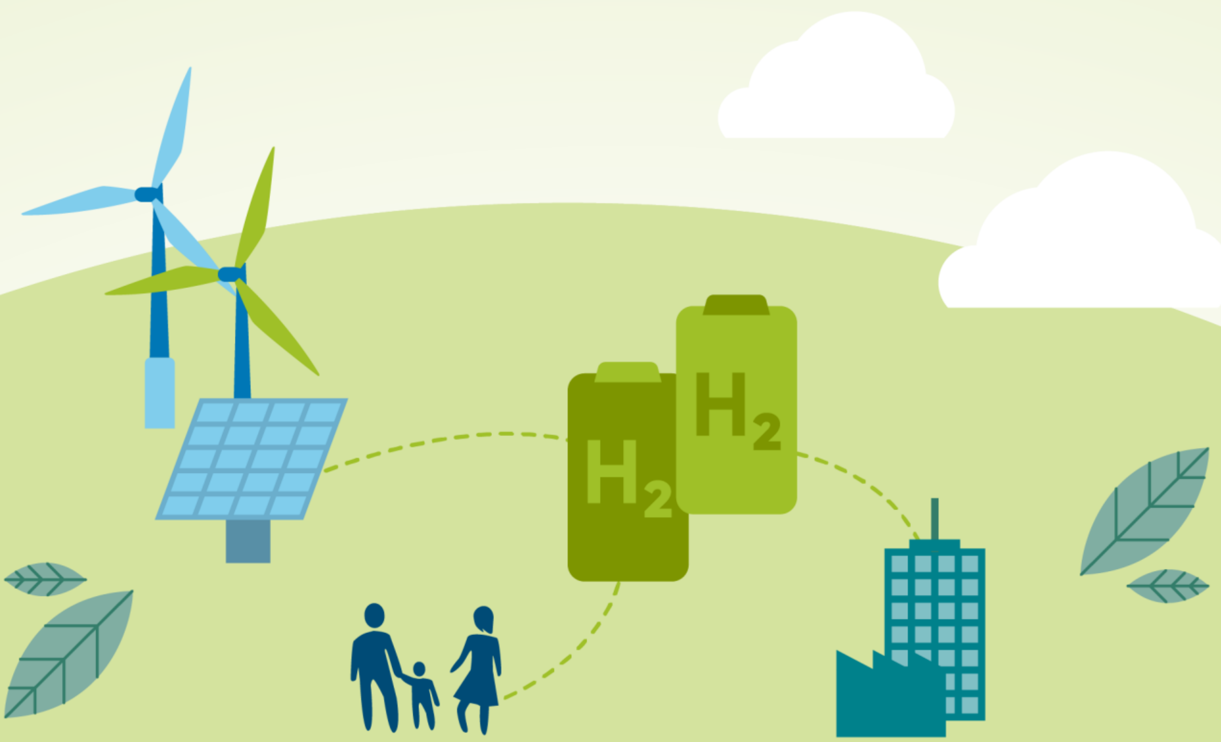
Namibia Green Hydrogen Programme

H2 Business Alliance

Localizing Green Industries in Namibia



Disclaimer

On request of the Ministry of Mines and Energy (MME) and Ministry of Industrialization and Trade (MIT), the Green Hydrogen Business Alliance (H2BA) commissioned on behalf of the German Federal Ministry for Economic Cooperation and Development (BMZ) this report, which was conducted by Systemiq between December 2023 and May 2024.

The H2BA is implemented by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and supports the Namibian government in building up a sustainable and inclusive green hydrogen economy.

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Context

Namibia is strategically positioning itself to become a global leader in the green hydrogen and power-to-X (PtX) markets over the next decade. The nation aims to leverage green power and green hydrogen as pivotal elements for attracting foreign investment, enhancing energy security, and supporting a just energy transition. Guided by a five-year strategy, the government is committed to using green hydrogen to significantly decarbonize its economy.

Aligned with its vision for 2030, Namibia is dedicated to industrialization that ensures widespread livelihood opportunities. The Harambee Prosperity Plan II articulates this vision through the "Green Hydrogen and Derivatives Strategy." Realizing this strategy demands a comprehensive, whole-of-government approach. Critical to this effort are the Namibia Green Hydrogen Programme and key governmental bodies such as the Ministry of Industrialization and Trade and the Ministry of Mines and Energy. These entities are instrumental in spearheading the development and implementation of strategic initiatives. Collaboration with private sector partners, investors, and financiers, both domestically and internationally, is crucial for success.

On 10-11 April 2024, the Ministry of Industrialization and Trade and the Ministry of Mines and Energy, supported by the Namibia GH2 Programme and delivered by GIZ partnering with Systemiq, hosted a pivotal two-day workshop at the Hilton Hotel in Windhoek. The event, titled 'Localizing Green Industries in Namibia,' gathered stakeholders from government, industry, finance, and the public to discuss the operationalization of Namibia's green industrialization ambitions. The workshop focused on identifying and evaluating the most promising sectors for green industrialization in Namibia and how these may be operationalized in the short- and mid-term. The discussions aimed to establish a clear path for building and localizing key industries that are economically efficient, environmentally sustainable, and socially transformative.

This report captures the insights and dialogues from the workshop, focusing on selected sectors poised to underpin Namibia's green industrialization and the essential cross-cutting enablers needed to advance these sectors.

Executive Summary

Overview

- **The global surge towards achieving net-zero emissions, fueled by plummeting costs of zero-carbon technologies and a universal push across sectors to meet emission reduction goals, offers Namibia a prime opportunity, given its vast wind, solar, and mineral reserves.** Vision 2030 and the Green Hydrogen and Derivatives Strategy laid the groundwork, but seizing this moment demands concerted action from government, industry, and international allies to incentivize green investments and formulate robust industrial policies in the face of fierce global competition.
- **Namibia's fusion of energy and mining capabilities emerges as a linchpin for propelling a unified Green Industrialization agenda, leveraging the country's inherent advantages of abundant energy resources and diverse mineral wealth.** The mining sector, historically pivotal to the economy, is able to attract substantial investments, bolstered by strategic assets like well-established infrastructure and stable governance, which have not only fueled past success but promise to drive this transition forward. The amalgamation of energy and mining within a single ministry underscores the government's recognition of their inherent interdependence.
- **Namibia's Blueprint for Green Industrialization pinpoints industries such as Green Hot Briquetted Iron (HBI) Production and Critical Raw Materials (CRM) Processing (lithium and rare earth elements) as prime candidates to ignite green industrialization, capitalizing on the country's distinctive geological blessings to serve the global energy transition relying on these green materials.** Essential investments in shared infrastructure and regulatory coherence to empower these sectors will also foster a synergistic environment for sustainable industrial growth across Namibia's other industries, including additional minerals.
- **Namibia's ambitions in green hydrogen and industrialization encounter hurdles amidst regional rivalry and global urgency, with the country yet to fully exploit its potential in renewable energy and hydrogen sectors.** Policymakers must prioritize establishing an enabling legislative framework to unlock Namibia's green industry potential, drawing inspiration from successful models elsewhere (e.g., Morocco), to translate aspirations into tangible projects amid resource constraints and competitive pressures.
- **Namibia confronts dual critical challenges: First, it must attract a greater number of industrial projects to compete. Second, it needs to ensure these projects advance to the Final Investment Decision (FID) stage, which has been historically difficult**. It must overcome what has been called Africa's infrastructure paradox: despite available funds, large pipeline and clear need, few projects reach financial close. To move to completion, Namibia will need to derisk these projects and create the sufficiently attractive environment with infrastructure.

Focus sector: Green Iron

- **Global steel production is in the throes of decarbonization, spurred by the industry's public commitments to reduce their significant greenhouse gas emissions, and green hydrogen-based steelmaking via the Direct Reduced Iron (DRI) route is emerging as a key technology route.** Project announcements of hydrogen-based steelmaking far outpace those of other technology routes. Downstream consumers, anticipating cost increases from green steel having a manageable impact on end-consumers, are actively engaging with upstream green iron/steel projects to secure supplies in what is anticipated to be a tight green iron supply market.

- **Namibia's potential to competitively produce low-cost green iron hinges on several key factors.** The shift towards DRI-based steelmaking favors regions endowed with gigawatts-worth of low-cost green power and thus green hydrogen, coupled with access to high-quality iron ore resources. This positions Namibia favorably as a potentially hub, given its renewable energy potential from solar, wind and imported hydro, and access to both in-country and regional sources of DRI-grade iron ore, notably from South Africa. Equally vital are investments in robust rail infrastructure to necessarily transport vast quantities of iron ore and iron economically, thereby establishing viable green iron value chains.
- **The European Union's Carbon Border Adjustment Mechanism (CBAM) introduces carbon pricing to level the playing field in carbon-intensive sectors, creating an opportunity for greener products like Namibia's green iron to compete internationally.** However, the economic viability of green hydrogen-based iron production under the CBAM depends on factors like hydrogen prices and consensus on green steel standards, necessitating robust implementation without opposition from entrenched industries.
- **To establish a successful green iron value chain in Namibia, stakeholders must prioritize securing reliable green power, clinching offtake agreements with downstream consumers, and harmonizing with evolving low-CO_2 steel standards.** This multi-faceted approach is essential for positioning Namibia as a hub for cost-effective green iron production and securing its first large-scale project.

<u>Focus sector: Critical Raw Materials – Lithium and Rare Earth Elements</u>

- **The global demand for lithium (Li) and rare earth elements (REEs) is projected to surge, driven by their essential roles in energy transition technologies.** By the 2030s, a supply shortfall looms for lithium, indispensable in rechargeable batteries, necessitating intensified production efforts amidst market uncertainties. Similarly, the scarcity of REEs, vital for magnet technologies, underscores the imperative for new mines. China's dominance in processing both lithium and REEs have triggered initiatives like the Minerals Security Partnership, signaling urgent international interest in diversifying the supply chain. With the market outlook indicating growing demand and heightened geopolitical consciousness, there are promising opportunities for investment in lithium and REEs outside of China.
- **Namibia holds substantial potential in both the lithium and rare earth elements markets, with estimates suggesting its lithium resources could account for around 1% of the global supply by 2030 and its REEs resources ample enough to meet significant demands.** Despite its nascency, Namibia's lithium sector boasts projects at various stages of exploration and development. Meanwhile, the REE ecosystem in Namibia is still in the exploration phase, with projects showcasing significant potential but requiring further evaluation.
- **The Li and REE value chains comprise three main segments – upstream, midstream, and downstream – wherein integration of renewable power and green hydrogen offers potential for emissions mitigation and therefore greener mining and processing practices in Namibia.**

The upstream phase encompasses ore mining and concentration, with midstream processes involving chemical transformations to refine minerals into usable forms, while downstream activities pivot on final product manufacturing. Across these phases, renewable power is applicable for mechanical movement and low-temperature heat provision, while green hydrogen is suitable for high-temperature heat needs and as a fuel for mining trucks.

- **Navigating Namibia's traverse through the Li and REE value chains entails grappling with unique hurdles at each juncture, necessitating a phased strategy that first prioritizes efficient upstream mine production followed by midstream localization, with strategic partnerships constituting linchpins for global market success.** While upstream mining poses non-trivial challenges, Namibia's established mining legacy and robust policies provide a sturdy foundation. The concentration of lithium and REE separation post-ore extraction poses steeper hurdles but are feasibly surmountable within Namibia with tailored methodologies. Progressing to midstream and downstream phases demands surmounting obstacles in accessing refining technology expertise, ensuring stable energy supply, and procuring substantial volumes of chemical inputs, notably acids.
- **Coordination at the national level as Namibia faces several key priorities in advancing its Li and REE sectors is therefore crucial for success.** Firstly, augmenting mining reserves to attain critical mass and converting discovered resources into economically viable reserves looms paramount. Secondly, ensuring a steady sulphuric acid supply, indispensable for lithium and REE processing, mandates strategic approaches to local production or cost-effective imports. Additionally, a comprehensive national CRM strategy is imperative for leveraging resources optimally, generating employment, and fostering local industrial growth. Adhering to international standards for responsible sourcing and low-emissions production emerges as pivotal to attracting offtakers and aligning with global market dynamics. These imperatives underscore the necessity for proactive governmental backing, streamlined regulations, and strategic alliances to fortify Namibia's competitiveness in the global CRM arena.

<u>Cross-Cutting Enabler: Power Infrastructure</u>

- **While Namibia is actively expanding its energy infrastructure to achieve universal electricity access by 2040 and meet rising demand, Namibia's local energy production remains insufficient to meet its needs.** Presently, nearly half the population lacks electricity access, and the country's installed capacity of 654 MW is set to require doubling by 2040. While Namibia diversifies its energy mix, bolstering renewable contributions and modernizing aging thermal sources, energy production inadequacies persist, resulting in heavy import reliance and fiscal vulnerabilities. Strategic policies target bolstering domestic generation capacities, particularly via renewables, but face hurdles like inadequate storage solutions and delayed infrastructure investments.
- **Green industrialization in Namibia will compound existing challenges in power generation and transmission sectors, with surging stepwise energy demands absent from current energy planning.** For instance, a single green iron plant would require access to 1.5 GW of baseload and dispatchable power, necessitating either oversizing electricity production with extensive hydrogen storage or connecting to a sufficient grid source in Namibia. Moreover,

processing all of Namibia's known lithium and REE resources domestically would further strain energy resources. Combining these sectors would potentially require around 2 GW of additional power generation in Namibia compared to the ~650 MW available nationwide today.

- **Overcoming these challenges to enable green industrialization mandates a paradigm shift from business-as-usual to a more ambitious, coordinated approach, encompassing several strategic options.** Firstly, revising the prevailing power market structure to boost efficiency and accommodate heightened private sector engagement could mitigate conflicts of interest and streamline processes. Secondly, reinforcing public-private partnerships (PPPs) could enhance collaboration with independent power producers (IPPs) for generation and independent transmission projects (ITPs) for transmission, models proven effective elsewhere in expediting power infrastructure expansion. Lastly, devising strategies to manage renewable energy intermittency, like enhancing battery storage technologies and coordinating regional efforts for low-carbon energy imports, will be pivotal for ensuring reliable, decarbonized energy baseloads for green industrial ventures. These strategies necessitate ongoing efforts to streamline planning and permitting processes, simplify regulatory procedures, and tackle existing challenges to foster a resilient energy sector in line with Namibia's green industrialization objectives, with closer coordination among the Ministry of Mines and Energy, NamPower, and the Electricity Control Board at the core.

Cross-Cutting Enabler: Rail Infrastructure

- **While Namibia benefits from well-maintained roads and established ports like Walvis Bay, upgrading its rail infrastructure's capacity to meet the demands of green industrialization, particularly for sectors like green iron, is imperative**. Rail transport offers a more efficient and sustainable means of moving heavy commodities like iron ore compared to road trucking, necessitating a robust rail network to underpin anticipated industrial expansion.
- **Urgent upgrades to Namibia's railway system are needed, including enhancements to rolling stock, modernization of signaling systems, and increases in axle load capacity of the rail lines, to accommodate the expected surge in demand driven by projects like the Lodestone iron ore mine and partnerships with regional sources of iron ore.** While discussions on most of these rail infrastructure upgrades and extensions are already underway, their significance amplifies within the new green industrialization paradigm, demanding concerted efforts to prioritize "no-regret" actions, including addressing investment challenges.
- **To swiftly advance Namibia's rail system, strategies akin to those employed by neighboring countries can be explored, such as opening rail access through public-private partnerships and innovative financing models.** Examples include Zambia's rail infrastructure improvements with investments from China and the United States, projects like the Lobito Corridor linking Zambian copper mines to an Angolan port, showcasing potential for cross-border collaborations, and Botswana's proposition for a new rail line through Namibia, offering opportunities for international investment, notably from the metals and minerals industry. Linking rail investment with industrial projects could significantly boost regional trade and propel Namibia's industrial expansion.

Cross-Cutting Enabler: Policies

- **To drive green industrialization effectively, robust alignment across industrial and regulatory policymaking are crucial.** The Government of Namibia has made strides in this direction and is currently iterating on, among others, a Special Economic Zones (SEZ) bill and a new Industrial and Productive Development Policy slated for early 2025. However, to fully embrace green industrialization, Namibia must broaden its perspective beyond neighboring countries to include a wider array of regions across the globe in its lens. This entails understanding competitors' strategies and aligning with potential partners in new value chains in order to develop robust, globally competitive policies for Namibia.
- **Designing fit-for-purpose Special Economic Zones can be a game-changing catalyst for Namibia's green industrialization.** SEZs, popular tools for global economic development, require careful implementation, as seen in Africa where mixed results are observed. Key success factors include a balance between fiscal and non-fiscal incentives and securing an anchor private player. Learning from successful examples like Morocco, where SEZs leveraged unique advantages and strong partnerships to transform the industrial sector, can help Namibia avoid common pitfalls.
- **Aligning on a nation-wide strategic framework for Critical Raw Materials is crucial for streamlining and turbocharging Namibia's approach to localizing its lithium and rare earth element value chains.** Lessons from Latin American countries offer suggested policy revamps, such as maximizing local value, investing in technology and innovation, strengthening environmental regulations, and fostering international collaboration and trade. Without national cohesion, Namibia may struggle to establish itself as a global player in these markets.
- **Namibia's diplomatic strategy of maintaining friendly relations with all nations positions it to harness diverse international partnerships for green industrialization.** To optimize these partnerships, Namibia must navigate between global giants like China and the U.S., ensuring alignment with partner markets' regulatory standards while maximizing value creation and job opportunities domestically. Navigating specific regulations such as the EU's CBAM and the U.S. Inflation Reduction Act requires strategic alignment and compliance to facilitate trade and cooperation. While CBAM offers opportunities for added value in Namibia's exports to Europe, the decision to align with it necessitates careful consideration of potential economic impacts and sector-specific analyses to outweigh risks and costs. Ultimately, Namibia's approach to international partnerships in green industrialization should prioritize compliance, strategic alignment, and targeted negotiations to maximize mutual benefits.

