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Green Hydrogen in Namibia: Opportunities and Risks

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Contents

Figures

Boxes

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Abbreviations

CO_2	carbon dioxide
EITI	Extractive Industry Transparency Initiative
GDP	gross domestic product
GW	gigawatt
HBI	hot-briquetted iron
IEA	International Energy Agency
kWh	kilowatt hour
kWp	kilowatts peak
MoU	memorandum of understanding
Mtpa	million tonnes per annum
MWh	megawatt hour
NGO	non-governmental organisation
PV	photovoltaics
SCDI	Southern Corridor Development Initiative
t	tonne
US	United States

Executive Summary

Namibia is a highly competitive location for renewable energy, which can be utilised to produce green hydrogen and various derivatives that are essential for decarbonising the global economy. Its government therefore has high hopes for this entire industrial complex, as do several European countries interested in importing green hydrogen and derivatives from Namibia. Large investments have in fact been announced, the largest one being US$10 billion, which is almost on the scale of Namibia's total gross domestic product. Although these investments are still under preparation, they have sparked a lively debate both in Namibia and internationally, showing that assumptions diverge considerably in terms of how realistic plans are and how much Namibia will benefit from these investments.

This discussion paper takes stock of where Namibia's plans currently stand and provides an initial assessment of the opportunities and risks inherent in the planned green hydrogen investments.

The hydrogen complex provides vast opportunities for domestic electrification, exports of green energy to South Africa as well as the export-oriented production of ammonia. At a later stage, further opportunities for value creation may arise based on internationally competitive renewable energy and green hydrogen costs. These include the export of sustainable aviation fuel, hot-briquetted iron for green steel production and fertiliser. Given Namibia's current development challenges – such as sluggish growth, deteriorating fiscal and current account balances, shallow economic diversification, dependence on volatile minerals-export markets, high unemployment and deficiencies in electricity supply – Namibia is well-advised to capitalise on its competitive advantages concerning renewable energy and green hydrogen.

The green hydrogen complex offers enormous prospects for foreign exchange earnings and economic growth. The most immediate opportunities lie in exporting green ammonia, as the localised costs of electricity will be low, and ammonia production is likely to be internationally competitive, provided that electrolyser investments can be attracted through competitive conditions and capital costs can be reduced via international guarantees. This said, considerable uncertainties remain regarding immature technologies, national production costs and international offtake prices. These call for a gradual scaling-up of hydrogen and ammonia investments, accompanied by continuous technology and market foresight, and carefully designed risk-sharing agreements with international investors. As renewable energy projects are rolled out, economies of scale will be reached that may allow Namibia to export clean electricity to South Africa, as a spin-off of ammonia exports. Down the line, other market opportunities may open up, including the export of sustainable aviation fuel, hot-briquetted iron and green fertiliser.

All of these industries create, at least hypothetically, opportunities for upstream and downstream industrial development and employment. Namibia's government is setting its hopes on wind tower and blade manufacturing, solar modules and electrolyser input production. We are, however, quite sceptical about these opportunities, as the experiences of more industrialised economies – including Brazil, India and South Africa – have shown how difficult it is to enter these complex industries. Similarly, although the temporary employment created during the construction phase of the green hydrogen infrastructure may be substantive, the government's optimistic employment estimates are not backed by evidence and seem to be grossly overstated.

Hydrogen investments come with political and environmental risks. Politically, the sheer size of the planned projects creates incentives for socially exclusive rent-seeking deals. Unless strict transparency rules are applied, directly partaking in deals with large investors may create opportunities for legal or extra-legal enrichment. Politically connected individuals and firms may

benefit from subcontracts and licences, for example for infrastructure works. Hence, it is essential to have full transparency for tenders and contracts. But even if all deals are fully transparent, this does not guarantee widespread benefits for the Namibian people. There may turn out to be fewer employment and other socio-economic spillovers than anticipated in the country's current strategy, projects may be less profitable than expected, and information asymmetries between large investors and Namibian policy-makers may translate into unfavourable risk- and benefit-sharing agreements. To ensure widely shared benefits, options for a pro-poor use of revenues from hydrogen projects should be explored to achieve socio-economic spillovers from financial investments in green hydrogen. These include direct dividend payments to citizens, earmarking of public revenues for development funds, mandatory oversizing of electricity generation and desalination to serve local communities, and co-ownership of energy projects.

From an environmental perspective, the most relevant risk factor seems to be maritime pollution, unless desalination plants use advanced technologies for reducing brine and ensuring appropriate controls when discharging it into the ocean. Another environmental risk lies in biodiversity impacts, especially when projects are located in declared national parks.

The discussion paper ends with seven policy recommendations to maximise the benefits and mitigate the risks of the hydrogen complex:

1. Invest in technology and market foresight and risk assessment. This paper highlights the manifold risks and uncertainties that may translate into project failure and increased public debt. Institutional support for evidence-based policy-making is essential to minimise such risks.

2. Conduct a detailed study on the labour-market effects of the various techno-industrial options. Current employment estimates are not sufficiently evidence-based and seem to grossly overstate the potential, partly because unrealistically high levels of domestic input manufacturing are assumed. Employment studies need to take entry barriers into account that may prevent firms based in Namibia from entering the respective value chains.

3. Public consultations about hydrogen projects should be improved. The principle of "prior and informed consent" is important, especially when large-scale projects with enormous potential spillover effects are prepared. Early engagement with public, industry and civil society stakeholders may lead to more inclusive project designs, allow for socio-ecological benefit-sharing, and ensure public acceptance of, and support for, hydrogen projects.

4. Large-scale investment contracts require due diligence to ensure a reasonable risk and benefit-sharing between investors and the host country. Institutional checks and balances for guarding against concentrations of power, bribery and corruption are of utmost importance when governments strike multi-billion-dollar deals. The Extractive Industry Transparency Initiative standard should be applied to large hydrogen investment projects to hold investors and government agencies accountable.

5. Regarding industrial policy and capacity-building, specific subsector strategies need to be devised to prioritise investments in national capabilities for promising technologies. Once agencies have – based on foresight activities – gained a better understanding of realistic value creation and employment opportunities, specific steps need to be taken to make targeted investments in specific skills and research centres, specifically to attract the most promising international investors that may help to develop those opportunities, and explore other support policies.

6. Concerning the development of revenue-sharing policies, especially direct dividend payments to citizens are a promising instrument to achieve poverty reduction and greater equity alongside greater accountability and public acceptance for hydrogen projects. Other

transfer mechanisms, such as community participation in investment projects or earmarking some of the hydrogen/ammonia incomes for development funds, may also have positive distributional effects.

7. Combine policies aimed at attracting hydrogen projects driven by foreign direct investment with the roll-out of renewable energy generation for other purposes. Renewables can improve the energy access of households and firms, help to overcome energy-import dependence and generate export revenues if surplus electricity is exported to South Africa. Pushing these objectives alongside hydrogen projects helps to create economies of scale for renewables, which in turn accelerate cost reduction and techno-institutional learning. Large international hydrogen investors are typically able to negotiate better financing conditions and pay lower interest rates than those proposing domestic-use projects, and investors can be encouraged to oversize their solar and wind parks to sell electricity to other off-takers. This requires comprehensive renewable energy incentive packages, including encouragement to oversize electricity production in hydrogen projects (e.g. making it a conditionality in hydrogen project tenders).

1 Introduction

Namibia's government has high hopes for green hydrogen, as do several European countries interested in importing green hydrogen and derivatives from Namibia. Large investments have been announced, the largest one being US$10 billion, comparable to Namibia's gross domestic product (GDP) in 2022 (US$12.9 billion: Hyphen Hydrogen Energy, s.a.-a). Although these investments are still under preparation, they have sparked a lively debate both in Namibia and internationally, showing that assumptions diverge considerably in terms of how realistic plans are and how much Namibia will benefit from these investments.

This discussion paper takes stock of where Namibia's plans currently stand and provides an initial assessment of the opportunities and risks inherent in the planned green hydrogen investments. The paper is a contribution to the HYPAT (Global H2 Potential Atlas) project, which is developing an atlas to identify potential partner countries of Germany for cooperative development on a future green hydrogen economy. Although it gathers information on Namibia's cost competitiveness as an exporter, the report's focus is on the opportunities and risks for Namibia and adopts an integrated national development perspective. Based on this assessment, some recommendations are derived for Namibian stakeholders as well as international development partners. The aim of these recommendations is to support hydrogen development pathways that contribute to inclusive and environmentally sustainable economic development while providing green hydrogen for the decarbonisation of industries.

The remainder of this paper consists of four sections. Section 2 offers a brief overview of Namibia's socio-economic challenges, with a focus on those aspects that may potentially be affected by the emerging green hydrogen economy. Section 3 presents Namibia's hydrogen production potential, the national development objectives associated with hydrogen, and some of the early actions taken to develop corridors, institutions and international partnerships. Section 4 then undertakes a critical assessment of the opportunities and challenges involved in massively scaling-up hydrogen investments in the country while considering socio-economic, political and environmental effects. Section 5 summarises and offers recommendations for Namibian policy-makers and international partners.

