic benefits for Morocco throughout its development and operation. The Moroccan Agency for Sustainable Energy (Masen), which manages the site, implements a three-pronged socio-economic strategy: integrating Moroccan companies into project value chains; developing local communities surrounding the project sites; and fostering local human capital with a focus on gender equality and the inclusion of minorities.

To ensure Moroccan companies were integrated into the value chains, tenders mandated minimum levels of local industrial participation and skills transfer. Masen provided detailed analyses of Moroccan companies' positions in relevant value chains, allowing private sector bidders to set self-imposed targets for local engagement. The creation of a "Cluster Solaire" further supported this by connecting local firms with international companies, offering capacity-building, business intelligence and networking to boost local industrial integration.

Masen monitored levels of industrial integration throughout the project's construction and operational phases and imposed penalties on suppliers in case of non-compliance with commitments. Additionally, Masen mandated that international suppliers contribute to applied research and technological innovation promotion at Masen's R&D Platform in Ouarzazate.

To improve the resilience and living conditions of local communities near the Ouarzazate site, Masen set up a dedicated entity to identify and finance high-impact projects proposed by local NGOs and leaders, ensuring these projects aligned with socio-economic criteria such as local strategy, inclusivity and sustainability. Masen staff studies the technical feasibility of projects, makes cost-benefit analyses and ensures that benefits flow to the entire community. Identifying projects locally helps ensure their relevance to local populations and secures local buy-in. Meanwhile, Masen's verification of inclusion criteria guarantees that benefits are equitably shared among entire communities, including minorities.

To support development of local human capital, Masen partnered with the National Agency for the Promotion of Employment and Skills (ANAPEC) to train and recruit local labour for the project. Special emphasis was placed on transferring cross-functional skills from related sectors and providing specialised training, such as welding, to ensure compliance with quality standards. For example, 150 local workers were hired as welders at the Noor Ouarzazate construction site. Masen's gender initiatives were culturally sensitive, aimed at fostering local acceptance and ensuring the meaningful inclusion of women.

Source: World Bank (2022), Maximizing Socioeconomic Benefits Triggered by Renewable.

Socio-economic elements of emerging renewable hydrogen projects

Namibia's Green Hydrogen and Derivatives Strategy identifies a significant opportunity to leverage the production of renewable hydrogen to spur the country's socio-economic development and industrialisation. If successfully implemented, it could boost GDP by USD 4.1 billion (in real 2022 dollars) by 2030, and USD 6.1 billion by 2040. It also has the potential to create 280 000 local jobs by 2030 and 600 000 by 2040, 30% of which would stem directly from the hydrogen industry. However, for these benefits to materialise effectively, significant investment in infrastructure and workforce training will be needed to create the necessary conditions for growth.

One of the government's key objectives is to foster socio-economic development through local manufacturing and investment in renewable energy. Aligned with this vision, Namibia has prioritised socio-economic considerations in renewable hydrogen projects, ensuring that these support and advance the country's broader development goals.

This section looks at two examples of how the Namibian government and its partners are addressing socio-economic factors in developing renewable hydrogen projects.

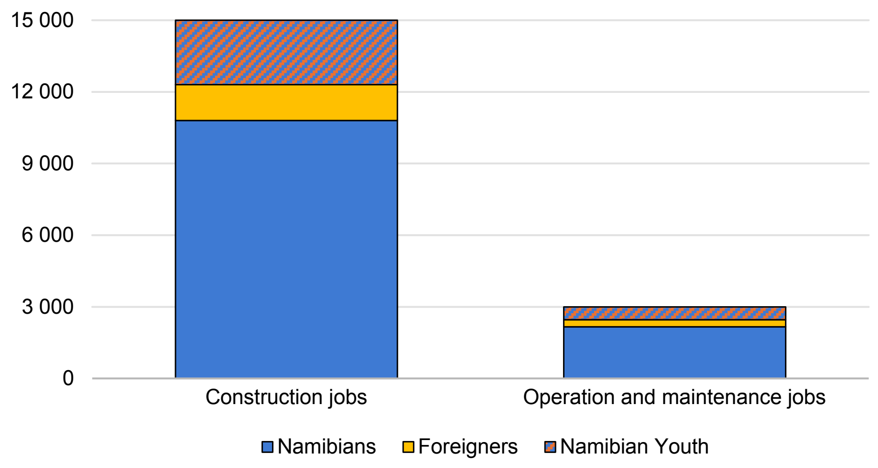
Hyphen's Socio-Economic Development Framework

As a large-scale renewable hydrogen project under development in Namibia – the largest in sub-Saharan Africa (see Chapter 4) – the Hyphen project could play a pivotal role in advancing socio-economic development. In 2023, Hyphen and the Government of Namibia launched a Socio-Economic Development Framework (SED Framework) as part of a broader Feasibility and Implementation Agreement. This agreement sets out a methodology for refining and establishing the project's targets on employment, local procurement and skills development, as well as enterprise and supplier development.