Cross-Cutting Enabler: Capital

- **Namibia's green industrialization demands investments over five times higher than its foreign direct investment (FDI) inflow over the last decade.** Despite its natural resource wealth attracting diverse global investors, sustaining this momentum requires navigating unfamiliar territory. While Namibia boasts a favorable investment climate bolstered by political stability and robust infrastructure, its green industrialization ambitions necessitate unprecedented investment in the magnitude of billions of US$. To mitigate uncertainty and attract such colossal FDI, Namibia must adopt strategic derisking measures. **These include partnering with reliable**

allies, fostering public-private collaborations, involving potential buyers as stakeholders, and exploring guarantees from multilateral institutions. Namibia can capitalize on the surging global interest in green infrastructure by showcasing low country risk and enacting regulatory reforms conducive to private investment and supportive of green industrialization.

1. Namibia’s Green Industrialization

1.1. Namibia’s green industrialization ambitions

The global economy is accelerating its transition to net-zero emissions. This is no longer driven primarily by government push; zero-carbon technology costs have plummeted, and it is now becoming a competitive advantage to power industries on the back of clean energy (including green hydrogen as a clean energy vector).

Namibia has several assets that enable it to play an outsized role in this transition. Critical and distinguishing assets are world-leading wind & solar resources, and deposits of critical metals & minerals. These are complemented with swathes of land that enable solar & wind installations, and extensive coastline that enables both export and certain industries.

On the back of these assets, Namibia has the opportunity to build a competitive green industrial economy. There is not one industry but rather many that can thrive with the benefit of such assets. These industries can also support one another, benefiting not only from sharing fixed costs to access key inputs (e.g., electricity, heat, hydrogen, water), but also certain industries providing direct input or synergies to other industries.

Namibia has set the vision and is beginning to move on this opportunity. Vision 2030 commits Namibia to industrialization and creating livelihoods for all Namibians by the end of this decade. Alongside the Harambee Prosperity Plan II, Namibia laid out its ambitions towards an industrialized future in its “Green Hydrogen and Derivatives Strategy”. First steps have been taken, most notably with the advancement of Hyphen – the first GW-scale green ammonia project. Beyond this, several other projects ranging from concept through to pilot phase make up Namibia’s growing ecosystem of green hydrogen projects, for example (but not limited to) hydrogen for green iron (HyIron), hydrogen for power storage (HDF Energy), hydrogen for trucking (Cleanergy), and others.

Ensuring the continued success of turning this Strategy into reality by identifying, developing, and seizing *broader* green industrialization opportunities will require a whole-of-government approach that draws on existing mechanisms, especially the recently established Implementation Authority Office (IAO), its core steering bodies – the Ministry of Industrialization and Trade (MIT) and Ministry of Mines and Energy (MME) – and a set of delivery partners who will support with the prioritization and operationalization of concrete strategic steps.

In particular, MIT holds the role of being chief proponents of industrial policy and is fully aligned with the aim of incentivizing green investments in technologies taking place at an appropriate scale duly. MIT recognizes the green industrialization agenda as a critical plank within industrial policy to mainstream the development of green technologies and investments, in service of ensuring the transition and transformation of the Namibian economy to a greener growth path. This perspective and more[1] are at present being addressed as MIT develops a new Industrial and Productive Development Policy for Namibia by early 2025[2].

Now is the time to lay the foundation for green industrialization in Namibia. The government will have to work with private sector partners as well as investors and financiers inside and outside Namibia. Similarly, the government and its industrial partners will need to engage the international community to draw attention to the opportunities in Namibia and garner international support for the transition. Time is of the essence, as other countries – both developed and developing – are racing to seize similar opportunities.

1.2. Combining Namibia's two key strengths: energy and minerals

There are substantial potential benefits to integrating Namibia's energy and mining capabilities to serve as a core anchor in a unified Green Industrialization agenda (Figure 1). Namibia possesses many essential elements required to kickstart a successful transition to green industrialization, including, on the one hand, affordable energy resources—both in terms of electrons (e.g., electricity) and potential green molecules (e.g., green hydrogen, green ammonia)—and on the other, a wealth of minerals.

The mining industry has historically been the backbone of the Namibian economy, contributing approximately 11% to the nation's GDP[3]. Namibia has successfully harnessed significant investments in key areas such as diamonds and gold, with major entities like NamDeb at the forefront of the industry. Additionally, Namibia's robust uranium sector, highlighted by China's substantial US$5 billion investment in the Husab mine – China's biggest entity investment in the African continent and ranked as the fourth largest mine globally[4]—demonstrates the sector's capacity to attract significant capital investments.

Namibia's mining success underscores several strategic advantages that could be similarly instrumental for the country's potential transition to green industrialization:

1. **Logistics Infrastructure**: Namibia is endowed with well-developed infrastructure, including a network of well-maintained roads, railways connecting key economic hubs, and the Walvis Bay port that provides direct access to key markets.
2. **Governance and Stability**: As one of Africa's most stable democracies, Namibia is recognized for its robust rule of law. It is also ranked as the seventh most competitive economy in Africa[5], providing a conducive environment for business and investment.
3. **Regulatory Framework**: The country has established comprehensive mining policies through legislations like the Diamond Act, the Environmental Management Act, the Mineral

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[1] See Chapter 6 below on Policies.

[2] Statement by Dr. Michael Nokokure Humavindu, 10-11 April 2024 on the occasion of the "Localizing Green Industries in Namibia' workshop: *"Industrialization, Investment policy and Enterprise Development at the Ministry of Industrialization and Trade"*

[3] Namibia National Planning Commission (2021), *The Impact of Mining sector to the Namibian economy*

[4] Embassy of the People's Republic of China in the Republic of Namibia (2023), *China and Namibia, Join Hands for Historic Opportunity*

[5] World Economic Forum (2017), *Africa Competitiveness report 2017*

Beneficiation Strategy and the Mineral (Prospecting and Mining) Act[6]. Best practice in mining governance has been continually identified as a priority for the Namibian government[7]. Notably, **the consolidation of energy and mining under a single key ministry in Namibia – the Ministry of Mines and Energy - underscores the government's ongoing recognition of the interdependence of these sectors.**

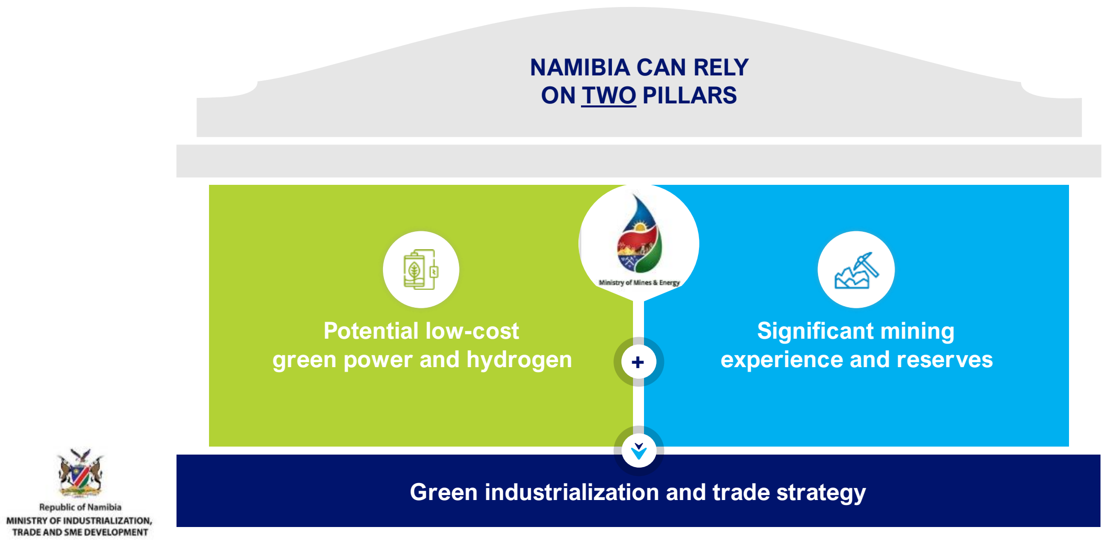


Figure 1: There may be benefits in combining Namibia's energy and mining strengths into a coherent green industrialization strategy.

Namibia's strategic approach to green industrialization, as outlined in its *Blueprint for Green Industrialization* emphasizes key industries that fall at the intersection of mining and energy. Key focus areas identified include:

- **Hydrogen Downstream Products**: encompasses the production of ammonia for use as shipping fuel or as a precursor for fertilizer production, and hot briquetted iron, a precursor to green steel.
- **Mineral Refining**: focuses on the mining and downstream processing of lithium and rare earth elements in-country.
- **Downstream Renewable Energy Manufacturing**: includes manufacturing of solar panels, wind turbines and electrolyzers.
- **Other Low-Carbon Industries**: for example, the production of flat glass using local silica sand and renewable energy sources.

[6] Statement by Dr. Michael Nokokure Humavindu, 10-11 April 2024 on the occasion of the "Localizing Green Industries in Namibia' workshop: *"Industrialization, Investment policy and Enterprise Development at the Ministry of Industrialization and Trade"*
[7] Much more detail in this arena can be found in the recently released independent report funded by the European Union as part of the HORIZON programme, entitled "Africa MaVal – Namibia Case Study".

While the above list is not exhaustive, other sectors such as the bioeconomy and forestry-related value chains have also been highlighted by the MIT as significant elements of a comprehensive green industrialization agenda[8].

For the purposes of this work, **specific focus on two pivotal industries at the nexus of minerals and energy in Namibia have been selected from the longer list above**:

1. **Green Hot Briquetted Iron Production**: Namibia could couple its nascent iron ore mining industry with renewable hydrogen to produce direct reduced iron (DRI) for export in the form of hot briquetted iron (HBI). Direct reduced iron could enable the export of a higher-value product that further increases Namibia's revenues, contributes to the creation of highly skilled jobs and stimulates the domestic economy.
2. **Processing of Two Critical Raw Materials (CRMs)[9]**: With a focus on lithium and rare earth elements (REE), this sector is vital for harnessing Namibia's unique geological resources to meet the growing global demand for technology and energy products that rely on these minerals.

While the connection between these three value chains and the mining and beneficiation industry is clear, the link to energy arises where both green power and green hydrogen could be essential for low-emissions processes along these value chains.

Namely, these chains can be categorized into four general stages: mining, beneficiation, processing, and export. Each stage is energy-intensive, necessitating the adoption of low-carbon power sources to minimize the overall environmental impact of the chain. Deploying solar photovoltaics (PV) and wind power plants can directly reduce the amount of diesel and heavy fuel oil consumed by the generators that run electrically powered mining equipment, lowering costs and raising energy security in the mining sector. Additionally, green hydrogen can also play a key role at each stage, as illustrated in Figure 2:

Definition of Green Hydrogen: Green hydrogen is produced from renewable energy sources, including solar, wind, and hydroelectric power.

1. **Existing Uses[10]:**
   - Crude Oil Refining: Hydrogen is crucial for reducing sulfur content and breaking down heavier fractions.
   - Ammonia Production: Used in the Haber-Bosch process to produce ammonia, primarily for fertilizers.

[8] Statement by Dr. Michael Nokokure Humavindu, 10-11 April 2024 on the occasion of the "Localizing Green Industries in Namibia' workshop: *"Industrialization, Investment policy and Enterprise Development at the Ministry of Industrialization and Trade"*
[9] Lithium and REEs are not the only Critical Raw Materials. The 2020 EU Critical Raw Materials List also contains cobalt, magnesium, phosphorus, tantalum, and bauxite, to name but a few.
[10] Note that the existing uses of hydrogen today are primarily done using grey hydrogen (i.e., hydrogen produced not from renewable but from fossil resources). The role of green hydrogen in these processes would remain the same as that of grey hydrogen.

- Methanol Production: Essential in producing methanol, which serves as a base for various chemicals and fuels.

2. **New Uses:**
   - Hydrogen as a reductant: Hydrogen acts as a reducing agent in industrial processes, where it removes oxygen from metal oxides to produce pure metals, significantly lowering the carbon footprint compared to traditional methods using fossil reductants (e.g., gas).
   - Hydrogen as a fuel:
     - High-Temperature Processes: Used in industries requiring elevated temperatures, hydrogen combustion emits only water, contrasting with CO_2 emissions from burning fossil fuels.
     - Power Generation: In specific scenarios where traditional electricity is impractical, hydrogen can generate power, ideal for powering heavy trucks, ships or planes.
   - Hydrogen for power system balancing:
     - Power Generation: hydrogen is likely to play a significant role in providing seasonal balance and dispatchable generation within power systems dominated by variable renewables (e.g., store surplus renewable energy and convert it back to electricity when needed).

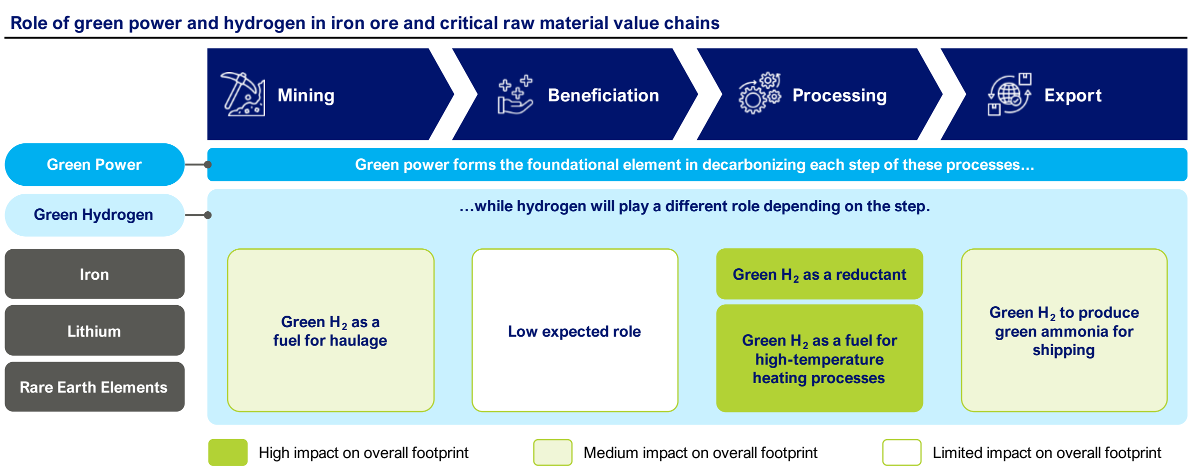


Figure 2: Green power and hydrogen can play a role in decarbonizing multiple parts of the iron, lithium and rare earth element value chains, unlocking common infrastructure for decarbonizing other sectors.

- **Mining stage**: Green hydrogen reduces emissions by replacing diesel in haulage operations. The International Council on Mining and Metals (ICMM) notes that fuel costs can account for up to 32% of total energy input in mines[11]. Since the combustion of hydrogen only emits water

[11] R.L Figueiredo et al., *Green hydrogen: Decarbonization in mining – Review*, Cleaner Energy Systems (2023), 5, 100075

vapor, transitioning to hydrogen-powered haulage trucks would cut emissions from mining haulage. Note that in some instances, the electrification of haulage trucks using green power could also be a viable alternative to both diesel and hydrogen. The choice of low-carbon energy vector deployed will depend on the technological maturity and economics of haulage trucks of various sizes and geographical locations.

- **Beneficiation stage**: Hydrogen is not expected to significantly contribute to decarbonization in this stage, given green power is expected in most cases to sufficiently provide the requisite energy.
- **Processing stage**:
    - Hydrogen is crucial as a fuel in decarbonizing high-temperature processes (above 1000 °C) required for processing critical raw materials like lithium or REE (e.g., calcination), as these temperatures are to date inaccessible through pure electrification technologies alone.
    - Hydrogen is also critical as a chemical feedstock to produce green hot briquetted iron. Here, hydrogen serves as a reductant to convert iron ore into iron, offering a sustainable alternative to traditional high-emission reductants like coal, coke or natural gas. This method significantly reduces CO_2 emissions, a critical factor given that primary steel production is responsible for approximately 7–8% of global emissions[12].
- **Export stage**: The path to long-distance shipping decarbonization is almost certain to involve hydrogen-based fuels – whether ammonia or methanol – combusted in adapted versions of existing marine engines[13]. Hydrogen can therefore help decarbonize the export of green HBI or CRMs to potential offtake markets of these products.

Notably, while the discussion above focuses on iron, lithium and REEs, these new value chains are expected to be able to trigger cross-cutting benefits that could also affect Namibia's existing mining sectors, namely:

- **Investments in common user infrastructure** that span across multiple minerals sectors, including power, logistics, water, etc.; and
- **Regulatory synergies** that create an environment for multiple mineral sectors to thrive in a green industrial economy, such as Special Economic Zones (SEZs), and both fiscal and non-fiscal incentives for low-emissions mineral value chain operations.

1.3. How Namibia stacks up in the green industrialization race today

Namibia is not alone in either its green hydrogen or its green industrialization ambitions. In the African continent alone, Namibia sits alongside multiple countries also racing in this space. Despite

[12] Ma, Y. et al., *Reducing iron oxide with ammonia: a sustainable path to green steel*, Adv. Sci. (2023), 10, 2300111

[13] Energy Transitions Commission (2021), *Making the Hydrogen Economy Possible: Accelerating Clean Hydrogen in an Electrified Economy*

its abundant natural resources, Namibia has yet to fully realize its potential in the renewable energy and hydrogen sectors, both of which will be key backbones for a broader green industrialization agenda.

Fehler! Verweisquelle konnte nicht gefunden werden. Figure 3 compares Namibia to other key countries in the region on the metrics of existing and forecasted wind and solar capacity, as well as expected hydrogen electrolyzer capacity according to announced projects to date. **While Namibia's position in installed renewables capacity to date may in large part be explained by its small national population** (see Figure 3, a per capita view is provided below in Chapter 4), **both forecasted renewables and electrolyzer capacity paint a picture of Namibia falling behind when it comes to green hydrogen project announcements.**

Several factors may contribute to this current view, resulting in a set of strengths and vulnerabilities unique to Namibia (Figure 4 indicates a qualitative view). While Namibia possesses the potential for low-cost green hydrogen and can look to its political stability and rule of law to attract projects, its relatively small economy to date means it lacks the brownfield industries and infrastructure at scale that, in some other countries, may constitute an existing backbone adaptable for a green industrial economy.