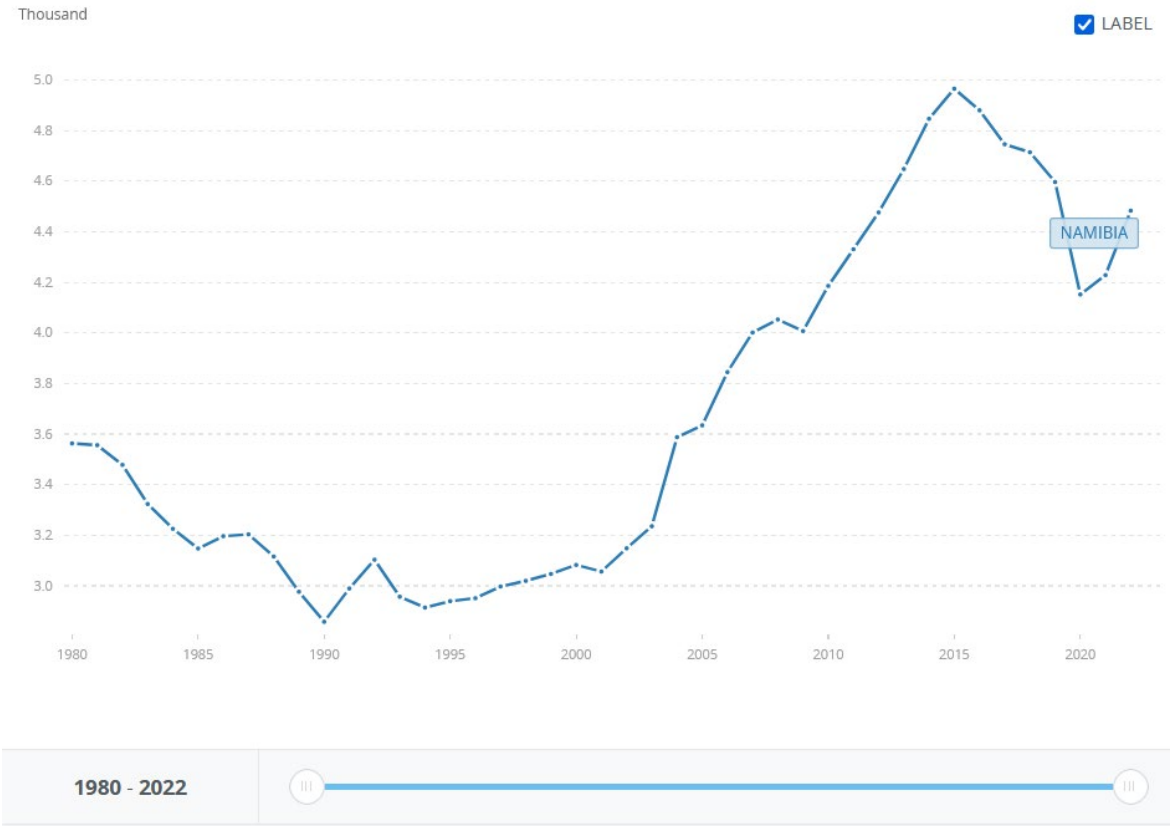
2 Namibia: some socio-economic challenges

With US$5,032 per capita (2022, in current US dollars), Namibia's per capita GDP is relatively high by the standards of Sub-Saharan Africa (World Bank, s.a.-a). It is classified as an upper-middle-income country by the World Bank, comparing favourably with most countries in Sub-Saharan Africa. This should, however, not obscure existing development challenges. First, the current economic basis for maintaining or increasing the relatively high per capital income is not sustainable, as it is highly dependent on exports of unprocessed minerals, with very little diversification into employment- and knowledge-intensive activities. This development pattern results in macroeconomic volatility, as commodity cycles directly impact on the domestic economy, without mitigating the effects from other activities. Lack of diversification, especially into employment-intensive activities, leads to another big challenge: Inequality is extraordinarily high, and large parts of the population are deprived of basic services for decent human development.

2.1 Minerals dependence, low levels of economic complexity and macroeconomic volatility

The current high-income levels are the result of an unusual commodity super cycle that spilled money into the Namibian economy. Between 2002 and 2015, the minerals sector experienced booming demand, largely driven by China's high economic growth and industrialisation. Extraordinary GDP growth was therefore achieved throughout this period, even in per capita terms. When prices of minerals fell back to normal historical levels, per capita GDP declined. The good news is that income levels are still substantially higher than before the commodity bonanza (Figure 1).

Figure 1: Namibia – GDP per capita in constant 2015 US$



Source: World Bank (s.a.-b)

However, macroeconomic indicators, for example the payments and trade balances, are deteriorating, and debt as a percentage of GDP increased from 55 per cent (2018) to 80 per cent (2021), with a forecast to increase to 90 per cent in 2023 (World Bank, 2021a). Prospects for further GDP growth are therefore not promising in the short run.

Namibia's key structural problem is its dependency on the export of unprocessed minerals – diamonds, gold, uranium, zinc, copper and others – as well as fish. Diamonds account for almost half of the country's foreign exchange earnings. A number of other minerals – including silver, lead, tin, lithium, cadmium and tungsten – are being extracted in Namibia, even though current export figures are still low. There are known deposits of oil and iron ore, and projects are being planned, especially for the production of iron. Raw material exports may allow for high mineral rents, especially when prices on the world market are high. However, to what extent governments are able to capture a significant part of these rents – and to what extent they use it for their national development – varies considerably depending on the country and the mineral.

Moreover, commodity prices are susceptible to price volatility (International Energy Agency [IEA], 2023), and mining tends to be dominated by foreign multinationals, inducing only very few forward and backward linkages with African firms, therefore contributing little to economic diversification and technological learning (Ericsson & Löf, 2019). With the share of mining jobs in overall employment oscillating between 1 per cent and 3 per cent, the mining sectors' employment effects are very low relative to its export share (ICMM, 2014). Namibia's mining sector, which accounts for 12.2 per cent of GDP, only provides 16,100 direct jobs, of which only 8,400 are permanent (Kaira, 2023). Moreover, automation and robotics are increasingly substituting labour in the mining industry (Paredes & Fleming-Munoz, 2021). Africa-wide, employment in minerals and metals is stagnating at around 800,000 jobs, despite considerable output growth (Andreoni & Avenyo, 2023, p. 44).

Next to minerals, tourism is an important source of income for Namibia and has a broader development effect, contributing 3.5 per cent to total GDP and directly employing 44,700, yet with very little job creation in rural communities (Deutsche Gesellschaft für Internationale Zusammenarbeit [GIZ], 2022b). Twenty-two per cent of the Namibian workforce is employed in agriculture, mainly on small farms, which yield low incomes. The majority of Namibia's population depends directly or indirectly on the agricultural sector for their livelihoods. Yet, despite its importance, the agricultural sector's contribution to the country's GDP (excluding fishing) has been just over 4 per cent for the last five years (International Trade Administration, 2024). Agricultural productivity is severely restricted by water availability, as Namibia is "the driest country in Sub-Saharan Africa" (World Bank, 2021b, p. 21). Almost the entire country is arid or, along the coastline, even hyperarid (Atlas of Namibia, s.a.). Only a small stretch of land in the extreme north is semi-arid. This is where sparse and irregular rainfall allows for smallholder agriculture. Over half of the population resides in rural areas, mainly concentrated in the better-irrigated north to north-eastern regions. Due to aridity, Namibia is the second-least densely populated country globally (DeBoom, 2020).

Given its economic structure, Namibia ranks very low on the Economic Complexity Index (Hausmann et al., 2022), which is a proxy of the knowledge accumulated through the economic activities of a country (Hidalgo & Hausmann, 2009). The challenge is thus to diversify the economy, both towards more labour-intensive activities as well as more complex and productive activities.

2.2 Inequality and exclusion

As a result of its economic structure, Namibia faces significant poverty and income disparities. With a Gini index of 59.1, Namibia is the most unequal country in the world, aside from South Africa (according to the last available figures from 2015: World Bank, 2021a). A majority of Namibians have less than US$2 per day for living expenses (DeBoom, 2020, p. 11). Inequality is also reflected in access to services covering basic needs, such as clean water and electricity. According to the Central Intelligence Agency (CIA, 2022), 8.6 per cent of Namibia's total population – and an even higher 16.8 per cent of the rural population – only have access to unsafe drinking water sources such as unprotected wells, springs or surface water. Only 55 per cent of the population have access to electricity, with significant differences between urban (78 per cent) and rural communities (33 per cent: World Bank, 2023), as Namibia's sparse population density increases the cost of grid connections. Approximately 1.12 million people, equivalent to around 300,000 households, lack access to electricity. Moreover, electricity prices have more than doubled since 2011 (GIZ, 2022a, p. 6). Namibia is a net electricity importer, with 3.4 billion kilowatt hours (kWh) of imported and 119 million kWh of exported electricity (CIA, 2022). Coal-based power from South Africa accounts for the largest share (Amesho, Edoun, Iikela, Kadhila, & Nangombe, 2022, p. 87; GIZ, 2022a, p. 2). Unemployment stood at around 20 per cent in 2023 (World Bank, s.a.-c), while underemployment is much higher.

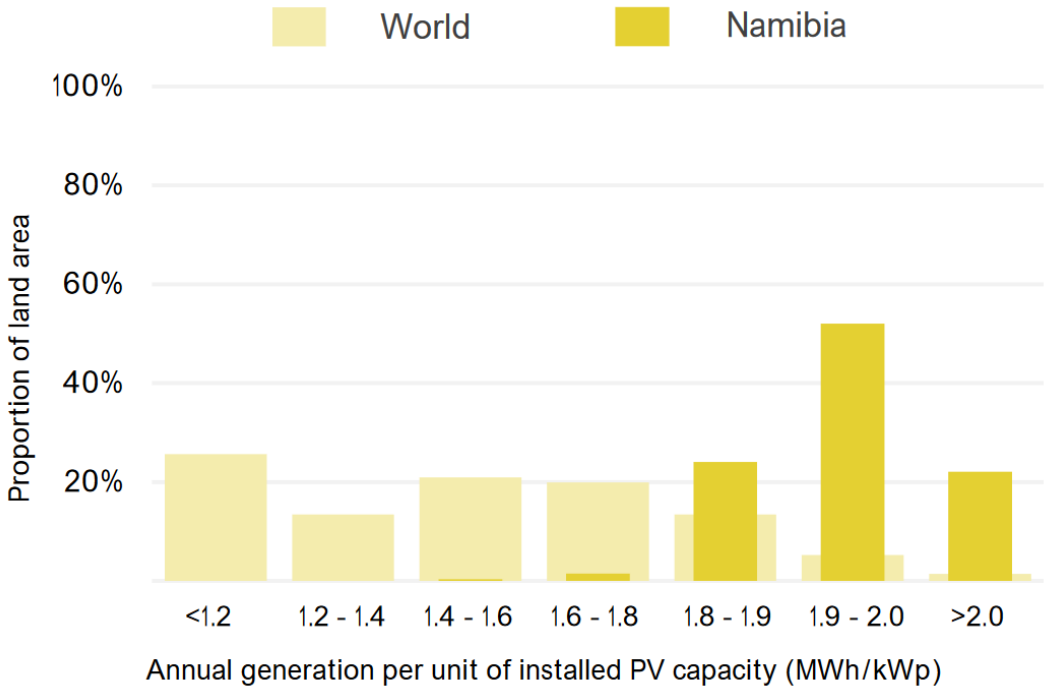
Overall, Namibia is struggling with a range of interdependent economic and social problems: sluggish growth, dependence on a volatile and socially exclusive mining industry, deteriorating financial indicators, and thus reduced policy space for investing in social welfare and economic diversification. The following section explores to what extent the growing global demand for green hydrogen offers prospects to mitigate or even overcome these structural deficits.