Hyphen estimates it could employ around 15 000 people during construction and 3 000 during operations, 90% of which could be Namibians (Figure 5.1), while local procurement could account for 30% of total project expenditures. The company has conducted a skills audit and gap analysis to target training interventions and skills development, the findings of which will inform discussions with the government on the final targets as per the SED Framework.

Both parties have expressed a desire to set a global standard for sustainable and equitable development of large-scale renewable hydrogen projects anchored in inclusive policies. Although Hyphen has not yet shared any further details, the project is considering supplying excess electricity to the country, including by oversizing electricity production beyond Hyphen's needs. The company has proposed a similar approach for the project's desalination plant, which could provide fresh water to the communities of Lüderitz and Aus.

Figure 5.1 Estimated employment impacts of the Hyphen project



Source: IEA analysis based on data from Hyphen (2023) Socio-Economic Framework.

The Daures Green Hydrogen Village model

The Daures Green Hydrogen Village, located in one of Namibia's poorest regions, is another renewable hydrogen project under development that centres around local community impact. This pilot project aims to validate the concept of sustainable renewable hydrogen and ammonia production while demonstrating the practical applications in the field – including local value creation through low-emissions agricultural practices that support local employment and partnerships.

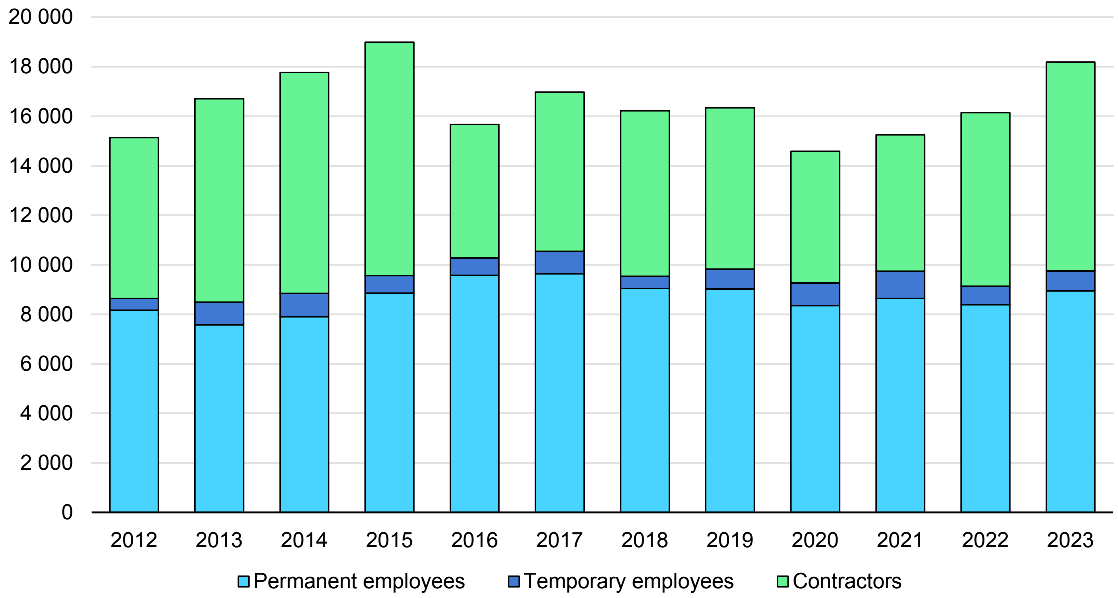
In the pilot phase of the project, water will be sourced from boreholes to produce hydrogen through electrolysis, with potential for the water to also support agricultural practices with irrigation. A water purification facility will be installed to provide clean water through reverse osmosis. In later phases of the project, desalinated water will be supplied via pipelines, which will notably serve housing and agricultural needs. Solar-powered boreholes will be installed in interested communities and connected to drip irrigation systems, while community members will receive training in horticulture and crop production, with a particular focus on tomatoes. The project also seeks to enter agreements with communities to collect, purchase, and resell crops on a regular basis. It foresees producing 18 t of H_2 and 100 t of NH_3 per year, which would be deployed for the producing ammonia sulphate fertilisers to grow crops in a co-located greenhouse. It also aims to support industrialisation efforts through the establishment of a solar-powered tomato paste processing plant. This initiative is expected to create sustainable jobs and bring improved food security to over thousand people in the constituency.

The project's partnership and shareholding structure reflects its local focus, with local community groups owning a 10% stake. The project has committed to source 50% of its workforce locally and award 30% of construction contracts to local small- and medium-sized enterprises, with both targets set to increase over time. The construction of the first phase of the project created 376 jobs for Namibians. Additionally, 30 permanent jobs will be created to support operations once the project is launched in Q4 2024.