While these latter factors, together with geographic location relative to potential offtake markets, are not within Namibia's control, key factors like governance and commitments are. It is therefore imperative for policymakers to continue all efforts in creating a legislated environment that enables green industries to thrive for the benefit of both the Namibian people and economy, as well as the global industries that will rely on Namibia to realize their net-zero transition goals.

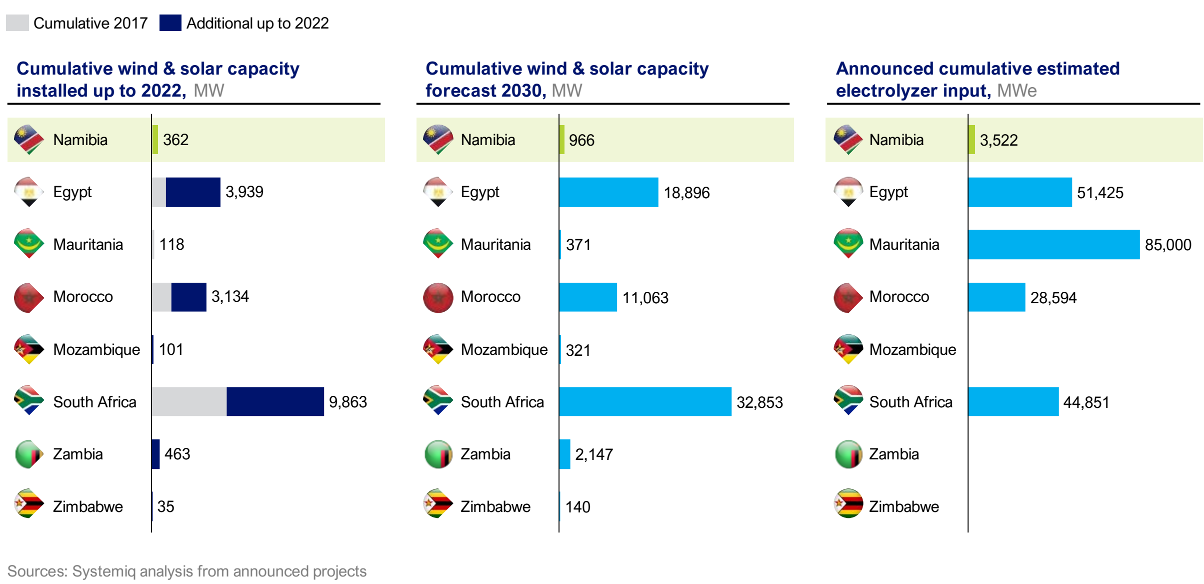
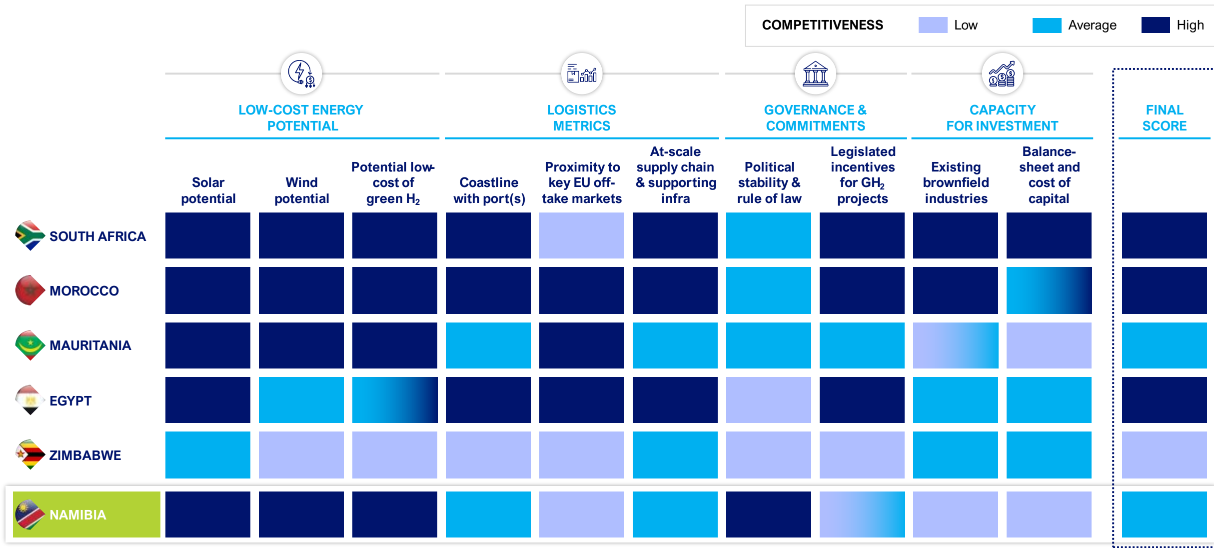


Figure 3: Despite abundant natural resources, Namibia has yet to fully realize its potential in the renewable energy and green hydrogen sectors.



Sources: Systemiq analysis

Figure 4: In comparison with regional countries also advancing on green industrialization, Namibia has its own unique set of strengths and vulnerabilities.

Legislation to support the energy and hydrogen sectors.

Looking to countries that are ahead of the pack in providing incentivizing legislation may provide inspiration as Namibia looks to develop its own fit-for-purpose policies. Morocco stands out as a key example. Among others, below are a list of policies and actions at national level that may have spurred on Morocco's success in positioning itself as a key market for green hydrogen and downstream industries.

Energy sector specific[14]:

- **National Energy Strategy (2009)** - Aimed at increasing the share of renewable energy in the electricity mix to 42% by 2020, improve energy efficiency, and promote regional integration of energy markets.
- **Climate Change Policy (2014)** - Established broader environmental objectives, including specific targets for reducing greenhouse gas emissions.
- **National Sustainable Development Strategy (2017)** - A comprehensive framework to promote sustainable development, including green industrialization across various sectors.
- **Nationally Determined Contribution (NDC) Update (June 2021)** - Morocco updated its NDC, raising its 2030 greenhouse gas (GHG) emission reduction targets from 17% to 18.3% unconditionally, and from 42% to 45.5% conditionally, depending on international support.
- **Industrial Recovery Plan (2021-2023)** - Announced post-COVID-19 by the Ministry of Industry, Trade, Green Economy, and Digital; includes measures to decarbonize Morocco's industrial sector, specifically focusing on reducing the carbon footprint of industrial activities.
- **Renewable Energy (RE) Program** - Achieving over 52% of installed electricity generation capacity from renewable sources by 2030.

[14] Policy Center for the New South (2021), *What will be the effect of the EU's Carbon Border Tax on Morocco, and how should Morocco react?*

Hydrogen / Power-to-X sector specific[15,16]:

- **Creation of the National Hydrogen Commission (2019)** - Established by the Moroccan Energy Ministry to oversee and promote hydrogen development.
- **Agreement with Germany (June 2020)** - Morocco signed an agreement with Germany to develop a regional market for Power-to-X (PtX) technologies.
- **Memorandum of Understanding with the European Union (October 18, 2022)** - Signed in Rabat to establish a Green Partnership, focusing on enhancing cooperation in the field of green energy, including hydrogen.
- **Royal Instructions for Green Hydrogen Development (November 22, 2022)** - The Sovereign directed the development of a Moroccan offer covering the entire green hydrogen value chain.
- **Green Hydrogen Cluster Formation** - As part of Morocco's strategy to foster collaboration between the public and private sectors in green hydrogen production:
    - Conducting technical and cost studies to choose the cluster and its related infrastructure
    - Including PtX in "Special Economic Zones"
    - Assessing grid needs
- **The Morocco Offer (March 2024)** - This framework was announced to advance the green hydrogen sector in Morocco, aiming to cover the entire green hydrogen value chain, from renewable power production to the manufacture of hydrogen and its derivatives:
    - Land Mobilization: Allocation of around 1 million hectares, starting with 300,000 hectares in large plots, for green hydrogen production.
    - Infrastructure Development: Commitment to developing crucial infrastructure like ports, hydrogen pipelines, and water resources, essential for the sector's success.
    - Investor Selection Process: A phased approach involving proposal submission, initial assessment, negotiations, and preliminary contracts leading to final investment agreements.
    - Incentives: Offers tax and customs benefits, import duty exemptions, and VAT exemptions on domestically purchased and imported goods to attract investments.
    - Governance and Oversight: The establishment of a governance structure involving MASEN (Moroccan Agency for Sustainable Energy) and key committees to ensure efficient oversight and support for investors.

A pertinent comparison for Namibia would be Mauritania. While its patchwork of strengths and vulnerabilities differ slightly (Figure 4). In many ways, Mauritania possesses several macro characteristics not dissimilar to Namibia, spanning across key geographic, demographic and renewable potential metrics (Figure 5, left-hand panel). However, Mauritania is currently outpacing Namibia 10-fold in its announcements of green hydrogen-related projects. Notably, the majority of these announcements come in the form of Memorandums of Understanding (MoUs) with oil and gas majors[17], echoing the aforementioned potential advantage of having had a pre-existing industry (in this case, oil and gas) in-country.

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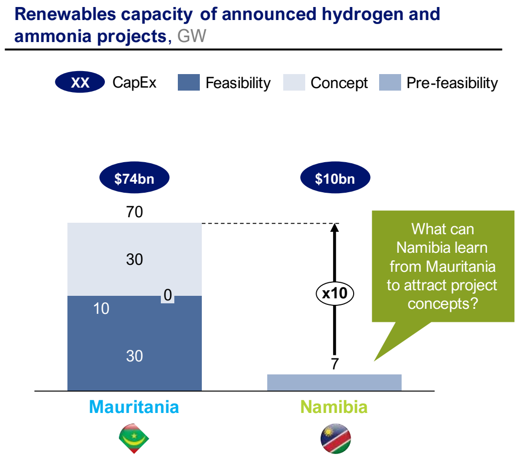
[15] IRESEN (2023), *Green Hydrogen in Morocco*

[16] Clifford Chance (2023), *Focus on hydrogen: Navigating Morocco's new policy*

[17] MoU with bp (November 2022): Explore large-scale green hydrogen production using local renewable resources; MoU with CWP Global (May 2021): Initiated the 30GW AMAN green hydrogen project; MoU with Chariot (September 2021): Advanced the Nour project, which later expanded into a joint development with Total Eren; MoU with Infinity Power Holding and Conjuncta GmbH (March 2023): A collaboration to develop green hydrogen projects, showcasing a partnership between Egyptian, UAE, and German entities.

Namibia and Mauritania macro comparison

		Mauritania	Namibia
General characteristics	GDP (2022)	$10.4 billion	$12.3 billion
	Population (2022)	4.6 million	2.5 million
	Size of the country	1,031,000 km²	824,292 km²
Renewable strengths	Solar PV potential	2,000-2,300 kWH/m²/year	2,200-2,400 kWH/m²/year
	Onshore wind capacity factor	~50% in the Nouadhibou region	~50-60% in the Lüderitz region



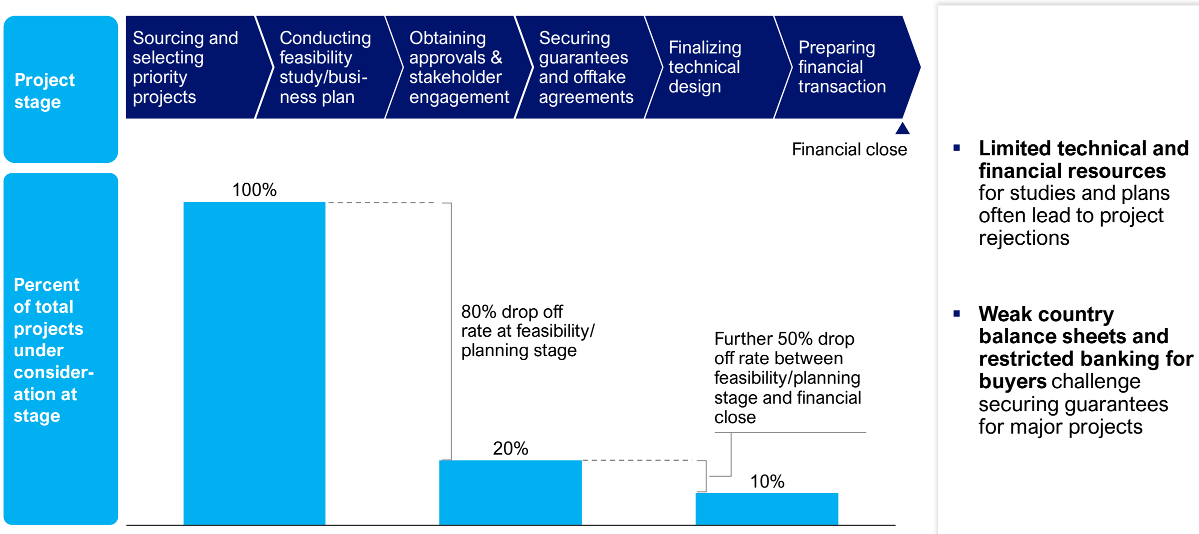
While Mauritania leads in project announcements, both Mauritania and Namibia are navigating the challenge of turning these announcements into financial commitments

Sources: Systemiq analysis from IEA (2023), *Renewable Energy Opportunities for Mauritania* ; publicly available information

Figure 5: In comparison to Namibia, Mauritania leads with 10x more announced hydrogen projects in the pipeline.

Having said this, not all announcements naturally lead to projects reaching financial close. Green hydrogen projects may well fall prey to the same reasons behind the steep drop-off historically observed in African infrastructure projects in reaching this latter milestone (90% drop – Figure 6[18]). Namely, limited technical and financial resources and weak country balance sheets are among the factors that could make or break green hydrogen ambitions. When it comes to green industrial projects at the nexus of the energy and minerals sectors, a menu of several puzzle pieces will need to be progressed in order to advance projects from announcement stage to final investment decision (FID; Figure 7). This work will focus on some of these in the context of iron, lithium and rare earth elements.

[18] McKinsey (2020), *Solving Africa's infrastructure paradox*



Sources: McKinsey (2020), *Solving Africa's infrastructure paradox*

Figure 6: Africa's infrastructure paradox: despite available funds, large pipeline and clear need, few projects reach financial close.

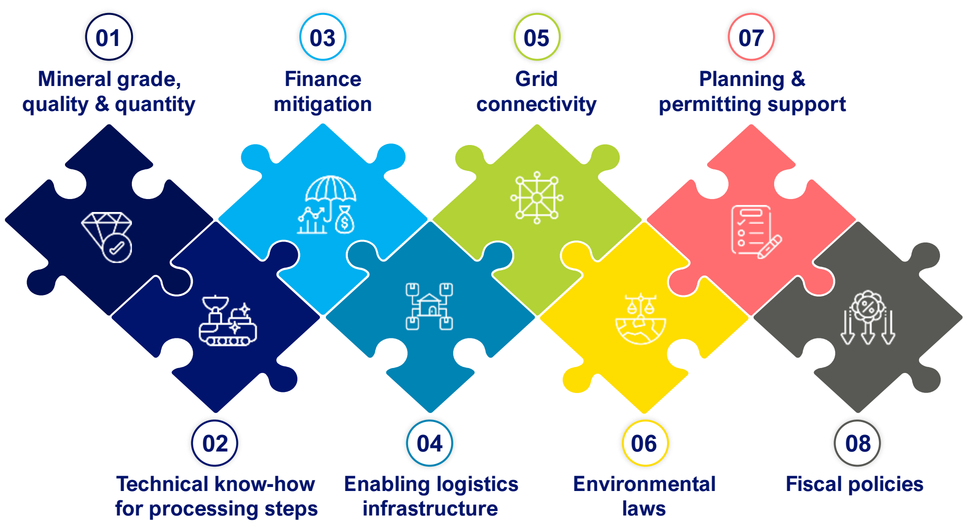


Figure 7: Several essential puzzle pieces must progress to advance projects from pre-feasibility to financial investment decision.

2. Green Iron, Key Derivative of Namibia's Green Hydrogen Ambitions

2.1. Global opportunities in green iron

2.1.1. Market outlook

Steel is critical to a low-carbon economy, but producing it is emissions-intensive, accounting for 7% of global GHG emissions[19]. Optimizing recycled volumes and production processes can deliver substantial emissions reductions. Nevertheless, limits to the quantity and quality of available scrap steel mean that up to 60% of steel in 2050 will likely need to come from primary, iron ore-based production in the absence of major materials and circularity breakthroughs[20]. Therefore, new technologies will be critical to either replace coal as a fuel and reductant with a fossil-free alternative, or capture and store the emissions from it[21]. Some of these technologies are already technically proven but not yet deployed at scale.

Progress this decade is essential, and steelmakers are stepping forward: the global steel industry has embarked on a decarbonization journey, with green hydrogen emerging as a key technology route to achieving this via green iron. Already, a third of the world's top 50 steel producers, including industry giants Baowu, ArcelorMittal, Posco, Nippon Steel, HBIS and others, have committed to achieving net-zero emissions by 2050 (Figure 8)[22]. Major steel-producing and -consuming regions, including the EU, USA, Republic of Korea, Japan and China, are also committed to net-zero targets, leaving little choice but to invest in a low-carbon future for steelmaking. These commitments are the crucial first step, but the necessary investment in low-CO_2 steel production will require a strong business case and policies that take global competition into account.

Parallel to these commitments, innovative technology players such as H2 Green Steel (H2GS), Boston Metal, and HYBRIT are revolutionizing the steelmaking process. H2GS has notably secured approximately €6.5 billion for the world's first large-scale green steel plant in northern Sweden[23], and is exploring expansion into other regions. H2GS' developments are made possible by advancements in green hydrogen technology, which is accelerating commitments to green steel projects in regions with characteristics similar to those of Namibia.