3 High hopes: Namibia's hydrogen potential, development plans and investment projects

3.1 Comparative advantage for renewables

Namibia is blessed with abundant solar energy resources, with more than 3,000 sun hours per year and an annual solar irradiation of 2,200 to 2,400 kWh/m² in many regions (GIZ, 2022a). Figure 2 compares annual generation potential per unit of installed photovoltaics (PV) capacity in Namibia and worldwide. It shows that almost the entire country has the capacity to generate more than 1.8 MWh/kWp (megawatt hours/ kilowatts peak) per unit of installed PV, clearly at the top end of the average global capacity.

Figure 2: Distribution of solar potential for Namibia



Source: International Renewable Energy Agency (IRENA, 2023)

Some coastal regions also offer high, constant wind speeds and are thus ideal for wind farms, especially along the southern coast near Lüderitz and in the coastal region on the Angolan border (GIZ, 2022a). Onshore wind turbines are thus similarly profitable in some regions. The combination of good wind and solar potential reduces intermittency problems and increases the full load hours of electrolysers (Fragoso García et al., 2022). Overall, renewable energy is thus much cheaper than fossil alternatives in Namibia.

With low-cost renewable energy, it is also possible to produce green hydrogen and derivatives such as ammonia and methanol at competitive costs, provided that investors have access to

capital and electrolyser technologies at competitive prices. Namibia can thus exploit its renewable energy sources threefold:

- to roll out renewables for domestic electrification;
- to produce hydrogen and derivatives: power-to-green hydrogen production costs are estimated at US$1.5 per kg of hydrogen by 2030 (IEA, 2021), which is among the lowest worldwide, equalled only by few competitors, including Chile and Saudi Arabia; and
- to export electricity to South Africa, where power production falls short of supply, as the country suffers from severe load shedding and has to close down many of its outdated, inefficient coal-fired power plants.

Targeting all three markets in parallel would create economies of scale and thereby increase production efficiency.

Another big competitive advantage lies in land availability. Given its vast tracts of arid, extremely sparsely populated land, Namibia potentially offers space for energy projects on government-owned land. Namibia's Green Hydrogen and Derivatives Strategy emphasises the role of state-owned land for the development of green hydrogen and points out that the Namibian government owns and can lease substantial amounts of land due to the country's low population density of three people per km² (Ministry of Mines and Energy [MME], 2022, p. 17). A notable exception are protected areas, such as nature reserves, game parks, military bases and some urban land, which account for approximately 14 per cent of Namibia's land. Additionally, the state owns all communal land, holding it in trust for the Namibian people, with a special emphasis on the interests of indigenous tribes. Communal land thus cannot be sold, but the current law allows for land leases; transfers of use rights, however, must go through the traditional authorities and Land Board (Republic of Namibia, 2002). In this light, Namibia's colonisation by Germany in 1884 (until World War I) is relevant, as several Namibian communities – whose ancestors were massacred by German colonial forces and had their properties seized more than a century ago – are again calling for re-negotiations with Berlin, demanding the return of ancestral lands (Gbadamosi, 2024). The competitive advantage of sparsely populated land availability thus needs to be addressed in the context of ongoing local and international land disputes.

Yet, compared to most other countries in the region, Namibia is considered to be politically and judicially stable, offering an investor-friendly business environment. It has an independent judicial system, property and contractual rights are protected, and infrastructure is good by African standards. For 2022, Namibia ranks 59th (of 180) in the Transparency International Corruption Perception Index (Transparency International, 2023) and 104th (of 190) on the Doing Business report (World Bank, s.a.-d), which compares well with the rest of the region.

3.2 Hydrogen-related development objectives

Given these comparative advantages, Namibia's government has high hopes for its national development. As spelt out in the Green Hydrogen and Derivatives Strategy, the main short-term opportunities are seen in the export of green ammonia. The world market for green ammonia is expected to grow fast and to serve as a substitute for fossil-fuel-based "grey" ammonia in fertiliser production and other chemical industry uses as well as to be used as low-carbon shipping fuel, among other things. The production in Namibia of other derivatives is expected to follow a few years later: methanol, e-kerosene and green hydrogen-based hot-briquetted iron (MME, 2022). Green ammonia is expected to be exported at competitive prices of approximately US$400/t (per tonne) ammonia by 2030, decreasing to US$350/t by 2040; below US$400/t, Namibian green ammonia would even become cost-competitive with "grey" ammonia (African Climate Foundation & SystemIQ, 2022).

Box 1: Green hydrogen and important derivatives

Green hydrogen is an energy carrier. It is produced by using renewable energy to split water into hydrogen and oxygen. Hydrogen can then be used to decarbonise sectors, especially those that cannot be decarbonised via electrification. Emission-intensive activities that require hydrogen for decarbonisation include the production of steel and cement as well as many other industries, including transport activities – especially aviation – shipping, and heavy-duty, long-distance land transport.

Green hydrogen can be converted into derivatives when refined with either nitrogen for green ammonia, or carbon dioxide (CO_2) for green methanol and sustainable aviation fuel. These derivatives can more easily be stored and transported. **Green ammonia** is produced by combining green hydrogen with nitrogen captured from the atmosphere via the Haber-Bosch process. Green ammonia will be essential for low-carbon fertiliser production and as a green fuel for shipping. **Green methanol** and **sustainable aviation fuel** require CO_2 and green hydrogen as inputs. The CO_2 can come from biogenic sources (such as organic waste and cultivated oilseeds), or it can be captured from the atmosphere or industrial plants using carbon capture and utilisation technologies.

Source: Authors

The country "aspires to reach green hydrogen production volumes of 10-15 Mtpa [million tonnes per annum] by 2050 (corresponding to 5-8 per cent of expected international hydrogen equivalent trade volume)" (MME, 2022, p. 23). This would start with 1-2 Mtpa hydrogen equivalent in 2030 and then increase rapidly.

The Namibian government is pursuing several objectives through the development of a green hydrogen economy.

Economic growth: Hydrogen investments at the envisaged scale would give an unprecedented boost to Namibia's small economy. According to the Green Hydrogen and Derivatives Strategy,

> an at-scale hydrogen industry could grow Namibia's economy substantially. By 2030, it could contribute US$4.1 billion (in real 2022 dollars) to GDP, 32 per cent more than 2030 GDP estimates with no hydrogen industry. By 2040, it could generate an additional US$6.1 billion, 32 per cent higher than current GDP estimates. (MME, 2022, p. 32)

Fiscal sustainability: As the currently planned mega-projects are export-oriented and the local demand for local uses is minimal, hydrogen investments are expected to significantly improve Namibia's balance of trade as well as its balance of payment. This is assuming that projects are successful and generate export incomes that at least compensate for upfront investments in imported solar, wind, electrolysers, pipeline and desalination equipment and infrastructure etc., as well as licence payments. Exports are difficult to estimate at this stage, but one study suggests that "upwards of US$15bn green ammonia exports in 2040" (African Climate Foundation & SystemIQ, 2022, p. 42) might be realistic. Likewise, the Namibian government can expect increased tax income, depending on the exemption granted to investors and assuming that additional tax incomes exceed obligations in terms of public investments, investment guarantees and the like. *Failed* investments, on the other hand, constitute a risk for public finances.

Industrialisation: While initial large investments will be realised by international companies, Namibia hopes to localise part of the green hydrogen value chain. As specified in the Green Hydrogen and Derivatives Strategy,

> local tower and blade manufacturing could generate US$7 billion direct GDP impact in 2035-40; […] localizing solar cell and module manufacturing could generate US$4 billion direct GDP impact

> in 2035-40 […] and localizing stack (non-membrane) and BoP manufacturing could generate US$5 billion direct GDP impact in 2035-40. (MME, 2022, p. 32)

Additional stimuli for industrial development are expected via the recruitment of energy-intensive manufacturing into the country (Republic of Namibia, 2022, pp. 4, 6). Overall, hydrogen is portrayed as a "once in a generation opportunity to jump start Namibia's industrialization" (Republic of Namibia, 2022).

Employment: Hydrogen projects are expected to have substantive employment effects. The national strategy expects the creation of

> an estimated 280,000 jobs by 2030 and 600,000 jobs by 2040. Of these, about 30 per cent would be direct (in the industry), 20 per cent would be indirect (through goods and services), and 50 per cent would be induced by the increase in household incomes. (MME, 2022, p. 31)

For some industries, employment assumptions have been specified, for example wind tower and blade manufacturing, solar cell and module manufacturing, and electrolyser manufacturing – 7,000, 4,000 and 5,000 direct jobs, respectively, by 2035-2040 (MME, 2022, p. 32). To harness these potentials for the Namibian workforce, the strategy recognises the need for major investments in skills development, implementing training programmes and policies to enable Namibian citizens to actively participate in the development of a hydrogen economy.