Examples of socio-economic benefits in the mining sector

Mining is Namibia's largest industrial sector (over 14% of GDP in 2023) and a major contributor to its economic growth, job creation, infrastructure development and community services. In 2023, the sector employed more than 18 000 workers (Figure 5.2), marking a 13% increase from the previous year, driven by the expansion of existing and the opening of new ones, where 98% of employees were Namibians. While accounting for just 3% of total employment in Namibia, mines provide job opportunities, especially in rural areas. Approximately USD 400 million in wages and salaries is circulating within local economies.

Figure 5.2 Direct employment of Namibian mines, 2012-2023



Source: IEA analysis based on data from Namibian Chamber of Mines.

Mining companies are not required to invest in local community projects, but they are encouraged to do so through their mining licences. The Namibian government also actively promotes community involvement as a part of sustainable mining practices and good governance principles, such as increased transparency and multi-stakeholder dialogue. To maintain good relationships with both government and local communities, mining companies often invest in areas like education, healthcare, sport, art and housing.

The mining sector currently faces two new opportunities: transitioning from raw materials extraction toward value-added commodities, and switching to renewable electricity in their operations (see Chapter 3). Both could further enhance societal benefits and help to address some of the negative environmental impacts.

The impact of renewables adoption on the socio-economic benefits of mining are still not well understood. However, there is potential for it to generate new employment opportunities (e.g. in installation, maintenance and operation) enhance energy security and reduce energy costs as well as greenhouse gas emissions. Renewables would also provide local communities with a stable, low-emission energy supply and offer long-term social and health benefits through reduced pollution. The final outcomes will depend largely on factors such as the engagement of the local community and its workforce.

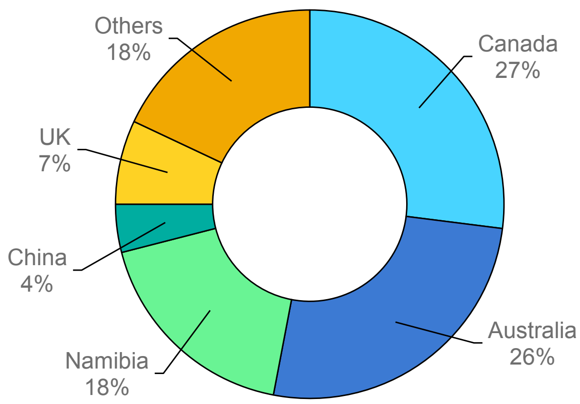
The shift to renewables also impacts infrastructure development, particularly through the expansion of electricity networks and substations which, once built, can also serve a wider set of end uses. Uranium mines, known for their high water consumption, have also invested in renewable-powered desalination plants that also provide water to local communities.

Integrating renewables into mining operations, including electrifying mining equipment, can significantly reduce the industry's environmental impact. By using renewable energy for power and transportation, mining companies can lower their CO_2 emissions, reducing their contribution to climate change. Electrification also lowers air pollution from diesel-powered equipment and improves air quality for workers and nearby communities. Additionally, switching to renewables reduces the risks of fuel spills and water contamination associated with fossil fuels.

To directly engage local communities in mining projects, the government mandated (from 2015 to 2018) that all mines seeking exploration licences to be partly owned (5%) and managed (20%) by historically disadvantaged Namibians. Mining companies faced difficulties finding qualified local partners and sought to invest in neighbouring countries instead. The policy was ultimately scrapped as a result, but in 2022, the Namibian government revisited the idea. It introduced a Draft Minerals Bill, which mandates government-held shares at no cost in Namibian mines. Specific details have not yet been disclosed.

Namibia took these steps because the country's mines are predominantly co-owned and operated by foreign companies and investors (82%) with the majority coming from Canada (27%) and Australia (26%). Most of Namibia's uranium mines are owned by China and Iran. Namibia holds 18% of the shares in the mining projects, with the Namibian government owning shares in gold, diamonds, uranium and copper mines (Figure 5.3).

Figure 5.3 The share of foreign companies operating Namibian mines, 2022



Source: IEA analysis based on data from the Namibian Chamber of Mines.

As part of expanding and diversifying their operations, mining companies have been providing training programmes to reskill and upskill local workers. They also provide training to their employees that focuses on bolstering soft skills that are transferable to other sectors such as leadership, supervisory management, project management, computer literacy and driving. Further investments in comprehensive, large-scale training programmes – organised jointly by the government and mining companies – could further benefit the workforce. Additionally, the introduction of new university-level curricula could broaden the reach and enhance skill development across a wider segment of the population. This has also been recognised by governmental policies and strategies.