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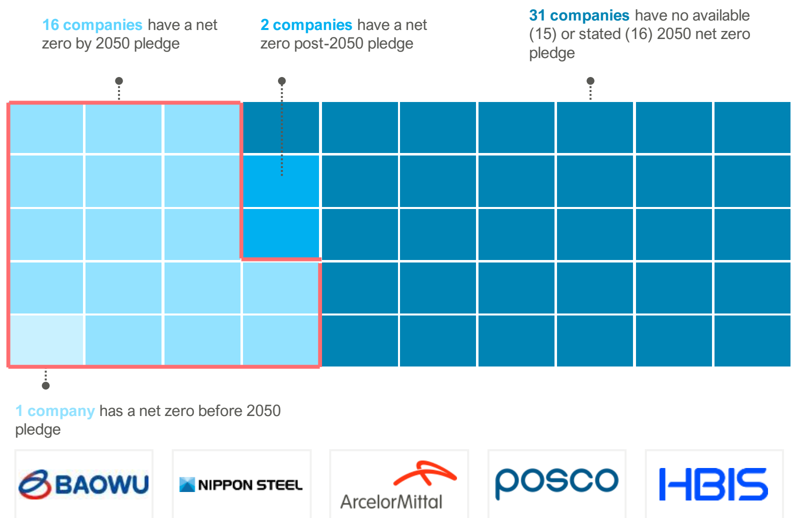
[19] Our World in Data

[20] Mission Possible Partnership (2022), *Making Net-Zero Steel Possible*

[21] Today, about 70% of the world's steel is produced via the blast furnace-basic oxygen furnace (BF-BOF) route. In this process, iron ore is reduced in the blast furnace to molten iron, which is subsequently refined to crude steel in the basic oxygen furnace. The reduction reactions and refining process require temperatures in the range of 1100 to 1600 °C, currently achieved with fossil fuels. This process emits an average of 2.1 tonnes of CO_2 per tonne of crude steel (t CO_2/t CS).

[22] Global Energy Monitor (2023), *A Matter of Ambition: Examining the Steel Industry's Commitment to Net Zero by 2050*

[23] H2 Energy News (2024), *H2GS Secures Billions to Forge Europe's Largest Green Steel Plant*



Sources: Systemiq analysis from Global Energy Monitor (2023), *A Matter of Ambition: Examining the Steel Industry's Commitment to Net Zero by 2050*

Figure 8: A third of the world's top 50 steel producers have set targets to reach net-zero emissions by 2050.

This momentum for steelmaking decarbonization is further supported by downstream steel consumers who are, in what is anticipated to be a tight supply market, increasingly moving up the value chain and entering into offtake agreements to secure supplies of green steel and even green iron and showing willingness to pay a premium for greener alternatives. Notable examples include Mercedes Benz's MoU with H2GS[24] (see below) and Volkswagen's agreement with Salzgitter[25].

Mercedez Benz moving up the value chain:
In 2023, Mercedes-Benz signed a supply agreement with Swedish start-up H2GS for over ~50,000 tonnes of low-CO_2 steel per year to serve Mercedes Benz's European press shops. They further deepened this partnership through a Memorandum of Understanding (MoU) with the aim of establishing a sustainable steel supply chain in North America. After taking an equity stake in H2GS in 2021, the new supply agreement enables Mercedes-Benz to bring low-CO_2 steel into series production. H2GS plans to start its production during 2025.

This strategy observed in the automotive industry is propelled by two primary factors: (i) net-zero commitments made by many original equipment manufacturers (OEMs) themselves and (ii) the manageable impact of a green premium on end-consumers. The latter refers to the fact that though decarbonization will incrementally raise the cost of steelmaking, the proportion of steel in the total cost of finished product ensures that any increase in steel prices will only slightly affect the final product prices. For instance, by 2030, the projected cost increase due to higher green steel

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[24] Mercedes-Benz (2023), *Mercedes-Benz and H2 Green Steel secure supply deal.*
[25] Salzgitter AG (2022), *Volkswagen Group and Salzgitter AG sign Memorandum of Understanding on supply of low-CO2 steel from the end of 2025*

prices is estimated to manifest as a green premium of only around 0.5% for passenger cars, 1.5% for white goods, and 2.1% for construction projects. By 2050, these cost increases are expected to reduce further to 0.3% for cars, 1% for white goods, and approximately 1.4% for buildings, as detailed in Figure 9[26].

Price difference of products containing steel produced by an average DRI-EAF fed with 100% green hydrogen compared to steel produced by an average BF-BOF

Consumer good	2020	2030	2040	2050
Passenger car	~$37,500	+0.5%	+0.4%	+0.3%
Building	~$0.8m	+2.1%	+1.9%	+1.4%
White good	~$400	+1.5%	+1.4%	+1.0%

Note: Percentage values show how much steel input prices would increase the final consumer price if the remaining bill of materials for the product remained the same as in 2020 with no inflation, assuming higher steel input costs do not induce any changes in product design. The goods in question are assumed to require only crude steel. In reality, consumer products such as these would require finished or specialty steel products. However, the decarbonisation of steelmaking is expected to have a less significant impact on the cost of finishing processes and specialty steelmaking than on crude steel production. Consequently, the additional costs associated with steps beyond crude steel manufacturing have been excluded

Sources: Mission Possible Partnership analysis; Energy Transition Commission Steeling Demand, and Material Economics, https://www.energy-transitions.org/publications/steeling-demand/; McKinsey & Company (2022), *Net-zero steel in building and construction: the way forward*

Figure 9: Comparing price differences of consumer goods across different low-carbon scenarios.

2.1.2. Different routes to steel decarbonization

A portfolio of solutions will be needed to decarbonise global steelmaking, as different technologies will be cost-competitive in different locations Fehler! Textmarke nicht definiert.**.** Most of today's primary steelmaking is in places that have historically offered affordable access to coal mines, iron ore deposits, and water and rail transport infrastructure. As decarbonized steelmaking relies on different technologies and inputs than fossil-based steel production, the transition to net-zero will necessarily shift the old geographical balance and add new location contexts. Access to low-cost, low-carbon electricity and hydrogen, bioenergy, carbon capture and storage (CCS) infrastructure and sequestration sites, competitively priced natural gas, and proximity to industrial clusters will shape the technology transition.

Among all technology options for decarbonizing steel, three primary approaches are emerging. The first leverages increased **use of steel scrap for secondary steelmaking (i.e., recycled steel)**. The second involves **retrofitting existing blast furnaces with CCS technology**. The third involves **direct reduced iron (DRI)-based steelmaking**.

As mentioned above, secondary steelmaking alone will not be able to meet most steel demand. Using Europe as a key steel-producing region today as an illustrative example: the steel value chain in Europe has high collection rates for recycling of about 85%, but currently yields low quality scrap

[26] Mission Possible Partnership (2022), *Making Net-Zero Steel Possible*

due to tramp elements like copper, especially in post-consumer scrap. This challenge will be especially significant in the European steel value chain, due to its current technologically driven orientation towards premium products with low tolerance for tramp elements. As a result, scrap availability is expected to be too low in the EU to meet the recycled content targets set by industry, due to insufficient time for the steel recycling value chain to adapt to higher scrap demand. The European steel industry will therefore have to rely on *primary* sources of green iron and steel in conjunction to meet their emissions-reduction targets, either via CCS or via the DRI route[27].

The viability of CCS as a major contributor to decarbonizing the steel sector is increasingly being questioned[28]. According to Agora Industry, since 2020, there has been a significant divergence in the development of new DRI-based steel plants compared to CCS projects for blast furnace operations. Commercial-scale plans overwhelmingly favour hydrogen-based or hydrogen-ready DRI technologies over CCS. Concretely, the global project pipeline for DRI plants by 2030 has expanded to 94 Mtpa, whereas CCS projects for blast furnace applications stand at just 1 Mtpa in comparison[29], as illustrated in Figure 10. This clear trend is multifaceted and reflects several key factors: the historical underperformance of CCS technologies (e.g., low capture rate), coupled with the growing economic feasibility of the DRI route as costs to produce of zero-carbon electricity and low-carbon hydrogen decrease. There is therefore a growing consensus that direct reduced iron will become the dominant ironmaking process, projected to increase from approximately 5% of today's steel production to 70-80% by 2050[26].

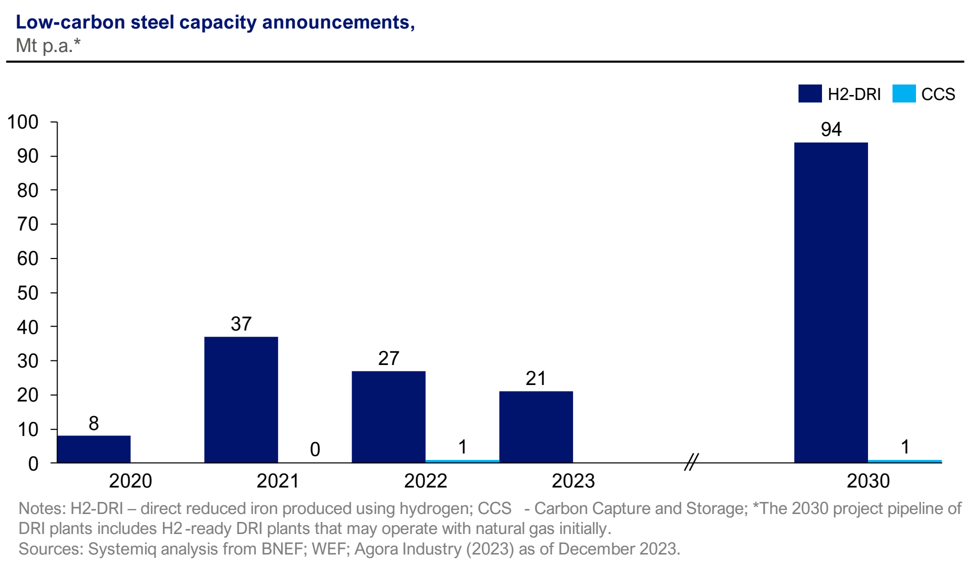


Figure 10: Green hydrogen could be the cheapest net-zero solution to make primary steel by 2050; hydrogen-based steel-making project announcements are far outpacing carbon-capture-based steelmaking project announcements.

[27] Systemiq (2023), *Circular steel: A System Perspective on Recycled Content Targets*
[28] Institute for Energy Economics and Financial Analysis (2024), *Carbon Capture for Steel? CCUS will not play a major role in steel decarbonization*
[29] Agora Industry, *Global Steel Transformation Tracker.*

2.1.3. Overview of the direct reduced iron value chain

Steelmaking from DRI is today a proven process, where iron is produced in the DRI step using natural gas as fuel and reductant, and this iron is then converted into crude steel in an electric arc furnace (EAF), giving rise to the total technology route termed DRI-EAF. Even using natural gas, DRI-EAF already provides an immediate emissions savings of about 1 tonne of CO_2 per tonne of crude steel (t CO_2/ t CS) compared to the average 2.4 t CO_2/t CS via the coal-powered blast furnace route. Predominantly adopted by Middle Eastern operators today with access to inexpensive natural gas, the future of DRI could see nearly zero emissions with the substitution of natural gas with low-carbon hydrogen. For true low-carbon operation, substantial amounts of green power are essential both for producing green hydrogen and for continuous, baseload operation of the DRI plant, as detailed in Figure 11 below.

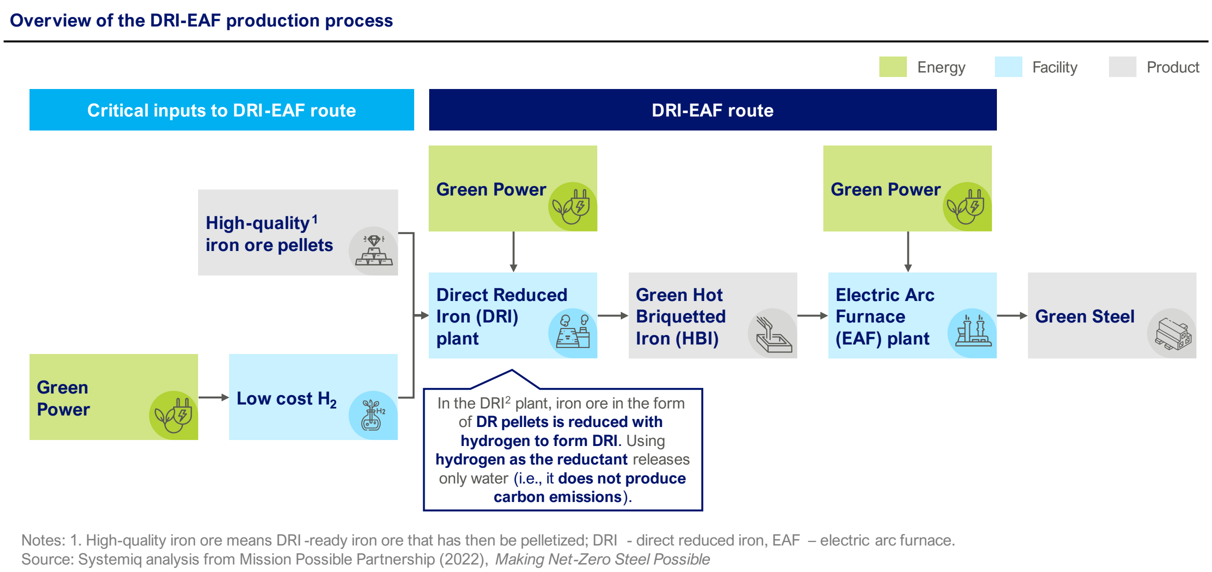


Figure 11: Low-carbon steel is derived from high-grade iron ore through several manufacturing steps requiring green power and green hydrogen.

However, the broader adoption of DRI is currently hindered by its requirement for high-quality iron ore (e.g., low-impurity iron ore with an iron (Fe) content of 67% or above), which currently constitutes only 13% of globally shipped iron ore[30]. In order for the DRI route to dominate by 2050, the steel industry must overcome this barrier through the development of new ore deposits, enhanced pre-processing of lower-grade ores, or innovative melter technologies that allow the use of lower-grade ores in DRI-EAF processes[30].

Accordingly, the geographical landscape of steel production is expected to shift in the coming decades, where regions that can provide both low-cost hydrogen and high-quality iron ore will likely emerge as new hubs for DRI-based steelmaking in a decarbonized global economy. This

[30] Mission Possible Partnership (2022), *Making Net-Zero Steel Possible*

potential has already begun to attract green steel projects to Mauritania (e.g., Chariot's 10 GW initiative[31]) and could make Namibia an increasingly attractive site for such developments.

In terms of strategic positioning, **Namibia could explore three options to develop its renewable energy potential for steelmaking**:

1. Producing and exporting low-cost hydrogen to (existing) integrated[32] DRI-EAF plants.
2. Producing green HBI for export to overseas EAF plants, where HBI is a briquetted form of DRI more conducive to transportation (see inset below).
3. Establishing end-to-end green steel production with integrated DRI-EAF facilities in-country.

Recent studies indicate that exporting hydrogen might not be economically feasible over long distances due to transportation and conversion complexities[33]. Thus, there is a **growing consensus on the strategic benefit of co-locating green hydrogen production with DRI facilities**, either for producing HBI for export or for local green steel production. In the short term, leveraging Namibia's two core strengths—its potential as a hydrogen producer and its high-quality iron ore reserves (see section 2.2) —suggests a focus on partnering with foreign EAF plants near downstream OEMs, rather than pursuing fully integrated green steel production.

This would also enable a phased approached, starting with scaling up iron ore mining operations alongside Namibia's green hydrogen endeavor to then set up a DRI plant facility. This sequenced strategy would match Namibia's green industrialization objectives and maximize Namibia's revenue, fostering the creation of highly skilled jobs and stimulating the domestic economy.

Why export HBI instead of DRI?
Hot Briquetted Iron (HBI) is preferred for export over Direct Reduced Iron (DRI) due to its enhanced transport and storage capabilities.

- Being a denser and more compact form of DRI, HBI is not reactive with atmospheric oxygen, making it safer and more stable for shipping. This greater degree of compactness also translates into higher transportation and storage efficiency, reducing costs significantly.
- HBI boasts superior mechanical strength and a high metallization rate of over 90%, positioning it as the highest quality among ore-based metallics for producing high-quality steel in Electric Arc Furnaces.
- The established export routes and energy-efficient production processes, especially using green hydrogen, further underscore HBI's advantages in the iron and steel industry[33].

2.1.4. Seeds of Namibia's green iron sector

Namibia's nascent iron industry is seeing significant development through projects aimed at enhancing green iron production and tapping into the country's mining potential:

[31] Energy Connects (2024), *Chariot submits feasibility update on 10 GW green hydrogen project in Mauritania*
[32] 'Integrated' implies that both ironmaking and steelmaking occur at the same site.
[33] Institute for Energy Economics and Financial Analysis (2023), *Green iron and steel offer MENA a chance to shine*

- **HyIron Oshivela Project**: This is set to be Africa's first industrial climate-neutral iron production facility. Located in western Namibia, it will produce iron using green hydrogen, following a proprietary rotary kiln technology that is currently being piloted at the Lingen site in Germany. The project, supported by the German government, aims to commence production in late 2024 with an initial output of 15,000 tonnes of DRI annually. The long-term goal is to expand production to 1 million metric tonnes of green iron per year[34].
- **Lodestone Dordabis Project**: Located in central Namibia, this project focuses on mining high-grade iron ore concentrate. With declared reserves of over 29 million tonnes of high-grade concentrate, the project has the potential to produce up to 2 Mtpa of high-grade iron ore concentrates (66% Fe) for 16 years and at its full potential could ramp up to 4 Mtpa for a further 20-30 years[35].
- In the rest of the country, various other companies are exploring further resources in the iron ore sector. These exploratory activities signal a burgeoning interest in expanding Namibian capacity to mine iron ore, laying the groundwork for potential future green iron projects.

2.1.5 Challenges associated to green iron production

Namibia possesses the foundational elements and potential to develop a robust green iron sector, bolstered by its high-quality iron ore reserves, renewable energy capabilities, and strategic geographic positioning (see section 2.2). This promising foundation sets the stage for the country to become a leader in environmentally sustainable iron production.