Energy security: The establishment of a green hydrogen economy is expected to have a positive impact on energy security and independence in Namibia (Republic of Namibia, 2022, pp. 4, 6). Namibia aims to achieve 80 per cent self-sufficiency in primary energy (including solar, wind, hydro and gas) for power generation by 2029 (MME, 2022, p. 35). As stated earlier, Namibia is currently dependent on energy imports from South Africa, which in 2023 declared a "state of disaster" over the national energy crisis (Voice of America, 2023). Moreover, Namibia has one of the most expensive end-customer tariffs in the Southern African Development Community region (Kruger, 2022, pp. 12, 18). Over the last decade, prices have more than doubled, further increasing accessibility challenges for the population. By attracting renewable energy investments, Namibia could shift from a risky and expensive energy-import dependence to profitably exporting electricity.

Decarbonisation: Namibia's Green Hydrogen Council published its Green Hydrogen and Derivatives Strategy during COP27 in 2022, aligning with the country's commitment to the Paris Agreement's goal of achieving net-zero emissions by 2050. The government aims to decrease greenhouse gas emissions by 91 per cent by 2030 (MME, 2022, 5). It should be noted that Namibia is not responsible for global warming, having emitted 3.95 million tonnes of CO_2 in 2022, compared to 37.15 billion tonnes of global emissions (in the same year, Germany emitted 665.60 million tonnes of CO_2; Global Carbon Budget, 2023). At the same time, Namibia is extremely vulnerable to global warming's adverse impacts. That said, and while hydrogen projects are mostly geared towards exports, some domestic uses for decarbonisation are being considered. In particular, hydrogen can be utilised in Namibia for heavy-duty transport (trucks and buses running on fuel cells, mine-site trucks, long-distance rail) and fertiliser production (African Climate Foundation & SystemIQ, 2022, p. 22; Republic of Namibia, 2022, p. 19).

To fully exploit its hydrogen opportunities, Namibia has created new – and added capacities to existing – institutions. Box 2 shows key institutions supporting the emerging hydrogen economy.

Box 2: Institutional set-up supporting green hydrogen

The Namibian government has created a set of new institutions supporting green hydrogen, including:

* an inter-ministerial **Green Hydrogen Council** and a **Green Hydrogen Commissioner**, currently James Mnyupe, to serve as political advisors to the Office of the President on this topic (IRENA, 2022, p. 49). The Green Hydrogen Council is chaired by Obeth Mbui Kandjoze, Director General of the National Planning Commission, the agency responsible for planning national priorities and directing the course of national development. Considering the advice of the Green Hydrogen Council, the Cabinet of the Government of the Republic of Namibia is responsible for approving hydrogen plans and projects under the Southern Corridor Development Initiative (SCDI, see below).

* the **Namibia Green Hydrogen Research Institute** (NGHRI). After signing an agreement with Germany, Namibia started to establish the NGHRI within the University of Namibia. It will consist of six centres with different green-hydrogen-related foci, spanning from production and use technologies to legal issues and societal impact (Etango, 2021).

Also, the following – already existing – entities play important roles in the market ramp-up:

* **Namibia** Investment **Promotion and Development Board** (NIPDB) is a public entity in the Office of the President and serves as a one-stop shop for all companies aspiring to do business in Namibia. The NIPDB highlights hydrogen production as a strategic instrument, particularly in reference to the country's Harambee Prosperity Plan II, launched in 2021, for economic recovery and inclusive growth (Republic of Namibia, 2022, p. 21).

* The **Ministry of Mines and Energy** (MME), specifically its Electricity and Renewable Energy Division, plays a crucial role in the planning, procuring and monitoring of future green hydrogen projects following the directive of the Green Hydrogen and Derivatives Strategy. The ministry has a particular stake in the strategy's goals to fast-track green hydrogen production for decarbonisation and achieve self-sufficiency from an electricity and primary energy perspective. Moreover, the increase of renewable-energy production capacity for the generation of green hydrogen – but also for an increase in the electrification rates across the country – falls under the responsibility of the ministry.

* The **Electricity Control Board** plays a significant role for private investors' access to the energy sector by setting up regulatory guidelines, issuing licences and permits, establishing quality supply standards, and developing tariff methodologies (Amesho et al., 2022, p. 90). Licensing has in the past often been slow, which can delay energy projects.

Electricity distribution and access to transmission grids has been traditionally controlled by the state-owned utility, Namibia **Power Corporation** (Pty) Ltd (NamPower), but due to market liberalisation efforts by the government, it is increasingly shared by NamPower and independent power producers.

* The **NGHRI** is an intermediate stakeholder serving in a research and advisory capacity to policy and industry stakeholders. It is hosted by the University of Namibia and aims to support sustainable energy initiatives to train (future) business leaders, impart needed skills in the field and promote "green" entrepreneurship in general.

Source: Authors

3.3 International hydrogen partnerships

Export-oriented hydrogen projects require reliable international off-takers. In fact, given the ambitious decarbonisation pathways in European and other advanced economies and the anticipated scarcity of green hydrogen supplies, there is considerable international interest in establishing international hydrogen partnerships to accelerate investments and offtake agreements.

Namibia has identified potential partner countries and regions for its green hydrogen endeavour, including China, Japan, Korea, Europe and North America. These are projected to be the primary recipients of green hydrogen by 2030, as they are driven by their ambitious decarbonisation targets (MME, 2022, p. 12). By strategically aligning with these partners, Namibia seeks to leverage its renewable energy capabilities and green hydrogen potential to solidify its position as a key player in the global green energy landscape.

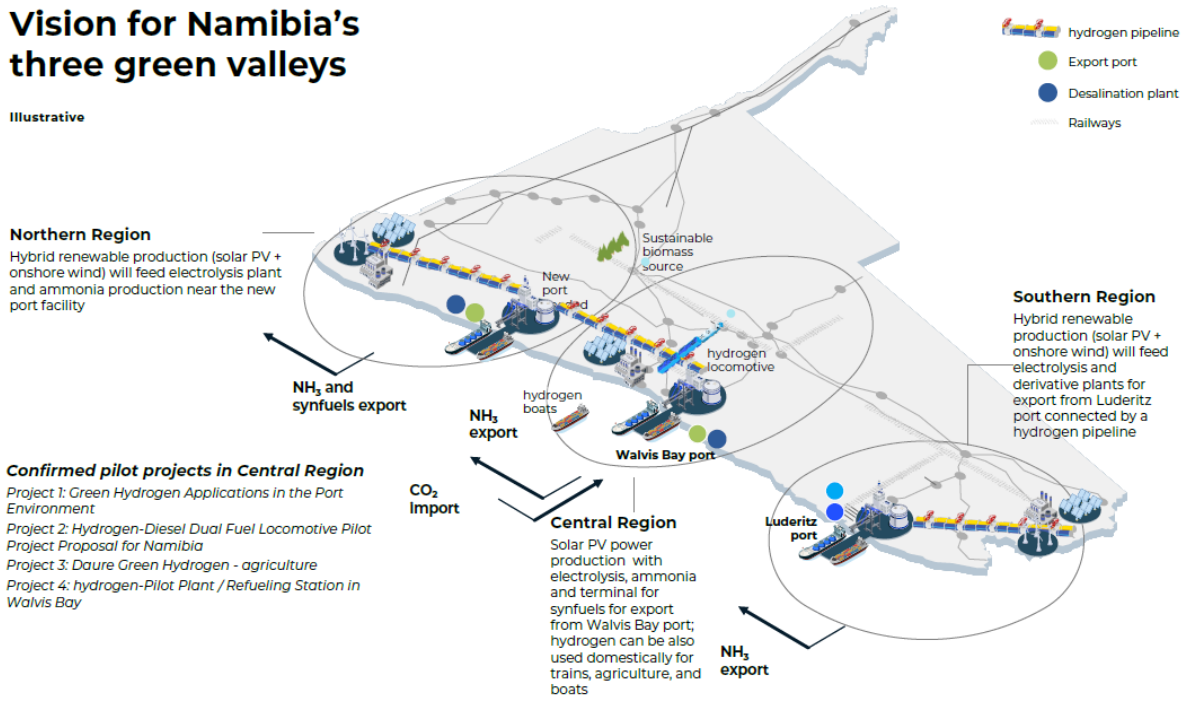
In August 2021, the Republics of Namibia and Germany signed a Joint Communiqué of Intent to govern their cooperation in the renewable energy sector. The Communiqué aims to promote cooperation between the two countries in the fields of green hydrogen and its associated derivatives, renewable electricity and infrastructure development (Federal Ministry of Education and Research [BMBF], 2021, p. 1). The cooperation involves exchanging information, strengthening technical and strategic partnerships, conducting feasibility research on renewable energy and green hydrogen production, and implementing pilot projects (BMBF, 2021, pp. 2-3). As part of the agreement, Germany commits to providing €40 million in grant funding. In return, Germany is assured of gaining a dominant position in Namibia's hydrogen policy (BMBF, 2021, p. 4).

Belgium has also signed a memorandum of understanding (MoU) with the Namibian government to provide assistance in developing hydrogen refuelling stations and a solar power plant (Republic of Namibia, 2022, p. 17). The Netherlands followed with an MoU in 2023, focusing on interests related to ports for the transport and export of green hydrogen, as did the European Union, whose MoU includes support for an upcoming study for the development of the Port of Walvis Bay into an industrial and logistics hub (European Union, 2023). Additional MoUs are being prepared, including with Japanese stakeholders (MME, 2022, p. 41).

3.4 The spatial dimension: hydrogen corridors

The Green Hydrogen and Derivatives Strategy envisions the creation of three hydrogen valleys located in the southern region of Kharas, which is the central region encompassing the port of Walvis Bay and the capital, Windhoek, as well as the northern region of Kunene. These hydrogen valleys are intended to become focal points for the development and deployment of green hydrogen projects (Figure 3).