Key enablers

Namibia has a clear vision to make its clean energy sector the cornerstone of a broader economic transformation. By harnessing its abundant renewable resources, vast areas of open land and strong and stable democratic institutions, the country is positioning itself at the forefront of catalytic change. Achieving these ambitions will depend on the interplay of three critical enablers – financing, policy and partnerships – without which this potential cannot be realised.

As clean energy projects are capital-intensive with large upfront costs, mobilising affordable finance is critical to secure investments. The cost of capital – a measure of how investors and financiers price the risks associated with an investment project in a given country – can be up to two to three times higher in emerging and developing markets than in advanced economies. Lowering this cost through targeted interventions combined with policy support will be at the heart of the interplays between these enablers. Policy design and calibration play important roles in de-risking projects by offering investors clear, transparent and predictable frameworks. Robust governance frameworks typically include guidelines for fiscal management and the use of sovereign wealth funds for natural resource revenues.

Building long-term partnerships with importing countries to create new markets for renewable hydrogen and its derivatives, as well as critical materials, will be equally important. They will allow exporting countries to secure reliable offtakers for their low-emission products and provide the required certainty to unlock investments. Useful experiences can be drawn from analogous industries, like liquified natural gas, whereby investments in infrastructure were underwritten at the outset by long-term take-or-pay agreements that guaranteed a revenue stream for developers.

Namibia has already been taking significant steps in pursuing all three enablers: it has signed memoranda of understanding with importing countries (see Chapters 3 and 4) to foster long-term partnerships; it has set up the country's first blended finance mechanism – the SDG Namibia One Fund – to support fund raising for renewable hydrogen projects; and it has established a sovereign wealth fund – the Welwitschia Fund – to promote the sound management of natural resource revenues, in view of ensuring prosperity across generations of Namibians. As it pursues its clean energy ambitions, Namibia can continue to learn from peers and experiment with policy innovations, charting its own path towards unlocking its potential to realise its sustainable development vision.

Annex

Explanatory notes

Terminology for hydrogen production

In this report, "low-emissions hydrogen" refers to hydrogen produced through electrolysis, with the electricity generated from a low-emissions source (renewable or nuclear resources), biomass, or fossil fuels with carbon capture utilisation and storage (CCUS). Meanwhile, "renewable hydrogen" is hydrogen produced via electrolysis, with the electricity generated from renewables. The same principle applies to low-emissions feedstocks and fuels made using low-emissions hydrogen, such as ammonia.

The IEA does not use colours to refer to the various hydrogen production routes. However, when referring to specific policy announcements, programmes, regulations and projects in which an authority has used a colour to define a hydrogen production route (e.g. green hydrogen), we use that terminology to report developments in this review.

Abbreviations and acronyms

ANAPEC	National Agency for the Promotion of Employment and Skills
CAPEX	capital expenditure
CCUS	carbon capture utilisation and storage
CO_2	carbon dioxide
CPPA	corporate power purchase agreement
DRC	Democratic Republic of Congo
DRI	direct reduced iron
ERGI	Energy Resource Governance Initiative
EUR	euro
FID	final investment decision
FIT	feed-in tariff
GDP	gross domestic product
GHG	greenhouse gas
HBI	hot briquetted iron
HPP	Harambee Prosperity Plan
H_2	hydrogen
IMF	International Monetary Fund
IPP	Independent Power Projects
JOGMEC	Japan Organization for Metals and Energy Security

LCOE	levelised cost of electricity
LHV	low heating value
LNG	liquified natural gas
LPG	liquified petroleum gas
MoU	Memorandum of Understanding
MSB	modified single buyer
NAD	Namibia dollar
NDP	National Development Plan
NGO	non-governmental organisation
NH_3	ammonia
NMC	nickel-manganese-cobalt
OPEC	Organization of the Petroleum Exporting Countries
OPEX	operational expenditure
PPA	power purchase agreement
PV	photovoltaic
R&D	research and development
REEs	rare earth elements
REFIT	Renewable Energy Feed-In Tariff
REIPPP	Renewable Energy Independent Power Producer Procurement Programme
RMIPPPP	Risk Mitigation Independent Power Producer Procurement Programme
SCDI	Southern Corridor Development Initiative
SDG	Sustainable Development Goal
SSA	Sub-Saharan Africa
TFC	total final consumption
TES	total energy supply
UNFCCC	United Nations Framework Convention on Climate Change
USD	United States Dollar

Units of measurement

bcm	billion cubic metres
GJ	gigajoule
kg	kilogramme
km^3	square kilometres
kWe	kilowatt electrical capacity
kWh	kilowatt hour
Mm^3	million cubic metres
Mt	million tonnes
MW	megawatt
MWh	megawatt hour
PJ	petajoule
TJ	terajoule
TWh	terawatt hour

IEA Publications
International Energy Agency
Website: www.iea.org
Contact information: www.iea.org/contact

Typeset in France by IEA - November 2024
Cover design: IEA
Photo credits: © Unsplash