However, realizing this vision entails facing several challenges:

1. **Capital and Financing**: Establishing a green iron production facility is capital-intensive, with cost estimates for a single plant—including the mine, electrolyzer, renewable energy sources, and the DRI plant—reaching approximately US$3 billion, as detailed in Figure 12.
2. **Electricity and Power Supply**: The operation requires continuous, 24/7 power supply to maintain production, necessitating substantial investments in renewable energy infrastructure capable of producing around 1.3 GW for green hydrogen production and generating around 0.2 GW baseload power to run the DRI plant while maintaining low-carbon intensity of all of these sources to be able to accredit the iron as sufficiently 'green'.
3. **Skilled Workforce**: Developing this sector will demand a highly skilled workforce. Estimates suggest significant employment opportunities, with the need to staff operations for 1.5 GW of renewable energy capacity, a DRI plant, and a mine producing 3 Mtpa iron ore.
4. **Transport Infrastructure**: Robust transport networks, particularly rail, are essential to support the efficient movement of raw materials and finished products, necessitating further infrastructure developments.
5. **Offtake Markets and Regulatory Environment**: Securing offtake markets is crucial, especially in light of evolving international regulations such as the CBAM in the European

[34] HyIron (2024), Oshivela
[35] Lodestone Namibia (2024), Dordabis Project

Union. Additionally, there are logistical considerations in deciding between exporting HBI and operating integrated plants to minimize heat losses during transformation[36].

Addressing these challenges will be critical for Namibia to capitalize on its potential and successfully establish a green iron sector that not only meets global demand for decarbonized iron but also creates economic value in Namibia.

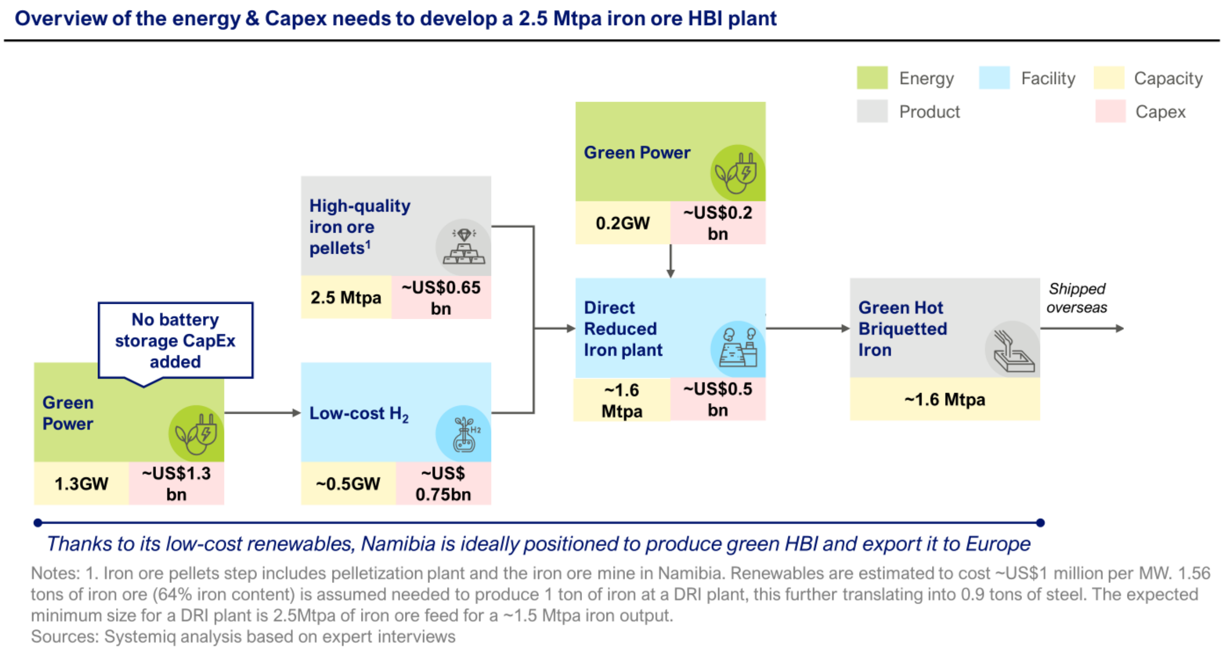


Figure 12: The quantum of green power and hydrogen required to drive a single green iron plant are immense.

2.2. Namibia's potential competitiveness in green iron and possible value chains

2.2.1. Securing DRI-quality iron ore

Availability of iron ore of sufficient quality is critical to the overall business case for green iron production. If a resource's quality is below the desired threshold (of ~67% Fe, with low levels of key impurities[37]), extra costs will be incurred to upgrade this to "DRI-quality", hampering overall cost-competitiveness of a project.

[36] Breaking up the value chain will entail some trade-offs versus an integrated DRI-EAF plant. The economic gains from producing green hydrogen in a location with more competitive hydrogen-production costs will need to outweigh the additional HBI handling and loading costs, the costs related to briquetting required before transportation, and the additional melting costs of HBI at the destination EAF plant (~100 to 150 additional kWh/t to melt).

[37] Pellet quality required to produce target quality HBI: 67.74% Fe, 1.83% SiO_2%, 0.29% Al_2O_3, 0.88% CaO, 0.22% MgO.

In addition to quality, quantity also matters, as a green iron plant would only make economic sense at full scale if it produces at a minimum output of 1.5 Mtpa iron, implying an input of ~2.5 Mtpa iron ore (Figure 12 above).

Namibia has potential access to multiple sources of quality iron ore within the region (Figure 13)**.** As mentioned above, Lodestone is looking to develop a DRI-quality iron ore resource within Namibia. Other iron ore resources in-country are also being concurrently explored and light will be increasingly shed on their potential relevance for DRI in terms of both their quantity and quality.

Looking further afield, South Africa, Guinea and Gabon also possess iron ore resources in the African continent. Neighboring South Africa are among the world's leaders in iron ore production, producing ~61 Mtpa iron ore today of mixed quality[38], some of which is near- or at DRI-quality grade. Rio Tinto's Simandou mine in Guinea alone is expected to produce 60 Mtpa of high-quality iron ore[39], constituting the world's largest untapped reserve of high-grade iron ore. Gabon is also a potential source of iron ore, with Fortescue's Belinga mine shipping iron ore as of 2023.

In the South African, Guinean and Gabonese cases, the availability of cost-effective logistics routes to transport millions of tonnes of iron ore annually to Namibia's green hydrogen locations will determine whether these sources of high-grade iron ore can birth viable regional green iron value chains for Namibia. While Guinea and Gabon might have to rely on shipping routes, the South African option – in particular iron ore from the Northern Cape – could foresee transport over land via rail across the Namibian-South African border. Kumba Iron Ore[40] may be considering this option with Namibian stakeholders and discussions are under way to better understand the implications of upgrading key rail lines to be fit-for-purpose (see Chapter 5 on rail infrastructure).

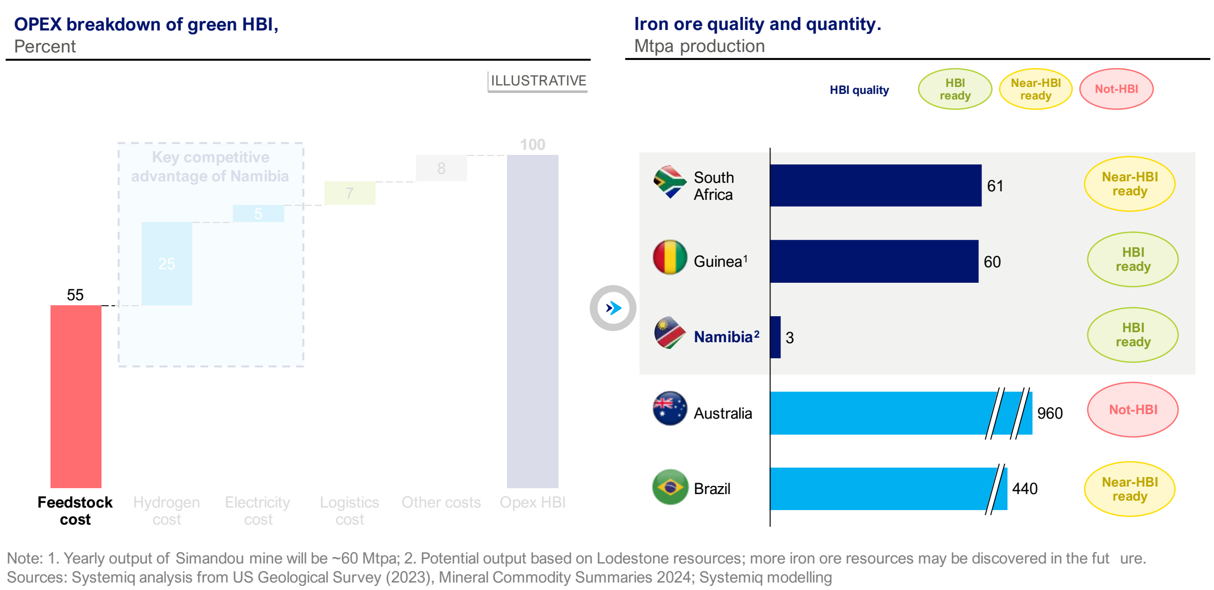


Figure 13: Iron ore quality and quantity comparison in some key producing markets.

[38] U.S. Geological Survey (2024), *Mineral Commodity Summaries 2024*
[39] Rio Tinto (2023), *Simandou iron ore project update*
[40] Anglo American's iron ore mining company in South Africa, currently the world's 5th largest iron-producer.

Outside of Africa, Australia and Brazil stand out as two countries that both possess their own iron ore reserves as well as have ambitions to supply green iron projects, some domestic. Notably, Australia's reserves are not of sufficient quality to be considered HBI-ready and will therefore have to either undergo upgrading or be used in other technology routes to green steel that do not involve direct reduced iron (some of which are not technologically mature yet), potentially undermining their cost-competitiveness. Brazil's reserves are near-HBI ready and may be considered a potential source for Namibia's green iron projects from across the Atlantic, although the economic viability of this longer transportation route would have to be tested.

2.2.2. Producing cost-competitive green power and green hydrogen

The second key ingredient to competitive green iron is low-cost green power and therefore also green hydrogen, with both components typically making up a total of ~30% of the OPEX cost stack of a green iron plant (Figure 14)**.** The expected ranges of future green hydrogen costs are a topic of heavy debate, and estimates have in recent times been pushed upwards to become less optimistic than previously thought. Nevertheless, if done right, this is an area where Namibia's world-leading natural solar and wind resources can ensure the energy and hydrogen costs going into a green iron plant remain low in *relative* terms when compared to other countries also looking to produce green iron.

Naturally, the final costs will depend on a project-level basis, where the careful selection of location and power offtake agreement may swing the needle in favour of locations other than Namibia. The availability of enough dispatchable grid power or power storage is also a key element besides cost that could make or break a location's viability for a green iron project. Collaboration of municipal/regional counterparts and the grid operator in Namibia together with potential green iron project developers from an early stage is therefore key to ensure all possibilities are explored and factored into project design from the onset.

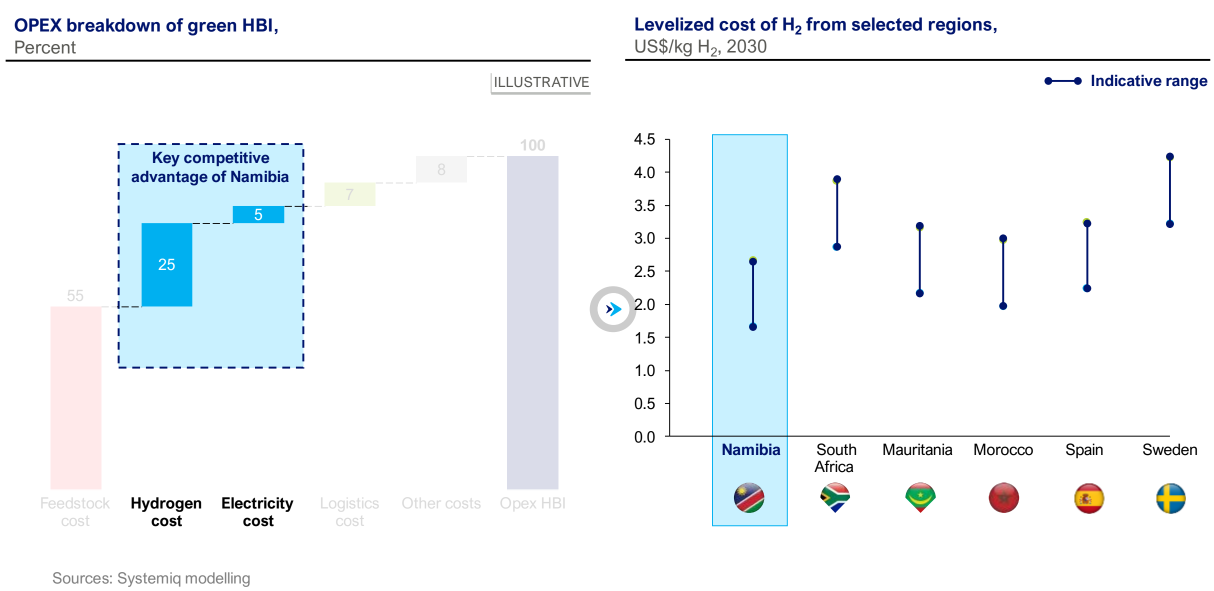
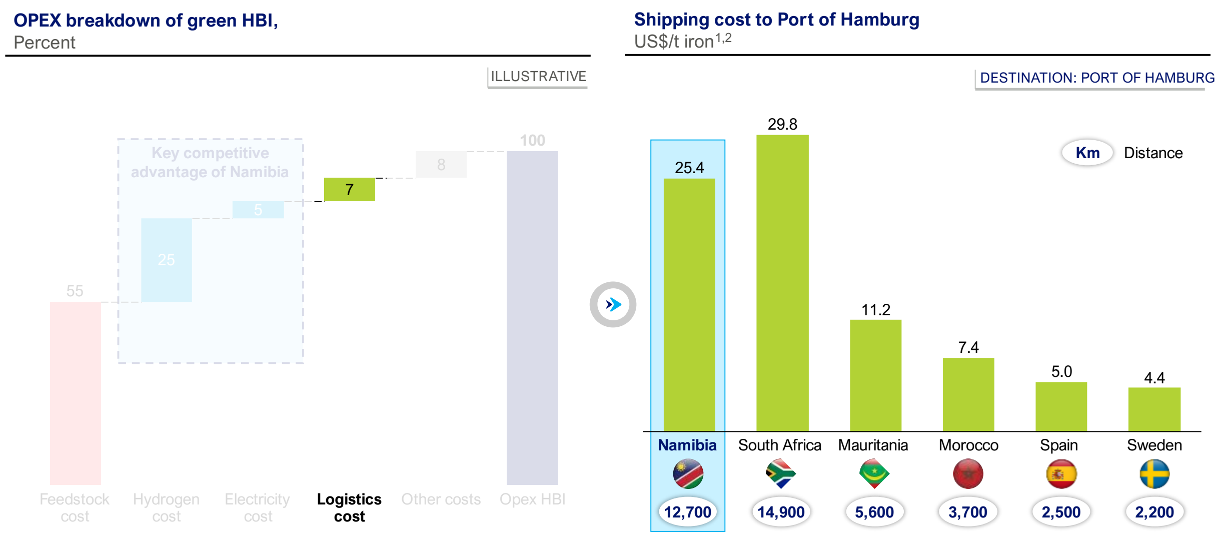


Figure 14: Levelized cost of hydrogen from key producing countries.

2.2.3. Optimizing logistics costs

Logistics costs can occur at various points in the value chain. Once the iron is produced, factoring in transportation costs to potential offtake markets (e.g., to turn into steel) is a smaller but nevertheless important part of the cost stack. Taking Germany as an end-point destination for potential green iron producers (Figure 15), the shipping distance largely determines shipping costs if all else is considered equal, meaning Namibia would be at a disadvantage compared to other iron-producing nations geographically closer to the EU offtake market (e.g., Mauritania, Spain). However, given this constitutes ~7% of the total OPEX cost stack in the Namibian case, this disadvantage can be conceivably outweighed if Namibia maintains sufficient cost competitiveness in the other more heavily weighted factors described above (iron ore, power and hydrogen).

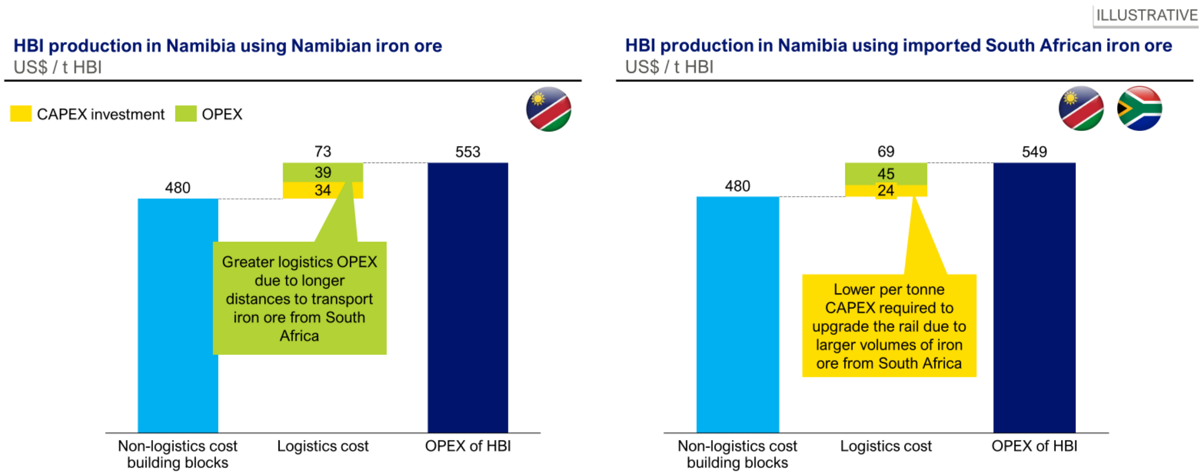


Note: 1. Shipping cost assumed at ~$0.002/ t / km; 2. No other rail, trans-shipments or port costs assumed here (see later figure).
Sources: Systemiq modelling

Figure 15: Comparison of shipping costs from iron ore export countries to Port of Hamburg as destination.

Further upstream in the value chain, obtaining the iron ore at the location of the green iron plant could add another element to overall logistics costs. Taking the example of iron ore mined in either Namibia (e.g., Dordabis) or in South Africa (e.g., Sishen in the Northern Cape) and comparing the costs associated with transporting both potential iron ore sources to a potential low-cost green hydrogen production hub in Lüderitz, the cost contribution of this journey to the overall cost per tonne of hot briquetted iron is not dissimilar, albeit with a different emphasis on CAPEX vs. OPEX (Figure 16). In both cases, rail upgrades (both for the line itself as well as investment in rolling stock) will require necessary CAPEX investment. However, due to the larger volumes of iron ore anticipated to be available from South Africa than from Dordabis, a higher utilization rate of this rail line for the former means a lower per-tonne-iron CAPEX cost. This may on the other hand be balanced out in part by the longer distance from Northern Cape to Lüderitz than from Dordabis to Lüderitz, resulting in a larger OPEX per tonne iron.