Figure 3: Namibia's plans for three "hydrogen valleys"



Source: MME (2022, p. 24)

For the southern region, Namibia's government has initiated the Southern Corridor Development Initiative (SCDI) to attract investment into green hydrogen infrastructure within the country. The SCDI outlines the government's action plan, aiming to establish Namibia as a major global hydrogen producer by March 2025. Key objectives of the strategy include the implementation of a fit-for-purpose legislative framework, the establishment of a one-stop-shop agency for streamlined execution, addressing conflicting land rights, and providing support mechanisms for cost-effective production, local content manufacturing, skills development and project financing.

The primary international and national focus lies currently on Tsau //Khaeb National Park (Hyphen SCDI), that is, the Hyphen project, which is planned to begin production in 2026. The first phase aims to generate 2 gigawatts (GW) of renewable energy to produce green hydrogen, which will then be converted into green ammonia (Republic of Namibia, 2022, p. 6). The project involves a green hydrogen and ammonia plant, sites for wind and solar power, as well as electrolysis and desalination facilities – at an estimated cumulative capital cost of US$4.4 billion. The intended surplus of electricity will be fed into the national grid and possibly even the Southern African Power Pool. Furthermore, desalinated water production is expected to exceed the plant's needs, allowing for additional supply to nearby communities (IRENA, 2022, p. 44). The project promises further co-benefits, including infrastructure outputs such as improved roads for tourism access in the affected areas and enhancements to rail tracks (Hyphen Hydrogen Energy, s.a.-a). Additional phases of expansion are planned for the late 2020s, with a combined renewable generation electrolyser capacity of 5 GW and 3 GW. This would increase the combined total investment to US$9.4 billion and green hydrogen production to 300,000 tonnes (GIZ, 2022a). The total investment volume for this planned project is currently estimated at US$9.4 billion (GIZ, 2022a, p. 4), and its success is seen as crucial in de-risking and paving the way for future hydrogen economy projects in Namibia (MME, 2022, p. 26). Currently, the project is undergoing the required environmental and social impact assessments.

Hyphen Hydrogen Energy (Ty) Ltd is a registered project development company in Namibia established with the objective of developing, constructing and operating green hydrogen production facilities in Namibia to supply international and regional markets. The company

successfully bid on two land parcels within Tsau //Khaeb National Park for the development of large-scale green hydrogen production facilities. It was granted a 40-year concession for more than 4,000 km^2 of land for this purpose. Hyphen is a joint venture between ENERTRAG and Nicholas Holdings. The company has signed an MoU with several stakeholders, including the Government of the Republic of Namibia, Namibian Ports Authority, NamPower, the Port of Rotterdam, Gasunie, Invest International and Germany's energy utility RWE.

4 A critical assessment of opportunities and challenges

Hydrogen investments can contribute to national development via a variety of impact channels. In Section 3.2 we presented the government's objectives in terms of economic growth, financial sustainability, industrialisation, employment, energy security and decarbonisation. Given a range of uncertainties regarding hydrogen development, however, the hopes set on hydrogen opportunities may not fully materialise. In fact, uncertainties and risks are manifold: that investments are not undertaken at the expected scale, because other destinations may be more attractive; because global decarbonisation plans suffer from political backlashes; because key technologies mature more slowly than expected; or because of internal opposition. Even if investments are scaled up as expected, in terms of profitability and socio-economic spillovers, expectations may fall short, and there may be unintended consequences in terms of land-use conflict and environmental costs.

In this section, we undertake a critical assessment of opportunities and challenges, drawing on stakeholder interviews and the literature discussing international hydrogen trends; the political economy of resource-based industrialisation; the hydrogen industry's characteristics (especially considering technological alternatives and entry barriers for countries with low levels of industrialisation and technological sophistication); lessons from similar industries; case studies on the environmental risks of green hydrogen and desalination; as well as information on Namibia's political economy and decision-making processes.

It should be noted that the hydrogen industry is not yet established, with manifold uncertainties regarding general and country-specific costs and risks. Hence, many determinants are still in flux. The following assessment is therefore preliminary and will need to be updated as the hydrogen economy matures. Any attempt to predict positive and negative effects at this stage needs to be treated with much caution. Yet, we hope our analysis helps to provide a deeper understanding of the challenges and trade-offs ahead, and thereby offer useful guidelines for policy decisions. In the following, we distinguish five dimensions that critically determine the extent to which green hydrogen investments may enhance or undermine Namibia's development.

4.1 Prospects for foreign exchange earnings and economic growth amidst economic uncertainty

Namibia's policy documents underline the high expectations regarding foreign exchange earnings, which will eventually enhance the financial sustainability of Namibia's economic growth. In fact, foreign exchange earnings will most likely become the most relevant contributor to Namibia's development, as we assess that the short- and mid-term prospects for industrial linkages and employment creation will be relatively modest (see Sections 4.2 and 4.3).

Foreign exchange earnings can be generated from a variety of exports:

- *Green ammonia, the most competitive near-term opportunity*. International market assessments predict enormous market growth, as grey ammonia, which is used for fertiliser production, will need to be replaced with green ammonia. Moreover, demand for ammonia will receive an additional boost, as many of the hydrogen-related, privately funded investment projects around the world target ammonia, including Namibia's most advanced large-scale project. Moreover, renewable energy and ammonia production costs are relatively well-known and predictable. The government's assumptions regarding price competitiveness seem to be backed by reasonable estimates: "By 2030, Namibia's ammonia production costs could fall to US$420-460/tonne and to US$320-360/tonne by 2050 as technology improves, volumes increase and standardization drives learning rates and lowers equipment costs" (MME, 2022, p. 18);

- *Renewable energy trade with other countries in the region*. South Africa's electricity market is still highly dependent on coal-fired power plants, most of which need to be shut down, not only due to their emissions, but also their inefficiency. The lack of investment in electricity generation has resulted in massive load shedding, which severely affects the entire economy. At the same time, the deployment of solar and wind projects has been slow. If renewable energy projects are developed and implemented at scale, Namibia could sell "electricity to Southern Africa's power pool at ~5-6 US¢/kWh" (African Climate Foundation & SystemIQ, 2022, 2022, p. 18);

- *Other derivatives and downstream industries, including sustainable aviation fuel, green steel and fertilisers*. Multiple industries may offer promising opportunities but do not seem to be realistic near-term options, as there are many open issues, such as carbon sources for sustainable aviation fuel, minimum-scale requirements for steel plants, Namibia's geographic isolation, etc. See African Climate Foundation and SystemIQ (2022) for a detailed discussion.

How large the earnings will be depends on a multitude of uncertain developments. Some of those can be controlled by Namibian policy-makers, others cannot. The ones that can be influenced domestically, through regulatory frameworks and financing conditions, include the scale of investments and the deployment speed of renewables and hydrogen projects, which in turn affect the levelised cost of green energy. The ones that are beyond Namibia's control are more problematic. Here, we briefly discuss two (interdependent) sources of uncertainty: technology and price.

- **Technological uncertainties:** The international green hydrogen economy is far from being fully established. Rather, it is in an "era of ferment" (Anderson & Tushman, 1990), which is typical of newly emerging technologies: The shift towards a hydrogen economy implies technological discontinuities, as major technologies – both for the production of hydrogen (e.g. industrial-scale electrolysis), for its transport (e.g. vessels for the safe transport of derivatives) and for its use (e.g. direct reduced iron steel-making, ammonia cracking) – are not yet established, at least not on a commercial scale. In an era of ferment, investors experiment with alternative technologies until a certain technology becomes the "dominant design" (Utterback & Abernathy, 1975) that attracts the most investments and therefore exploits economies of scale and allows for rapidly falling prices. Investments during the era of ferment are costly (before technological progress and economies of scale bring costs down) and risky, as the optimal technology as well as its potential spillovers to, and interaction with, socio-ecological systems is not yet known. For example, four competing electrolyser technologies are currently being tested. In the case of green hydrogen, additional uncertainties stem from the competition between green and blue hydrogen (low gas prices and rapid advancements in carbon capture and utilisation technologies may undermine or postpone the price competitiveness of green hydrogen); from uncertainty regarding the relative demand of various derivatives, which in some cases can be used as

substitutes; and from uncertainty about when sufficient, dedicated tank ships, for example for ammonia, will become available.

- **Price uncertainties:** All of the technological uncertainties have obvious and strong repercussions on prices, for example technological progress determines how rapidly the costs of electrolysers come down (IRENA, 2020). Plus, there are additional sources of uncertainty affecting the production costs of hydrogen and derivatives, competitiveness vis-à-vis alternatives and the prices that off-takers are willing to pay. The hydrogen market is being driven by political commitments to decarbonise. Incumbent (fossil) technological alternatives are considerably cheaper, as long as environmental externalities are not fully accounted for. Hence, regulatory pressure, such as binding, industry-specific decarbonisation targets (e.g. aviation fuel blending requirements) as well as carbon pricing policies and decarbonisation subsidies (such as carbon contracts for difference) are decisive for hydrogen demand. All of these framework conditions are subject to political changes and industry lobbying in the main offtake markets, which makes projections difficult. A further source of uncertainty is the competition between green and other "colours" of hydrogen: Blue and "pink" hydrogen (using nuclear energy) may be acceptable in some jurisdictions, but not in others, and they directly compete with the green option in the international market. Last but not least, the cost of capital for investments in Namibia is not internationally competitive (African Climate Foundation & SystemIQ, 2022), given the risk premiums, which depend on international rating agencies. Given all these uncertainties, long-term agreements with international offtakers are a necessary precondition for mobilising capital. Given current prices, offtakers may be willing to offer such agreements if they face regulatory pressure in their home markets (such as requirements to blend aviation fuels with an increasing percentage of fuels of sustainable origin) or when subsidies are offered to compensate the difference between supply and demand prices (such as the H2Global scheme, a tendering scheme based on public and philanthropic grants). Still, most investment projects so far are based on non-binding MoUs with prospective offtakers. This is also the case of the Hyphen project that still struggles to raise some $4 billion from equity investors (Cassidy & Quitzow, 2023).

Like any other player in the emerging global hydrogen economy, Namibia has to cope with these uncertainties. Three coping strategies help to mitigate the risks involved:

- *Invest in technology and market foresight*. The better Namibia understands the technological and market dynamics, the better it can assess opportunities and risks, and the better informed policy-makers will be to deal with large foreign investors. For a small country with limited expert pools and public budgets, international agencies such as the World Bank, the International Energy Agency (IEA) and IRENA can be used to improve the national information base.

- *Due diligence in making contracts with international investors*. Contracts with large foreign investors entail manifold cost- and risk-sharing arrangements, for example concerning investment risk guarantees, currency risk guarantees, project insurances, commitments concerning who pays for infrastructure, etc. Careful risk-sharing assessments are needed to ensure that project failures do not result in excessive public debt.

- *Prioritise renewable energy investment over downstream hydrogen investments and target several green electricity markets in parallel*. Although downstream hydrogen investments are subject to the various risks outlined above – many of which are not under Namibia's control – investments in renewable energy projects are a safer bet: First, because technologies are mature and the levelised cost of electricity is relatively easy to predict; second, because renewable energy can be developed for various target markets in parallel, substituting energy imports, tapping into the South African market and supplying green electricity for industrial uses. Namibia would be well-advised to adopt a gradual hydrogen

entry strategy while expanding renewable energy projects for various target markets in parallel.

4.2 Political risks and opportunities

Assuming that foreign exchange earnings will materialise as expected in the national Green Hydrogen and Derivatives Strategy, Namibia's macro data can be substantially improved. This would provide the fiscal space to finance the necessary investments to achieve the Sustainable Development Goals.

Development concerns, for example issues of justice, equity and poverty reduction, are prominent in Namibia's policy documents, such as the Harambee Prosperity Plan II (2021-2025), which has "social progression" as an important pillar. In the same vein, the hydrogen strategy promises to ensure "environmental and community-responsible development" (MME, 2022, p. 8), entailing a policy design that maximises development effects. In fact, the bidding process for the first hydrogen investments required bidders to specify their contributions to "economic growth, national empowerment objectives, employment creation and alleviation of poverty" (Namibia Investment Promotion and Development Board, 2021, p. 7).

However, the history of large-scale export projects exploiting natural endowments in African countries shows that pro-development and pro-poor outcomes are by no means automatic. Deliberate policies are generally required to amplify productive spillovers, such as enterprise development and broad-based employment, as well as pro-poor spending of revenues. Civil society organisations in Namibia also voice concerns regarding what they deem to be insufficient transparency concerning hydrogen decision-making, and they express doubts about fairness in dealing with risks and benefits (Economic & Social Justice Trust, 2023). In the following, we highlight five political risks that should be addressed early on:

- **Socially exclusive rent-seeking deals or bribery.** The sheer size of the planned hydrogen investment projects, relative to any previous or parallel investments, creates incentives for rent-seeking and bribery. Unless strict transparency rules are applied, directly partaking in deals with large investors may create opportunities for legal (e.g. consultancy fees) or extra-legal (bribes) benefits, and politically connected individuals and firms may gain privileged access to secondary sources of incomes, that is, benefit from subcontracts and licences, for example for infrastructure works. Hence, it is essential to have full transparency for tenders and contracts. Yet, there have been critiques regarding the lack of public disclosures and public consultations as well as non-compliance with transparency rules in the case of hydrogen investments in Namibia. A "procurement tracker" publication revealed several irregularities in the bidding procedure for the Hyphen project (Institute for Public Policy Research, 2022). In the case of the Uis lithium mine (lithium beneficiation is one of the potential hydrogen-use cases in Namibia), Xinfeng Investments, a Chinese-owned firm, has been accused of acquiring the mine through bribery and developing an industrial-scale operation using permits for local small-scale miners to avoid meeting environmental obligations (Global Witness, 2023, pp. 8ff.). While we cannot ultimately scrutinise the validity of these claims, they do point to potential risks and underline the importance of due diligence mechanisms. Especially the Extractive Industry Transparency Initiative standard (EITI, 2023), which has been widely adopted in the oil, gas and mining industry, should be fully applied to hydrogen as well as mining investments. "Namibia is one of the few mineral-rich countries in Africa that has not yet joined" the EITI (Global Witness, 2023, pp. 8ff.).

- **Insufficient public information and consultation**. The principle of "prior and informed consent" should be applied whenever investment projects have potentially far-reaching effects on local communities. However, in a public letter to (former) Namibian President Hage Gottfried Geingob, an alliance of local NGOs complains about the "lack of adequate

public consultations and checks and balances" (Economic & Social Justice Trust, 2023). In the cases of

> the Erongo Green Hydrogen Hub […] and the Dâures Green Hydrogen project, which threatens to deplete the groundwater in an already water-stressed area that the indigenous communal farmers depend on for survival, no consultations with local communities on those projects took place. (Economic & Social Justice Trust, 2023)

- **Unfair distribution of benefits, lack of acceptance and political resistance.** Even when deals are transparent and all political actors behave in a fully welfare-oriented manner, this does not automatically imply widespread benefits for the Namibian people. There may be fewer employment and socio-economic spillovers than anticipated in the strategy, projects may be less profitable than expected – given all the technological and price uncertainties – and information asymmetries between large investors and Namibian policy-makers may translate into unfavourable risk- and benefit-sharing agreements. Namibian NGOs fear that

> the risks are not covered by corporate Europe but by the producer states that invest public funds towards the development of green hydrogen, [concluding that] […] it is a huge gamble for the Namibian government to enter into green hydrogen agreements without having fully understood the financial implications for the Namibian nation through adequate feasibility studies. (Economic & Social Justice Trust, 2023)

In fact, information on risk- and benefit-sharing between investors and the Namibian state (e.g. who bears the risks of upfront infrastructure investments if a project fails economically) either do not exist or at least have not been publicly disclosed.

Also, no information is provided on how the government intends to use revenues from hydrogen projects, for example whether it plans to earmark incomes for regional development or welfare programmes. Many countries – especially in natural resource-exporting industries, in which tax incomes are often substantive, whereas employment effects are relatively small – adopt measures to enhance the developmental and pro-poor effects of such income. This includes transferring a portion of the government's hydrogen revenue directly to citizens. This would have several positive effects: First, it would have a progressive distributional effect; second, it could increase public acceptance of hydrogen mega-projects; third, it would enhance accountability, because citizens who are entitled to receiving a share will have an incentive to scrutinise deals with investors as well as the use of funds. The technical means to organise such transfers are well-established, also in African countries that are using debit cards with biometric information to make cash transfers (Devarajan, 2011; Devarajan & Do, 2023). In fact, several countries and states are using such schemes successfully, including Mongolia, Alaska and Norway, as well as Botswana and Ghana in Africa (Moss & Young, 2009; Standing, 2014). In addition to direct dividend payments to citizens, several other mechanisms can be used to ensure broader development effects. This includes policies that encourage companies to share the ownership of renewable energy projects with local communities (Goedkoop & Devine-Wright, 2016; IRENA, 2021; San Martin, Morales, Antas, Seumas, & Wallace, 2022; Toledano, Albin-Lackey, Diez Andres, & Brauch, 2023). Also, a portion of hydrogen revenues could be earmarked for special funds, such as local economic development funds.

So far, there is no systematic debate in Namibia about hydrogen revenue use, and the topic is not being addressed in government strategies, despite international experiences suggesting that demands for a "social licence to operate" are becoming a standard requisite for large foreign investments, especially when natural resources are exploited.

- **Land-use conflicts.** Local conflicts over land, exacerbated by historical injustices from Namibia's colonial era, present a significant socio-political challenge. Ancestral land claims hold profound importance for many Namibian communities, complicating efforts to resolve

disputes. Although the Namibian Ministry of Mines and Energy acknowledges the importance of recognising land rights and involving local stakeholders in renewable energy projects, challenges persist. Namibia's judiciary theoretically guarantees property and contractual rights, yet in practice controversies arise, particularly in areas with indigenous populations asserting ancestral land rights (Mamo, 2022, p. 102).

Previous conflicts in Namibia highlight the intricate balance between development projects and environmental conservation. One instance involved plans for a hydroelectric dam at Popa Falls near the Botswana border, where concerns over the Okavango Delta's ecology and potential human displacement led to a government-mandated halt (CIA, 2022). In 2021, tensions escalated with the oil and gas exploration of Reconnaissance Energy Africa, which employed hydraulic fracking in national park regions of Kavango West and East. Indigenous and local communities opposed these methods, citing risks to water resources and biodiversity (Mamo, 2022, p. 107). Similar disputes emerged around uranium mining concessions (DeBoom, 2020, p. 13). Conflicts may also arise around land use, as seen with the Hyphen project in Tsau //Khaeb National Park. NGOs argue that this industrial project contradicts conservation and tourism plans, potentially harming endangered species and the park's ecological balance (Economic & Social Justice Trust, 2023).

- **Water conflicts.** These conflicts are emerging as a significant potential conflict in Namibia's future. As an arid country already facing water stress, several regions, including the capital, Windhoek, are experiencing challenges in accessing freshwater. Climate change adds further unpredictability to the country's water resources (MME, 2017, p. 10). Water shortages put a severe constraint on agricultural production and productivity. The Erongo region, which houses the two largest mines, has repeatedly encountered water shortages. In dry areas, the mines must transport water from more than 60 miles away, leaving local communities with limited options to address these scarcities. In some instances, residents have already been relocated (DeBoom, 2020, p. 13).

  Green hydrogen production requires massive amounts of freshwater for electrolysis. The additional water requirements would need to be covered entirely by seawater desalination plants in order for them to be built as part of the hydrogen investment projects. The Hyphen mega-project includes seawater desalination. Here, desalination plants are designed to produce beyond what is needed for electrolysers, thereby enabling the provision of surplus freshwater to local communities. In such arrangements, water stress would be mitigated rather than enhanced. What remains are concerns about the environmental impact of desalination; see Section 4.5 below.