In conclusion, while logistics costs will not typically constitute the lion's share of a green iron project's total operating costs, the necessary infrastructure must be available to a sufficient standard and may require significant upfront CAPEX investment if not.



Note: Analysis includes rail transport costs for Dordabis-Lüderitz or Sishen-Lüderitz (700km or 1000km, respectively) and Lüderitz-Hamburg shipping (12,700km). Investment for rail upgrades based on a CAPEX of US$1.3M/km, diesel locomotives, and US$65,000 per rolling stock, excluding carbon costs. Total iron ore transported is 2.5 Mtpa for the Namibian option and 5 Mtpa for the South African option. Assumes an LCOH of US$2.4/kg H_2; US$0.02/km for rail and US$0.002/km for shipping. Carbon cost has not been included in other costs.
Source: Systemiq analysis

Figure 16: Higher CAPEX required to upgrade rail infrastructure for importing South African iron ore is offset by its potentially higher utilization potential.

2.2.4. Effect of the EU's Carbon Border Adjustment Mechanism

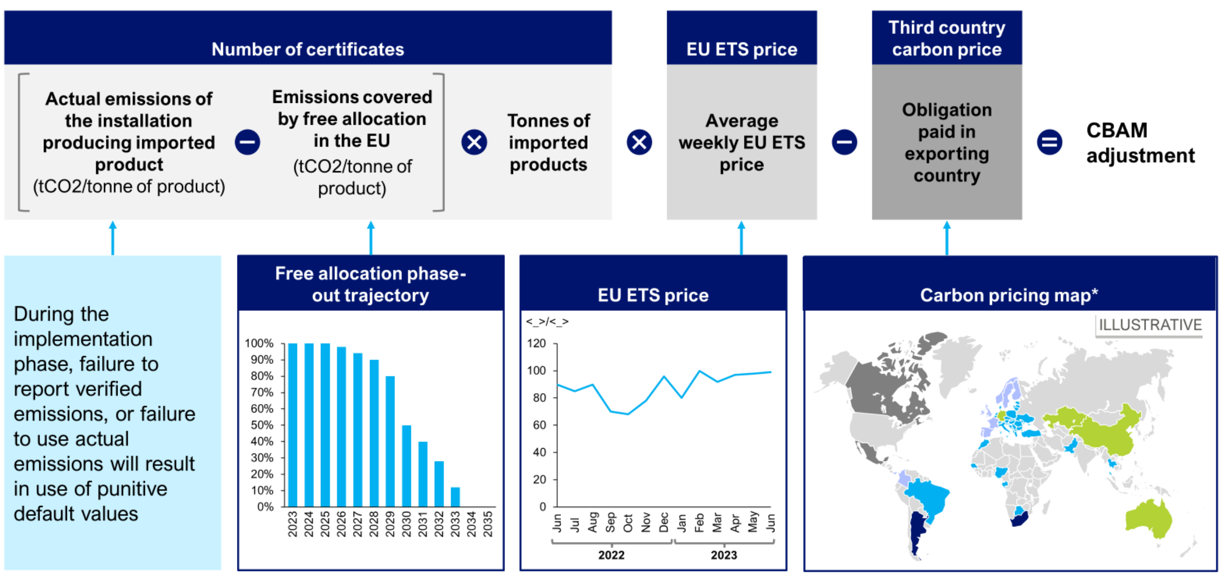
The recent implementation of the European Union's Carbon Border Adjustment Mechanism (CBAM) has catalyzed discussions on green iron production that otherwise may not have been possible without this new policy framework.

The EU has long been at the forefront of incorporating environmental costs into economic systems, particularly through its Emissions Trading System (ETS). This system aims to reduce greenhouse gases by assigning a price to carbon and establishing a market for carbon emissions. Historically, the ETS has provided free allowances to certain industries to help mitigate the economic impact of these environmental policies. However, these allowances are set to be phased out, coinciding with the implementation of the new CBAM. This synchronization is designed to ensure that all producers, both within and outside the EU, face equivalent carbon pricing.

The CBAM is a pivotal policy introduced by the EU to address carbon emissions in the import of carbon-intensive goods such as iron and steel. It aims to level the playing field between goods produced inside the EU and those imported from elsewhere by ensuring that both incur similar costs for their respective carbon emissions. As illustrated in Figure 17, this is achieved through a system that assesses the carbon content of imported goods, compares the carbon price paid by the producer to that under the EU's ETS, and applies a tax if the imported goods have not incurred comparable carbon costs. This mechanism is particularly relevant as it makes conversations about producing greener products like Namibia's green iron viable, given the changing cost dynamics under the CBAM.

In practice, the CBAM is designed not only as a fiscal tool but also as a transformative approach to EU trade and environmental objectives. It initially targets sectors like iron, steel, hydrogen, cement, fertilizers, and aluminum, aiming to reshape the supply and demand dynamics in these industries. By aligning carbon costs across borders, the EU incentivizes global producers to adopt cleaner technologies, thereby contributing to global environmental efforts.

The CBAM is currently in a transitional phase that will last until 2026, during which its rules and tax rates will gradually be introduced. The carbon price under the CBAM is expected to rise significantly, reaching approximately €150 per ton of CO_2 by 2030[41]. This gradual introduction allows time for industries to adapt to the new pricing realities and aligns with global market shifts towards investments in carbon reduction technologies.



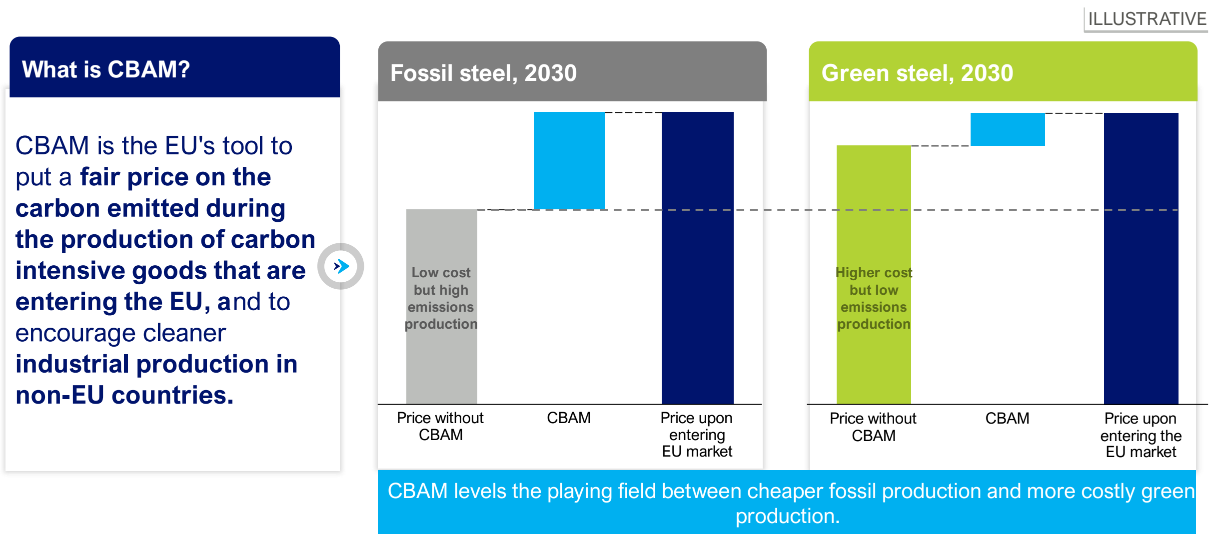
Notes: *Illustrative map: Colors indicate different carbon pricing instruments around the world. The World Bank has developed a carbon pricing dashboard for reference
Sources: Systemiq analysis from ERM Sustainability Institute (2024), *The Great Equalizer: Turning EU carbon border tax compliance into business opportunities*

Figure 17: How the EU carbon tax is calculated

In summary, the EU's Carbon Border Adjustment Mechanism represents a bold step towards integrating environmental costs into the framework of international trade. By equating the price of carbon between domestic products and imports, the CBAM not only promotes fair competition but also encourages a global shift towards more sustainable industrial processes. For industries like iron production, where traditional methods are highly carbon-intensive, the **CBAM narrows the cost gap between cheaper, fossil-based methods and greener alternatives,** as illustrated in Figure 18. This leveling of the playing field enhances the competitiveness of products like Namibia's green iron and green ammonia. As the EU seeks cleaner imports to meet its environmental targets, Namibia

[41] BNEF (2023), *2H 2023 EU ETS Market Outlook*

could find a significant offtake market for its green products, which are now more viable under the CBAM's structured pricing of carbon emissions.



Note: "Fossil production route" indicates the BF -BOF method (Blast Furnace -Basic Oxygen Furnace), and "green steel route" denote s the H2-DRI-EAF technique (hydrogen direct reduction and Electric Arc Furnace).
Sources: Systemiq analysis

Figure 18: The European CBAM has made the conversation about competitive Namibian green iron possible.

The economic viability of green HBI depends critically on the implementation of carbon taxes, according to our cost analysis for 2030 and 2034, as illustrated in Figure 19. In 2030, the production cost is estimated at approximately US$435 per tonne for pig iron using coal and at US$355 per tonne for HBI using natural gas. In contrast, the projected cost for green HBI ranges from US$525 to US$600 per tonne, heavily influenced by the price of green hydrogen[42] as it requires 55 kg H_2 per tonne of HBI produced. Each US$1 increase in the price of a kg of hydrogen can therefore elevate green HBI costs by US$55 per tonne HBI, potentially undermining its competitiveness.

The introduction of CBAM coupled to a carbon tax of US$120/t CO_2 in 2030 could make green HBI competitive with pig iron produced from coal, given the former's minimal emissions of 0.78 t CO_2/t HBI compared to the latter's 1.86 t CO_2/t HBI (Figure 19).

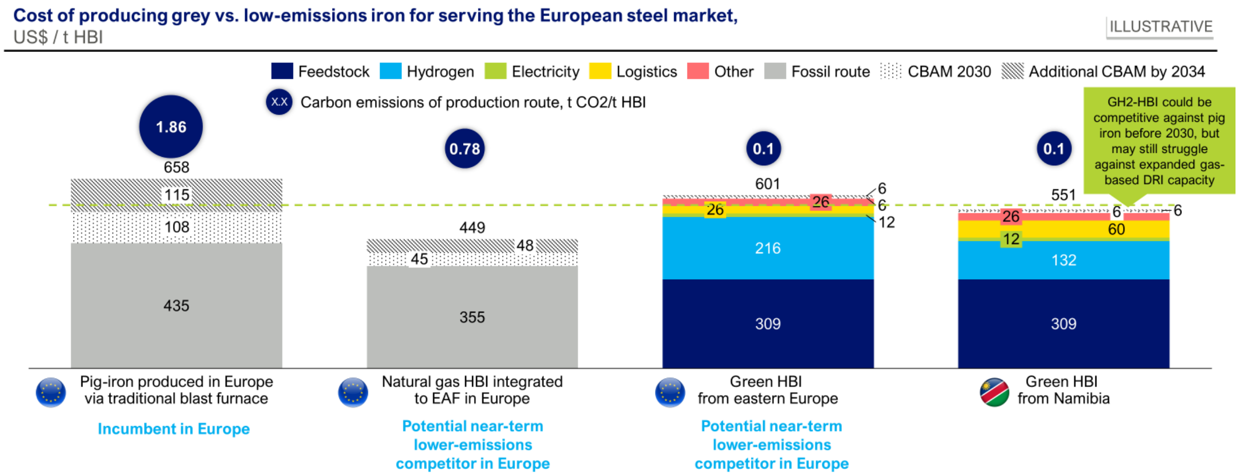
However, this competitive edge is contingent upon three crucial factors:

1. Robust implementation of the CBAM without significant opposition from established industries;
2. Stabilization of green hydrogen prices at or below €5 per kg[43]; and
3. Consensus among downstream stakeholders on what constitutes green steel and whether DRI production with natural gas is sufficiently green or not.

The above means that green HBI may indeed face a challenging competitive landscape against HBI produced from natural gas, which is likely to remain more cost-effective even under

[42] Here, ranging from US$2.4/kg H_2 to US$4/kg H_2.
[43] Recent estimates suggest green hydrogen costs at ~ €8/kg H_2. Source: HydrogenInsights (2024), *EU hydrogen targets are 'impossible' as green H2 costs eight times as much as grey H2 today: Total CEO*

significant carbon taxation. The recent commitments by the European Union to 20-year liquefied natural gas (LNG) import contracts and the construction of DRI plants initially powered by natural gas could create a natural gas lock-in effect. These developments may inhibit the transition to green hydrogen, highlighting the critical need for strategic decisions concerning the future of steel production technologies in offtake markets such as Europe.



Note: US$198/ t DR-grade pellet price in 2030 assumed. Analysis includes rail transport costs for Dordabis-Lüderitz or Sishen-Lüderitz (at 700km or 1000km, respsectively) and Lüderitz-Hamburg shipping (12,700km). Investment for rail upgrades based on a CAPEX of US$1.3M/km, diesel locomotives, and US$65,000 per rolling stock, excluding carbon costs. Total iron ore transported is 2.5 Mtpa for the Namibian option and 5 Mtpa for the South African option. Assumes an LCOH of US$2.4/kg H_2; US$0.02/km for rail and US$0.002/km for shipping. Carbon cost has not been included in other costs.
We assume a HBI cost with natural gas price of ~US$355 /t in 2030 with a corresponding footprint of 0.78 t CO_2/t HBI at a carbon price of US$120/t CO_2. Effective carbon tax applicable to steel producers in the EU is estimated to reach ~50% of the EU ETS price in 2030, which serves as basis for CBAM tax. We assume a pig iron price of ~US$435 /t pig iron in 2030 with a corresponding footprint of 1.86 t CO_2/t iron at carbon price of US$120/t CO_2.
Sources: Systemiq analysis from World Steel (2022), *CO2 Data Collection*

Figure 19: Investing in green HBI is a strategic move with a long-term outlook, with EU CBAM levelling the playing field by 2030-2035.

2.3. Key priorities for Namibia

Given the opportunities and challenges described above for Namibia to establish a green iron value chain, stakeholders need to convene and determine priority next steps in creating an environment in which first projects may thrive and reach feasibility as testament to Namibia's potential. Below is a selection of considerations that could 'make or break' Namibia's trajectory in establishing successful green iron projects and therefore deserve significant and collective problem-solving efforts.

For green hydrogen and therefore green iron to be truly sustainable, as previously noted, it necessitates a reliable green power baseload. This energy is vital for operating DRI plants continuously by compensating for periods when intermittent renewable energy sources (solar, wind) are temporarily unavailable. Considering the significant energy requirements – often exceeding 1 GW capacity – the availability of a decarbonized "*green energy of last resort*" or sufficient energy capacity is crucial; lacking these could severely impede progress in establishing a green iron plant. Namibia's energy governing bodies (e.g., MME, NamPower, Electricity Control Board (ECB)) should work together with potential green iron developers to understand the required parameters of this baseload power and jointly explore region-specific options.

Securing offtake agreements is a significant challenge in emerging markets such as green iron and green steel, crucial for ensuring demand certainty and derisking investments. An effective strategy that could serve as a model for Namibia involves partnering with downstream corporations that purchase steel. This approach guarantees future demand, providing the stability needed to attract investment. Various methods to signal demand include signing offtake agreements to purchase specified amounts at predetermined prices, or engaging in co-investments that distribute risks and rewards between the producer and the buyer. For example, H2 Green Steel has successfully implemented this strategy by partnering with various downstream entities in its value chain, such as Mercedez Benz, Daimler and Kingspan[44]. These partners have not only committed to offtake agreements but also invested in the company. Emulating such collaborative and integrated approaches could be a strategic move for Namibia to support green projects and draw in investors. Relatedly, supporting green iron developers in a close working relationship with banks is crucial to understanding what financiers would need to perceive sufficient project derisking, and likely coming out of this would be an emphasis on securing long-term offtake contracts and having offtakers as investors in the project.

A critical focus for Namibia should be to closely monitor and adapt to the evolving definitions of "low-CO_2" steel, essential for aligning with international green steel standards. While a universal definition of green steel has not yet been established, the industry is rapidly evolving, and OEMs aiming to decarbonize their scope 3 emissions are increasingly demanding steel produced with minimal carbon footprints. Achieving steel production that emits only near-zero-CO_2 emissions per tonne of steel—a reduction of 95%[45]—is currently only possible through the green hydrogen DRI-EAF route.

All of the above necessitates a deeply committed government and the local municipalities involved – not only from the perspective of aligning national policies and energy supply, but also from the perspective of unlocking other key project components local to the area: land permitting, sufficient skilled workforce, and the infrastructure required to support a project and workforce of this size.

Therefore, Namibia's priorities for green iron should consist of 4 complementary components: (i) developing a robust and integrated green energy/baseload strategy, (ii) supporting green iron project developers secure offtake interest and investment alignment, (iii) maintaining a proactive stance on international developments concerning low-CO_2 steel and effectively incorporating these standards into the practices of its emerging iron sector, and (iv) ensuring alignment with local municipalities from the outset. This multi-pronged focus will be vital for Namibia to position itself as a location where green iron can be produced at low-cost around the clock and secure its first mega-scale green iron project.

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[44] H2 Green Steel

[45] Mission Possible Partnership (2021), *Steeling Demand: Mobilising buyers to bring net-zero steel to market before 2030*

3. Critical Raw Materials: New Opportunities from the Minerals Industry

3.1. Global opportunities in lithium and rare earth elements

3.1.1. Market outlook

The United States Energy Act[46] of 2020 defines:

- **A "critical material"** as any non-fuel mineral, element, substance, or material that the Secretary of Energy determines: (i) has an elevated risk **of supply chain disruption**; and (ii) **serves an essential function in one or more energy technologies**, including technologies that produce, transmit, store, and conserve energy; or
- **A "critical mineral"** as any mineral, element, substance, or material designated as critical by the Secretary of the Interior, acting through the director of the U.S. Geological Survey.