4.3 Industrial linkages and technological learning

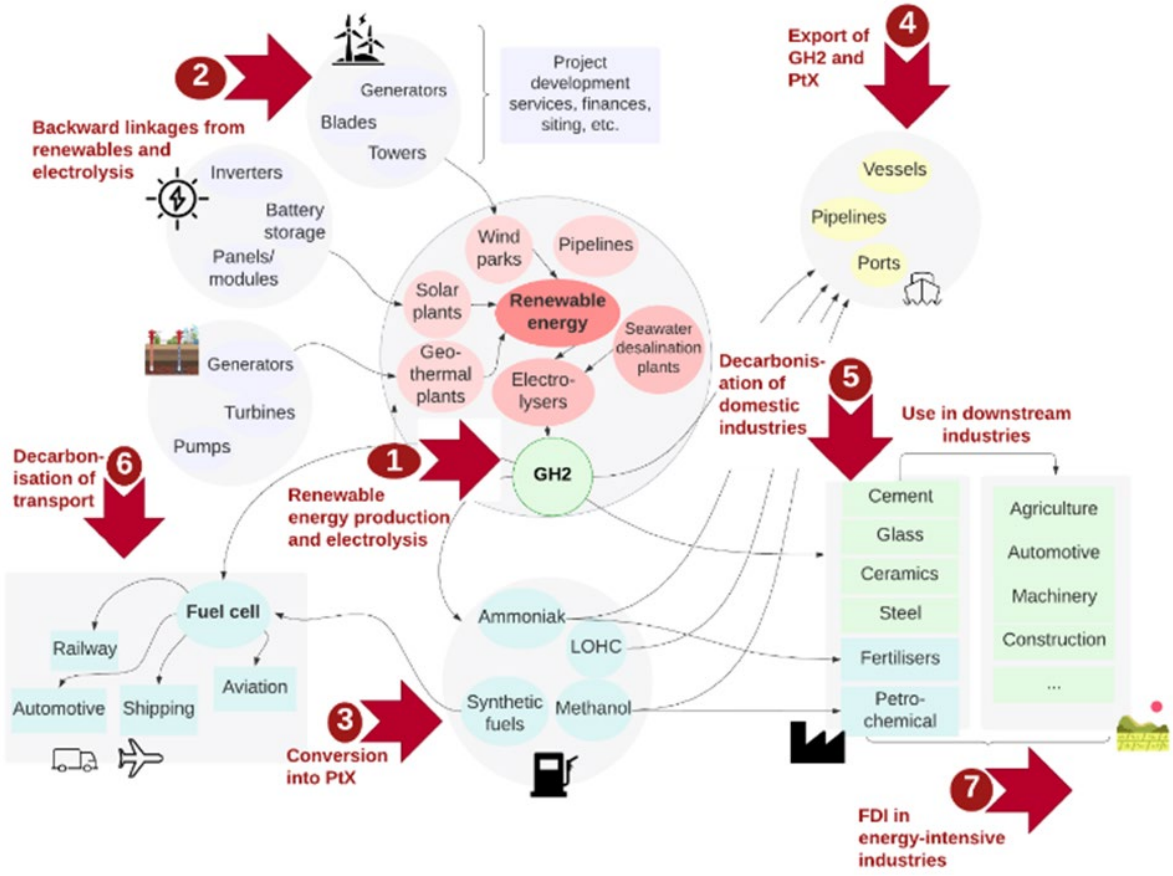
Green hydrogen can in principle have manifold forward and backward linkages. Figure 4 shows the industrial forward and backward linkages that can potentially develop from green hydrogen projects, classifying them into seven clusters.

If only a relative small fraction of these linkages materialise, this might indeed "jump start Namibia's industrialization" (Republic of Namibia, 2022). Moreover, many of the direct links may have knock-on effects: If low cost hydrogen attracts green steel manufacturing, all sorts of steel-using industries may become more attractive; if green fertiliser production becomes competitive, it may raise agricultural productivity.

Most of the related industries, however, are highly demanding in terms of minimum scales, capital investments and technological sophistication. In a country that has a very small domestic market and is located far from larger markets, these factors may pose real binding constraints. What, then, are the realistic options for industrial linkages with positive spillovers in terms of

economic diversification, technological learning and employment? In the following, we discuss four groups of economic industries in which spillovers may materialise over time.

Figure 4: Industrial linkages of the green hydrogen economy



Source: Stamm, Altenburg, Strohmaier, Oyan and Thoms (2023)

Export-oriented industries based on competitive advantages in solar and wind energy. For Namibia, the most promising industries would be those that produce exports for which Namibia has a clear cost advantage based on the levelised cost of electricity. This applies to derivatives, especially ammonia, for which technologies are mature and markets already exist. It also applies to exports of renewables-based electricity to South Africa. Both would require major investments in related industries (clusters 1-4 in Figure 4).

In the longer run, additional downstream industries could emerge. However, these industries would require certain preconditions:

Sustainable aviation fuel is one promising option, although it requires a carbon source. Two options should be explored further: using carbon captured in South African industries, mainly Sasol's chemical industry complex and the steel industry; or using invasive bush species as an organic carbon source. Bush encroachment is a major environmental problem in Namibia (Brüntrup et al., 2016; Deutsche Umwelthilfe, 2023), and its removal to utilise it as a carbon source might be a win-win opportunity for the environment and for broad-based employment opportunities.

Low-carbon fertiliser production is another option to be explored. Namibian ammonia production will mainly be used for fertiliser production abroad, at least in the near future. Hence, using some of the produced ammonia for domestic fertiliser production is an obvious option, thereby substituting imports of fossil-fuel based fertiliser, which would contribute to decarbonisation and

improve the trade balance. In 2021, Namibia imported 90 per cent of its fertiliser (US$32 million) from South Africa, which in turn imports from third countries (Namibian Agronomic Board, 2022). More studies are needed to explore the economics of domestic production, as the domestic market (in 2020, Namibia consumed only 2,981 tonnes of fertiliser) is probably too small for a viable fertiliser plant, unless Namibia can tap into the South African market (in 2020 it was 761,900 tonnes) (Namibian Agronomic Board, 2022). This, in turn, depends on price competitiveness vis-à-vis fossil-fuel based fertiliser.

Hot-briquetted iron (HBI), an intermediate product in the steel-production process, offers another potential opportunity to take advantage of green hydrogen. Here, iron ore would be converted into HBI in a direct reduced iron plant. This makes sense in locations where iron ore is available in sufficient quantities at competitive prices. For Namibia, the local iron ore supply may be insufficient for meeting minimum scale requirements, yet it could be increased with imports from Gabon, Guinea or South Africa (MITSMED et al., 2024, pp. 36ff.). The newly formed German-Namibian firm HyIron Green Technologies (Pty) Ltd announced that the Oshivela project (HyIron, s.a.) would produce 15,000 tonnes of HBI in the first phase of a project, which might then be upscaled to take advantage of a modular technology. Another project – the Dordabis Iron Ore Project, planned by Lodestone Namibia (s.a.) – aims to produce high-grade iron ore concentrates using green hydrogen. However, both projects are still at an early planning stage.

Construction and services are in most cases not fully tradable, hence they need to be supplied locally, which gives Namibian firms an advantage. Specialised infrastructure required for ports, pipelines, storage tanks and Power-to-X plants will most likely be built by international companies importing equipment, whereas construction workers will largely be hired locally. Construction of housing and roads can be localised and will be labour-intensive. Similarly, specialised services such as project development will initially be provided by international firms, whereas local firms are likely to handle the demand for water, sanitary, health and education services.

Inputs into renewable energy and hydrogen production. Namibia's hydrogen projects require a massive roll-out of solar and wind parks. This, in turn, creates a market for solar cells and modules, metal frames, wind towers, blades and turbines (cluster 2 in Figure 4). Namibia's strategy paper envisages the localisation of such industries, specifically local tower and blade, solar cell and module manufacturing, adding up to US$11 billion in direct GDP impact in 2035-40 (MME, 2022, p. 32). However, these industries compete with imports from countries that benefit from enormous economies of scale (especially China) and are subject to massive subsidies, as the United States and the European Union have started to subsidise these industries in response to Chinese subsidies and overcapacities. This makes local production in Namibia very unlikely, also when considering that larger economies (including South Africa, India and Brazil) used local content requirements to localise such industries and often failed (Bazilian, Cumings, & Kenyon, 2020; Hansen, Nygaard, Morris, & Robbins, 2020). Considerable local content can probably be achieved in steel underframes for solar parks and maybe wind towers, which are the least sophisticated parts. Moreover, envisaged plans to localise the non-membrane parts of electrolyser stack production as well as electrolyser assembly based on the detailed specifications of exporters seem more realistic. Here, a US$5 billion GDP impact is envisaged for 2035-40 (MME, 2022, p. 32).

Inputs for the mining industry and transport. Namibia's mining industry is facing pressure to decarbonise in order to meet growing concerns in import countries. This provides some opportunities for hydrogen-based technologies. Green hydrogen might be used to refine lithium and rare earths for export, which requires high-temperature heating. Hydrogen may therefore unlock opportunities for value creation beyond the mining stage (MITSMED et al., 2024). In addition, Namibia might employ mine-site trucks running on fuel cells with green hydrogen. This is currently being piloted by Anglo American in South Africa, and it may be used in Namibia as well. Likewise, heavy-duty trucks and long-distances buses and trains may run on fuel cells

using green hydrogen, including trucks shipping mining products to the ports. The South Africa Hydrogen Valley Final Report (Engie Impact, 2021) has advanced plans for similar projects, which may be replicated in Namibia. Although this creates opportunities for the local use of hydrogen, all related technologies are scale- and knowledge-intensive, and therefore there is no realistic option for domestic manufacturing, at least not in the short run. Still, some employment opportunities could be created in niche markets, as the following pilot projects suggest.

Cleanergy Namibia is a joint venture between the private Namibian group Ohlthaver & List and British CMB.TECH, which are aiming to create Africa's first-ever public green hydrogen refuelling station and make it fully operational by mid-2024 (BMBF, 2023). In the Erongo region, €25 million was awarded by the Namibian government to develop a hydrogen refuelling station at Walvis Bay, and another €7.63 million was allotted for a hydrogen dual-fuel locomotive pilot to be carried out in cooperation with the main nation rail services operator in Namibia, named TransNamib (Zawya, 2022).

The government has published optimistic employment estimates for green hydrogen, mentioning "600,000 jobs by 2040. Of these, about 30% would be direct (in the industry), 20% would be indirect (through goods and services), and 50% would be induced by the increase in household incomes" (MME, 2022, p. 31). However, the evidence base for these assumptions has not been disclosed. The Hyphen mega-project – aiming at 3.5 GW of renewable and 1.5 GW of electrolyser capacity and 1 million tonnes of ammonia exports per annum – expects 3,000 permanent jobs to be created when it is in full operation, plus 15,000 temporary jobs for a four- to five-year construction period (Hyphen Hydrogen Energy, s.a.-b). This would be a tiny fraction of the national goal. The African Climate Foundation and SystemIQ (2022) study, arguably the most detailed study of Namibia's hydrogen potential, calculates that "in excess of 100,000 jobs (direct & indirect) could be envisioned before 2040" – yet, there has been no detailed disclosure of the underlying data. This would be six times lower than the national estimate.

The Green Hydrogen and Derivatives Strategy only specifies certain underlying assumptions for its employment estimates. First, for renewable energy deployment in general, the employment multipliers mentioned are between five and seven jobs per MW during construction and just under one per MW during operations. The seminal study by Rutovitz, Dominish and Downes (2015) mentions 2.5 jobs per MW during construction and 0.2 per MW during operations for wind onshore, and 11 jobs per MW during construction and 0.3 per MW during operations for solar PV. Especially during operations, the study's estimates are thus much more conservative than those of the Namibian government. Second, estimates are provided for some specific upstream and downstream industries. The strategy mentions the employment potentials of 7,000 jobs in local wind tower and blade manufacturing, 4,000 in solar cell and module manufacturing and 5,000 in electrolyser manufacturing, all by 2040. As stated above, these assumptions are in stark contrast with the experiences of more industrialised countries that failed to attract such industries.

Overall, employment estimates seem to be grossly overstated. More detailed research is needed to assess hydrogen-related employment potentials. Such estimates need to take country conditions into account, especially when assumptions are made about technologically sophisticated upstream and downstream industries.

It should also be noted that the current labour supply cannot easily match demand. Firstly, because some of the planned large-scale green hydrogen production sites are located within sparsely populated (or in the case of the Hyphen project, completely unsettled) regions, where labour would need to be relocated, this would require considerable infrastructure investments for housing, health, education, sanitation and community services (to minimise the social challenges often associated with temporary, informal settlements). Secondly, another reason is that some reskilling will be needed to ensure employability in hydrogen-related activities.

Dedicated training academies, work-based learning and overseas training programmes (African Climate Foundation and SystemIQ, 2022, p. 47) will be required to address the expected skills mismatch.

4.4 Environmental risks

Two main environmental risks need to be considered. The first relates to seawater desalination. When seawater is desalinated, highly concentrated brine is produced as a side-product. This is commonly discharged into the ocean, increasing the salinity and thereby impacting marine ecosystems. Although different technologies are being developed to reduce brine, the problem remains and requires a careful assessment of the environmental impacts (Elsaid, Sayed, Abdelkareem, Baroutaji, & Olabi, 2020; Soliman et al., 2021).

The second risk relates to impact on the biodiversity in national parks. Although it is advantageous that Namibia is very sparsely populated in terms of reduced risks of land-use conflicts, investments in solar and wind parks, pipelines and ports may conflict with nature conservation. The projected site for the large-scale Hyphen project, for example, is located in the Tsau //Khaeb National Park, an important refuge for the country's unique flora and fauna. Green hydrogen may thus conflict with the country's efforts to protect its unique plant- and wildlife and can pose a challenge to the tourist sector, which contributes a significant amount of income to the country's GDP (between 11 and 15 per cent).

5 Outlook and policy conclusions

Namibia is a highly competitive location for renewable energy. This provides vast opportunities for domestic electrification, exports of green energy to South Africa as well as the export-oriented production of ammonia. At a later stage, further opportunities for value creation may arise based on competitive renewable energy and green hydrogen prices. These include the export of sustainable aviation fuel, HBI for green steel production and fertilisers. Given Namibia's current development challenges – such as sluggish growth, deteriorating fiscal and current account balances, very shallow economic diversification, dependence on volatile minerals-export markets, high unemployment and deficiencies in electricity supply – Namibia is well-advised to capitalise on its competitive advantages concerning renewable energy and green hydrogen.

This said, the type of investments that are attracted for this purpose will not automatically have broad-based positive effects. If not handled carefully, the renewable energy endowments may become a curse for the country, as investment projects may fail, leaving sunk investments in infrastructure as well as additional public debt; or the projects could end up as technological enclaves with limited domestic benefits, except for employment during the construction phase. Criticism of "extractivism" is common in Namibia, as in most other African countries (Greco, 2020), which clearly underlines the need for a "social license to operate" in resource-based export sectors. Failing to deliver broad-based benefits would most likely spark societal discontent and opposition. Moreover, the currently planned investments are so massive – relative to any other investment in the country – that they entail considerable incentives for rent-seeking or even corruption. Although Namibia is a democratic country and ranks fairly high on transparency indicators, multi-billion-dollar investment projects involving a wide range of licensing issues and public–private risk-sharing agreements by their very nature create incentives for non-transparent political deals. Due diligence and checks and balances are therefore central to ensure the best use of hydrogen opportunities and preserve trust in public institutions.

What, then, are the key measures to maximise the development opportunities for Namibia? In the following, and based on the arguments laid out in the previous section, we distil seven policy recommendations, both for Namibian policy-makers and international agencies in the field.

1. Invest in technology and market foresight and risk assessment. This discussion paper has highlighted the manifold risks and uncertainties affecting technology choices and prices, given the nascent stage of the global green hydrogen market. This translates into a lack of clarity about national development opportunities in terms of industrial linkages, technological learning, profits and employment associated with various potential pathways. Uncertainty entails risks in terms of investment failures, increasing public debt and public discontent. Investing in technology and market foresight while drawing on the expertise of dedicated agencies such as the IEA, IRENA and the World Bank is therefore essential to improve the evidence-base of decision-making.

2. Conduct a detailed study on the labour market effects of the various techno-industrial options. Current employment estimates are not sufficiently evidence-based and seem to grossly overstate the potential, partly because unrealistically high levels of domestic input manufacturing are assumed. Employment studies need to take entry barriers into account – capital intensity and costs, technological sophistication, licence fees, minimum scales, etc. – that may prevent firms based in Namibia from entering the respective value chains. Moreover, they should consider regional employment dynamics and the effects of intra- and inter-country migration.

3. Public consultations about hydrogen projects should be improved. The principle of “prior and informed consent” is important, especially when large-scale projects with enormous potential spillover effects are prepared. The criticisms of Namibian NGOs suggest that many do not feel sufficiently informed or consulted. Early engagement may lead to more inclusive project designs and ensure public acceptance of, and support for, hydrogen projects.

4. Large-scale investment contracts require due diligence to ensure reasonable risk- and benefit-sharing between investors and the host country. Institutional checks and balances for guarding against concentrations of power, bribery and corruption are of utmost importance when governments strike multi-billion-dollar deals. The EITI standard, which has been widely adopted in oil, gas and mining industries, should be applied to large hydrogen investment projects to hold investors and government agencies accountable.

5. Regarding industrial policy and capacity-building – based on thorough technology and market foresight and risk assessment (point 1 above) – specific subsector strategies need to be devised to prioritise investments in national capabilities for promising technologies. Once agencies have a better understanding of value creation and employment opportunities – which may (or may realistically not) lie in wind towers or steel construction for PV, in project development services, fertiliser production, sustainable aviation fuels or pipeline manufacturing, for example – specific steps need to be taken to make *targeted* investments in *specific* skills and research centres, *specifically* to attract the most promising international investors, who may help to develop those opportunities, and explore other support policies. Successful industrial policy is about understanding market opportunities and tailoring industry-specific support for the most promising activities (Altenburg & Lütkenhorst, 2015; Rodrik, 2004).

6. Innovative forms of direct benefit-sharing should be explored, as many of the direct benefits that the Green Hydrogen and Derivatives Strategy is hoping for in terms of industrial development spillovers, export diversification and employment seem to be based on overly optimistic assumptions. Given the type of capital-intensive, high-tech investments, this is essential to avoid large-scale enclaves that may further exacerbate Namibia’s enormous inequality. Especially direct dividend payments to citizens are a promising instrument to achieve poverty reduction and greater equity alongside greater accountability and public

acceptance for hydrogen projects. Other transfer mechanisms, such as community participation in investment projects or earmarking some of the hydrogen/ammonia incomes for development funds, may also have positive distributional effects. As a first step, Namibia may want to commission a study to determine, based on international evidence, the most suitable revenue-sharing instrument(s) for its own country context.

7. Policies aimed at attracting foreign investment in hydrogen projects should be combined with the roll-out of renewable energy generation for other purposes. Renewable energy is a safe bet for Namibia, given its extraordinary solar and wind conditions. Renewables can improve the energy access of households and firms, help to overcome energy-import dependence and generate export revenues if surplus electricity is exported to South Africa. Pushing these objectives alongside hydrogen projects may create win-wins: It helps to create economies of scale for renewables, which in turn accelerate cost-reduction and techno-institutional learning in relation to running solar and wind projects. Large international hydrogen investors are typically able to negotiate better financing conditions and pay lower interest rates than those proposing domestic-use projects, and investors can be encouraged to oversize their solar and wind parks to sell electricity to other off-takers. This requires comprehensive renewable energy incentive packages, including encouragement to oversize electricity production in hydrogen projects (e.g. making it a conditionality in hydrogen project tenders).

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