The above definitions are broadly accepted worldwide and applied to classify vital minerals such as lithium and rare earth elements as critical raw materials.

Lithium (Li) in particular plays a pivotal role in the global energy transition. Known as the lightest metal on Earth, lithium is extensively utilized in rechargeable batteries for various applications, including laptops, cellular phones, and electric vehicles (EVs), and is also used in ceramics and glass manufacturing. Lithium-ion battery manufacturing capacity has more than tripled in the past 4 years, reaching 2.5 terawatt-hours (TWh) in 2023, with a third of this capacity added in 2023 alone[47]. This remarkable expansion has been propelled by a rapid rise in EV sales[48]. This trend is set to persist, with lithium demand projected to increase tenfold by 2050 according to the International Energy Agency's Net Zero Emissions Scenario[49]. The U.S. Department of Energy's highest demand scenario forecasts that approximately 97% of lithium demand will be driven by electric vehicle batteries and stationary storage batteries by 2035[50]. Despite the development of new battery chemistries (e.g., sodium-based batteries), lithium is anticipated to remain the preferred metal for the near future, underscoring its criticality to the future of transportation and energy storage solutions[51].

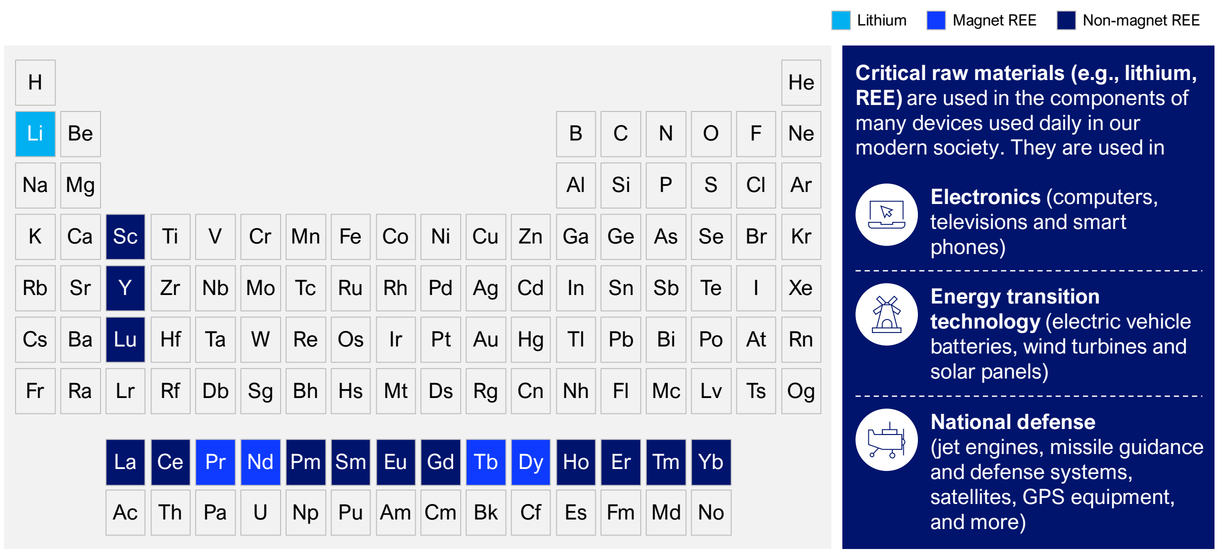
Rare Earth Elements (REEs), a group of 17 elements in the periodic table, are also classified as critical minerals due to their essential role in numerous high-tech and green energy applications, including wind turbines, electric vehicle motors, and energy-efficient lighting. REEs

[46] United States' Department of Energy, *What are critical materials and critical minerals?*
[47] International Energy Agency (2024), *Global EV Outlook 2024*
[48] International Energy Agency (2024), *Batteries and Secure Energy Transitions*
[49] International Energy Agency (2023), *Critical Minerals Data Explorer*
[50] US Department of Energy (2023), *Critical Materials Assessment*
[51] IRENA (2022), *Critical materials for the energy transition: Lithium*

are particularly crucial due to their unique magnetic, luminescent and electrochemical properties, and can be divided into two categories based on their uses and properties:

- **Magnet REEs**: These include neodymium (Nd), praseodymium (Pr), dysprosium (Dy) and terbium (Tb), which are integral to the manufacture of powerful permanent magnets used in electric vehicle motors and wind turbine generators[50]. The demand for magnet REEs is driven by their efficiency in converting electrical energy into motion and vice versa, making them critical for energy-saving technologies.
- **Non-magnet REEs**: These encompass elements like cerium (Ce) and lanthanum (La), which are widely used in catalysts, glass polishing and other industrial processes that do not involve magnetism. Although they may not be used in energy production directly, their role in manufacturing processes that support energy technologies is indispensable.

Like lithium, the demand for rare earth elements has escalated due to their irreplaceable role in modern technology. The future of many sustainable technologies depends on the steady supply of these elements, highlighting their significance under global energy policies and the pressing need to secure their sources and streamline their supply chains.



REE: Rare earth elements
Source: Systemiq analysis

Figure 20: Lithium and rare earth elements – what they are and what they are used for.

Leading experts predict a global lithium supply deficit by the 2030s (Figure 22), underscoring the urgency to escalate production and production efforts today[52]. This situation presents an opportunity for new regions to enter the market through long-term investments in these capital-intensive projects. However, market uncertainties, price volatility, and geopolitical tensions pose significant challenges to scaling up production.

Recent trends in lithium pricing, as detailed in Figure 21, highlight the market's volatility[53]:

- **2019 Price Collapse**: primarily due to an oversupply of spodumene from Western Australia.

[52] Center on Global Energy Policy at Columbia (2023), *Lithium in the Energy Transition: Roundtable Report*
[53] The Oxford Institute for Energy Studies (2024), *Lithium price volatility: where next for the market?*

- **2022 Price Surge**: triggered by post-COVID-19 recovery efforts, government economic stimuli, and a surge in purchasing driven by a phase of irrational exuberance.
- **Subsequent Price Decline**: influenced by various factors including:
  - Chinese Market Dynamics: overcapacity and intense competition among Chinese producers, coupled with aggressive international expansion;
  - Chinese Macroeconomic Policies: significant investments, approximately US$900 billion in 2023, directed towards emerging industries like solar power, electric vehicles (EVs), and battery manufacturing;
  - EV Market Pressures: intense price competition among OEMs and the phasing out of EV subsidies;
  - Supply-Side Adjustments: a 20% year-over-year increase in exploration budgets, with new lithium sources primarily being developed in Zimbabwe and China, alongside Western efforts to decrease reliance on Chinese supply chains.

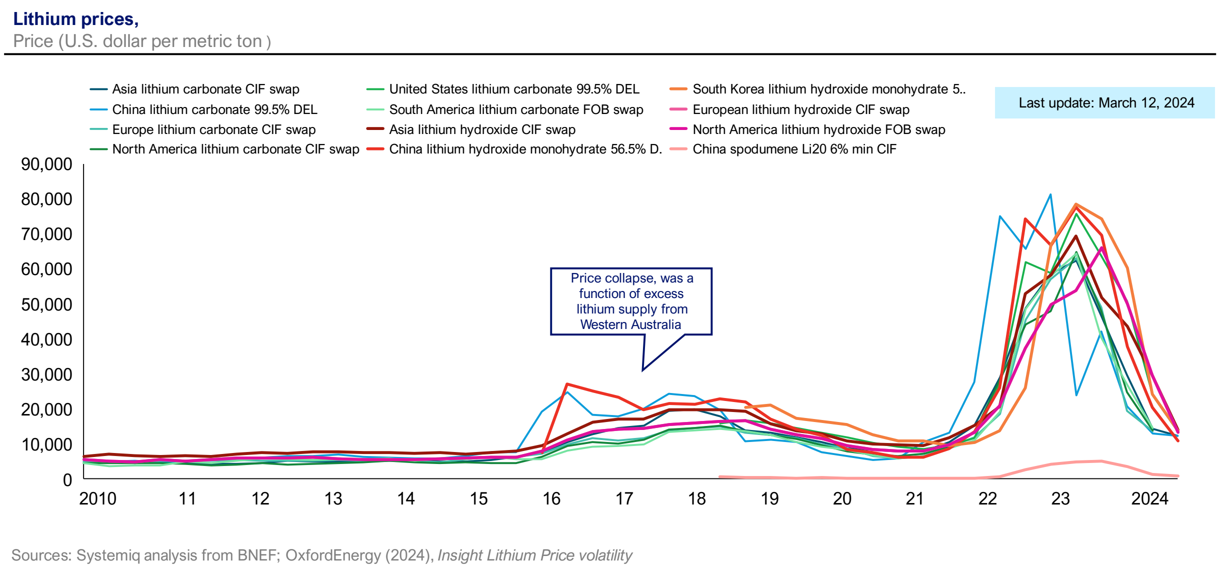


Figure 21: Lithium prices have been volatile due to Chinese supply chain dominance, but supply chain diversification and strong demand forecasts provide positive outlook.

An impending shortage of rare earth elements, similar to the lithium shortfall, is projected by 2030 despite adequate global reserves. Global demand for magnet rare earths like neodymium is set to triple, increasing from 170 kt in 2022 to 466 kt by 2035, representing an 8% compound annual growth rate[54]. Although the reserves of neodymium are sufficient to meet the cumulative demand through 2050, estimated at 2 to 4 Mt against reserves of 8 Mt, a supply gap by 2030 remains a critical challenge, as illustrated in Figure 23[55]. This gap could potentially be bridged by developing new mines, which would require coordinated governmental efforts to streamline the exploration and mining processes, including simplifying the mineral-rights application and permitting procedures. Additionally, the advancement of rare-earth-free technologies for electric vehicles and wind turbines could mitigate the dependency on these critical materials but would necessitate accelerated

[54] The Boston Consulting Group (2023), *Five Steps for Solving the Rare-Earth Metals Shortage*
[55] The Energy Transitions Commission (2023), *Material and Resource Requirements for the Energy Transition*

development to become viable alternatives. Additionally, similar to the lithium market, the REE market is heavily concentrated in China, heightening the risk of supply shortages and intensifying the competitive barriers for new mining projects.

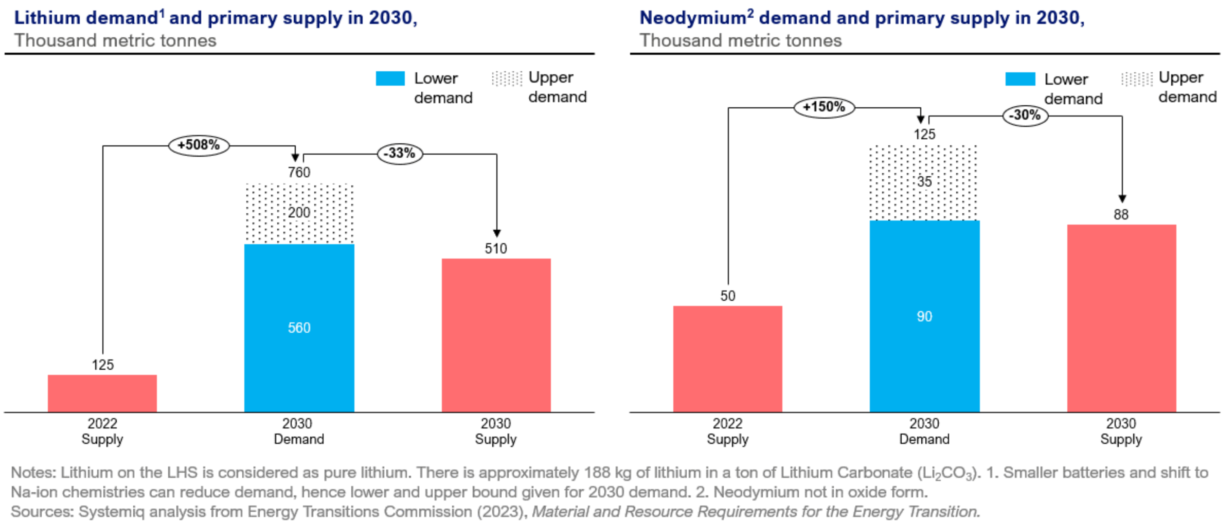


Figure 22: The short-term challenge: estimated supply growth for CRM could be insufficient to meet rapidly rising demand by 2030.

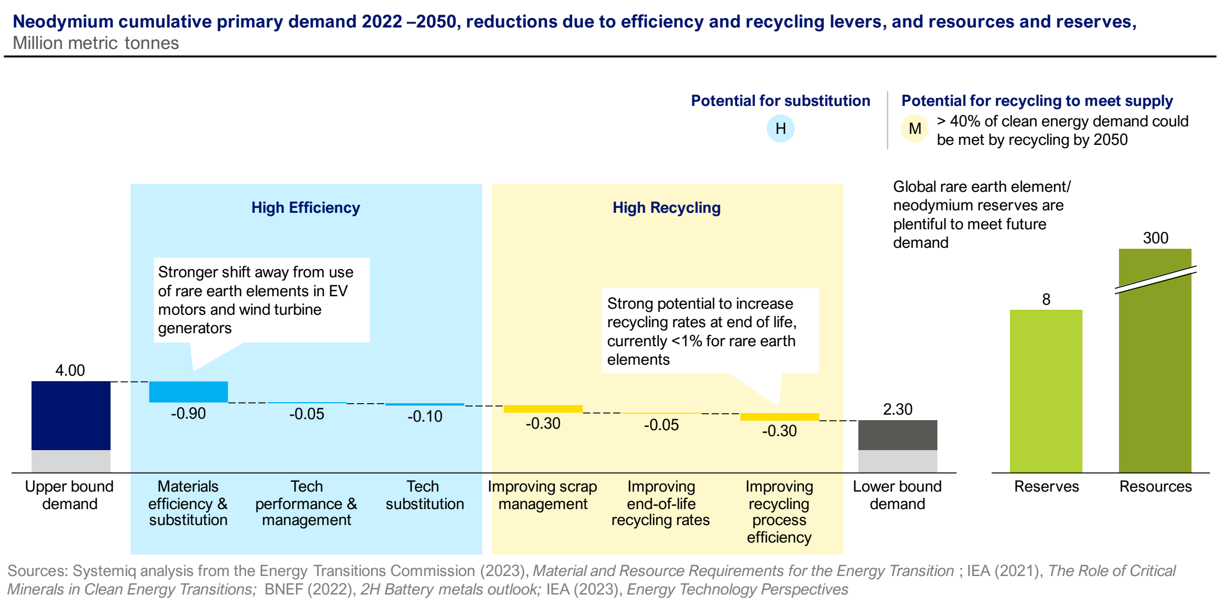
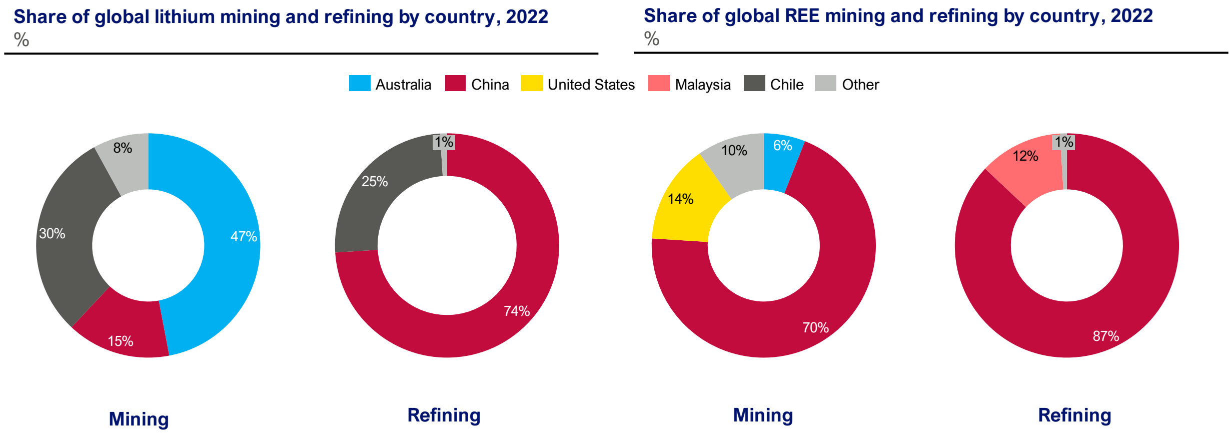


Figure 23: Cumulative primary demand for neodymium, a rare earth element, between 2022-2050.

China is currently a significant barrier to increased investment in global lithium and rare earths processing outside of the country because of its control over the market through foreign investment (e.g., in Zimbabwe's lithium mines) and, importantly, its dominance in both lithium and REE refining (Figure 24). The lower capital and operational costs in China, combined with a decade-long head start in these sectors, present substantial barriers for other nations aiming to compete in mineral refining. For instance, capital costs for new lithium processing facilities in Australia are approximately 2.5 times higher than those in China[56].



Sources: Systemiq analysis from Energy Transitions Commission (2023), *Material and Resource Requirements for the Energy Transition* ; Shuang-Liang Liu et al. (2023), *Global rare earth elements projects: New developments and supply chains;* expert interviews

Figure 24: Mining and refining of CRM today is highly concentrated in China, exposing global markets to supply risks.

Despite the recent price downturns and China's dominance in the lithium market, **there are promising opportunities for other markets looking to capitalize on the growing demand for lithium and perhaps REEs**. Alongside the projected supply deficit in the 2030s and the expectation that spot prices will likely adjust positively later in the year, another key piece of market context is the accelerated trend in recent years of potential offtake markets actively prioritizing CRM supply chain diversification as a pillar of their national strategies. Among others, this is exemplified by the recent launch of the Minerals Security Partnership between the US, EU and several partner countries, including Namibia[57]. Germany recently earmarked €1 billion for raw material investments as it seeks to reduce dependency on producers such as China for critical minerals, with its development bank KfW to manage the investments[58]. While several countries outside of China have been building up their lithium value chains for a few years (see Chapter 6.3), rare earths are also now seeing accelerated movements (Figure 25[59]). Countries and companies outside of China have a critical window to invest in and develop their lithium and rare earths mining and processing capabilities in this nexus of economic and geopolitical catalysts.

[56] Center on Global Energy Policy at Columbia (2023), *Lithium in the Energy Transition: Roundtable Report*
[57] Press release – European Commission (5 April 2024), *EU and international partners agree to expand cooperation on critical raw materials*
[58] Bloomberg (February 2024), *Germany Invests €1 Billion to Counter China on Raw Materials*
[59] Lynas, an Australian company, has recently received nearly US$120 million from the US Department of Defense; Iluka Resources, another Australian company, is currently partnering with the Australian government and received a non-recourse loan of around US$800 million for the construction and commissioning of a REE refinery.

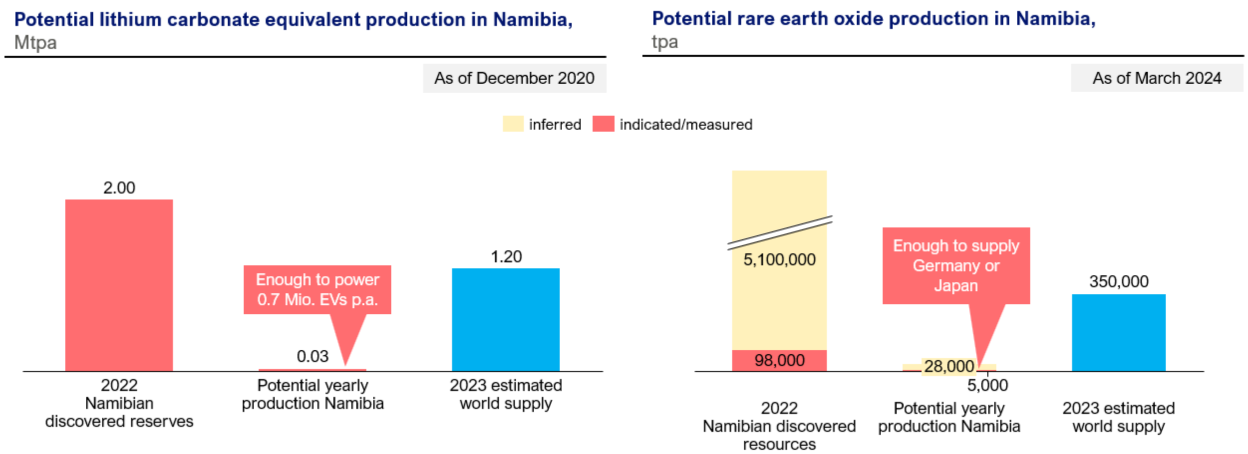
Figure 25: Geographic location of key players in the rare earth elements value chain today.

Namibia can be one of these countries. According to estimates from the Namibian Ministry of Mines & Energy and the Namibian delegation of the German Federal Institute for Geosciences and Natural Resources[60], known lithium resources in Namibia today sit at around 2 Mtpa of lithium carbonate equivalent (LCE)[61] production (Figure 26, left). This would translate into a potential yearly production of 30-50,000 tonnes of LCE[62], which is around 2-4% of 2023's estimated global supply of 1.2 Mt. The global lithium market is expected to reach 2.4 Mtpa in 2030, meaning that Namibia could then represent around 1% of the total global market. Namibia's resources are therefore not insignificant and could enable the production of batteries for ~1 million electric vehicles per year, which is more than 50% of today's annual sales in the entirety of France (around 1.8 million EVs sold in 2023). As interest in lithium grows in Namibia, the country's annual production capacity could expand significantly with the discovery of new resources.

Namibia also stands to significantly influence the rare earth elements market, with its currently indicated/measured resources[63] already ample enough to meet the demands of a major consumer like Japan (Figure 26, right). This potential has led the Japan Organization for Metals and Energy Security (JOGMEC) to sign a Memorandum of Understanding with Namibia's state-owned mining firm, Epangelo, to collaborate on REE projects[64]. Additionally, other earlier stage ventures, such as

[60] Ministry of Mines & Energy (2020), *BGR Namibia Lithium Potential Study*
[61] Lithium carbonate equivalent is the standard term commonly used in the lithium industry to compare the lithium content of different lithium-bearing compounds, by indicating its equivalent in terms of lithium carbonate.
[62] Assuming a 40-year lifetime of these resources. Realistically, capacity constraints may result in a smaller annual output (~30,000 tpa nationally). 30,000 tpa LCE would still equate to 1% of the global lithium market by 2030.
[63] See section 3.1.3 inset for definition of different categories of resources.
[64] Reuters (2023), *Japan signs deal with Namibia to explore for rare earth minerals*

the Broadmind Mining project, boast inferred resources of 28,000 tonnes per annum of rare earth oxides equivalent. Though further work is still underway to necessarily validate these resources and categorize them as indicated/measured, this output could account for about 10% of the current global supply, positioning Namibia among the world's largest REE suppliers. This development not only boosts Namibia's strategic importance in the REE sector but also aligns with global market dynamics where diversification and security of supply are increasingly crucial.



Note: Lithium on the LHS is considered as pure lithium. There is approximately 188 kg of lithium in a ton of Lithium Carbonate (Li_2CO_3).
Sources: Systemiq analysis from Energy Transitions Commission (2023), *Material and Resource Requirements for the Energy Transition;* Ministry of Mines & Energy (2020), *BGR Namibia Lithium Potential Study;* Shuang-Liang Liu et al. (2023), *Global rare earth elements projects: New developments and supply chains;* expert interviews

Figure 26: Given its potentially large resources, Namibia could play a role in the global lithium and REE markets.

3.1.2. Lithium and rare earth value chains: overview and likely priorities for Namibia

The lithium and REE value chains can be segmented into three primary categories:

(i) **Upstream:** This involves mining the mineral ore[65] and subsequently concentrating it to increase the percentage of the mineral ore per tonne of material. This phase typically doesn't involve significant chemical conversions.

(ii) **Midstream:** Characterized by a complex series of steps, predominantly chemical processes, aimed at transforming the mined mineral into another chemical form. This often entails altering the oxidation state of the base element. The end product is the critical raw material in a form suitable for downstream processes.

(iii) **Downstream:** Here, the focus shifts to converting the critical raw material into manufactured products. In this stage, the critical raw material is just one component among many in the final product.

Figure 27 and Figure 28 provide an overview of the primary production pathways for processing mined lithium hard rock and mixed rare earth elements (REEs), respectively. While these serve

[65] Lithium can also be produced from lithium brines, which does not involve mining. This route is not described here, given the vast majority of Namibia's lithium resources are in hard rock form, not brine.

as general frameworks, it's crucial to acknowledge that the uniqueness of each deposit necessitates tailored conditions for both concentration and midstream processing.

- In the case of lithium, the upstream process yields a lithium ore concentrate, such as lithium spodumene or lepidolite, with a higher lithium content (up to 8%) compared to the mined hard rock. Subsequent processing involves high-temperature and chemically intensive steps to purify the ore and yield lithium-bearing minerals in the form of water-soluble compounds, namely lithium hydroxide or lithium carbonate, the primary lithium commodities in the market today. Typical routes to produce either of these two commodities involve temperature elevation to trigger a phase transition in the material, followed by acid roasting and/or alkaline-/water-based leaching; together, these steps make up the bulk source of direct greenhouse gas emissions from fuel consumption and electricity in the entire processing value chain[66].
- For REEs, upstream processing serves not only to concentrate rare earth oxides (REOs) from non-REE material but also to separate different REOs co-existing in the same deposit. Techniques like magnetic separation, electrostatic separation, and froth flotation are commonly used for concentration[67]. Further separation of REOs typically involves a sulphuric acid bake step followed by leaching due to the chemical similarities among REEs. The complexity of this separation phase is heightened by the unique composition of each REE deposit coupled with the chemical similarity of the different REOs with one another, rendering separation more difficult. Presently, the majority of global REE production originates from five deposits or districts[68], each with its specialized beneficiation and separation chemistry. Any new REE production from a fresh resource demands a customized technological approach adapted to the specific mineral ore. Following separation, the midstream steps in the REE value chain involve refining to obtain REOs in salt form, subsequent metal production, and potentially alloying with various metals.

The integration of renewable power and green hydrogen holds significant promise for minimizing emissions within the lithium and REE mining and processing value chains in Namibia. Applicability of these two energy vectors is contingent upon the energy intensity of specific steps; their potential roles can be delineated as follows:

- **Renewable Power:**
  - **Powering Mechanical Movement:** Renewable power sources can be used to power motor equipment that would otherwise rely on non-renewable sources such as non-zero-carbon grid power or on-site diesel generators. For instance, numerous mechanical processing steps as highlighted in Figure 27 and Figure 28 are amenable to renewable power applications.
  - **Providing Low-Temperature Heat (<300 °C):** Electrification of heat provision is feasible today at reasonable technological readiness levels for temperatures below

[66] International Lithium Association (2024), *Determining the Product Carbon Footprint of Lithium Products*
[67] McNulty T., et al., *Processing the ores of rare-earth elements*, MRS Bulletin (2022), 47
[68] Bayan Obo (Inner Mongolia); Mianning-Dechang (Sichuan Province in China); small firms and artisanal miners in five Chinese provinces or regions with heap-type mines; Lynas/Mt. Weld in Australia with concentrate treatment taking place in Malaysia; Mountain Pass Materials in California. Source: footnote 67.

a few hundred degrees Celsius. Both the acid roasting and leaching processes in lithium and REE value chains would necessitate heat within this range.

- **Green Hydrogen:**
  - **Providing High-Temperature Heat (>500 °C):** Currently, natural gas is a common source for industrial heat, but to decarbonize processes requiring temperatures above 400°C, electrothermal energy storage (ETES) and hydrogen present viable alternatives. ETES is particularly suitable for continuous heat applications at industrial sites looking to transition from fossil fuels to renewable energy sources like wind or solar. While ETES systems capable of reaching up to 1500 °C are still under development, with a target rollout by 2030, green hydrogen emerges as another solution for achieving elevated temperatures around 1000 °C and beyond. This makes green hydrogen an ideal option for processes such as the calcination in lithium production and metal forming in REE processing, particularly in countries like Namibia where green hydrogen is set to be affordable.
  - **Fuel for Mining Hauling Trucks:** In scenarios where electrified mining trucks are not currently available in the requisite size or configuration, hydrogen-powered hauling trucks offer a low-emissions alternative to traditional internal combustion engine trucks. Anglo American has already initiated pilots of such trucks at its mines in South Africa since 2022[69].

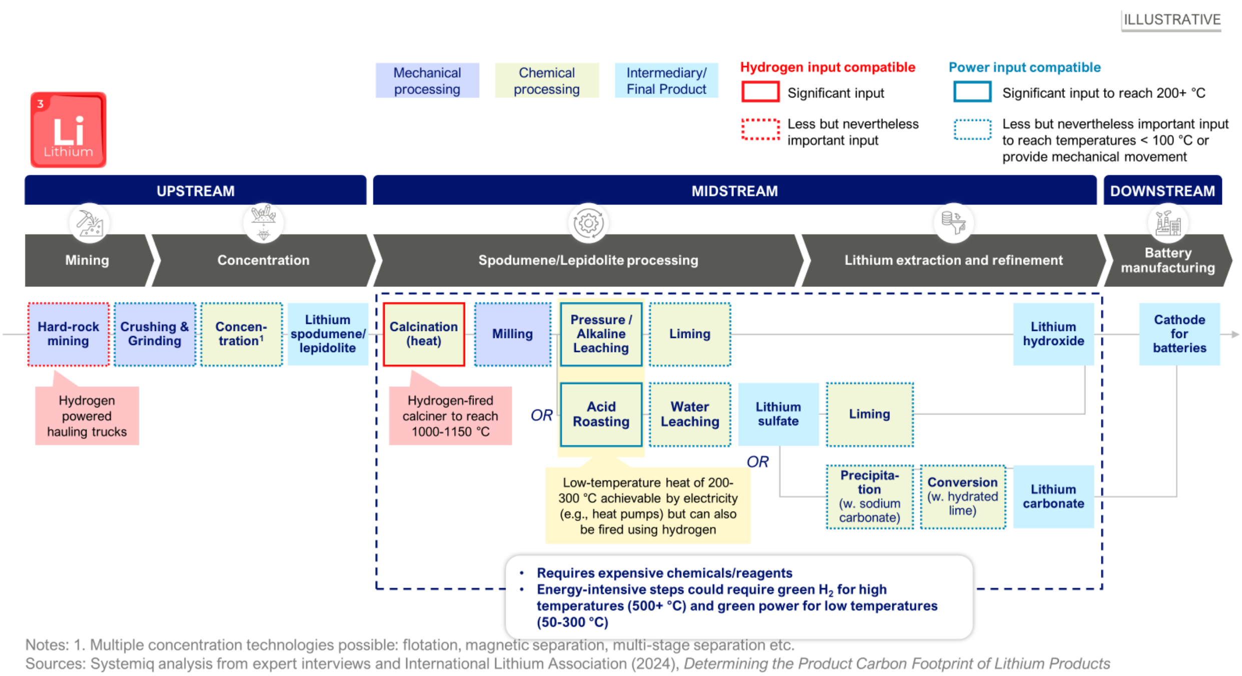


Figure 27: Midstream lithium operations require complex chemistry and energy-intensive processes.

[69] Press release: Anglo American, 6th May 2022, *Anglo American unveils a prototype of the world's largest hydrogen-powered mine haul truck - a vital step towards reducing carbon emissions over time*

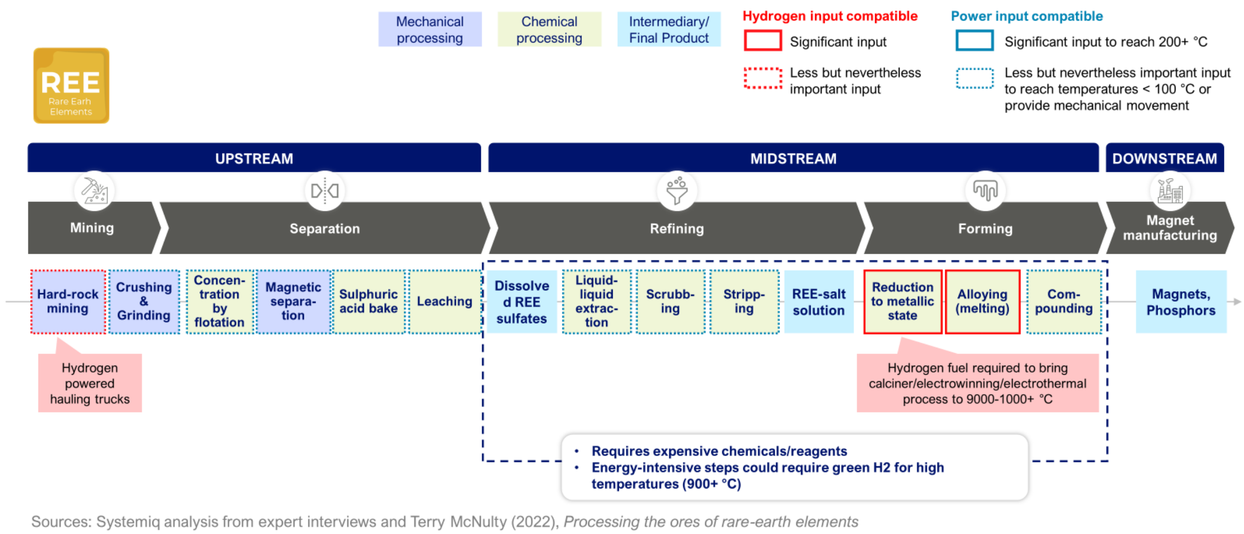
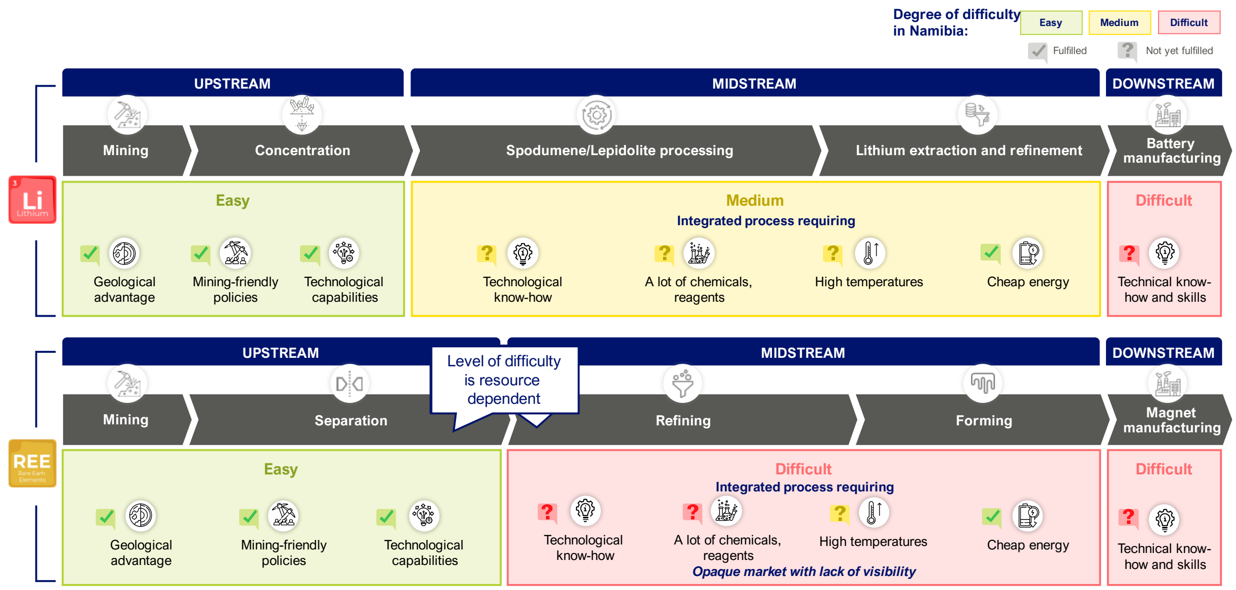


Figure 28: Midstream REE operations require complex chemistry and energy-intensive processes.

The accessibility of Namibia to different stages of the lithium and REE value chains varies, with near-term feasibility characterizing earlier stages and longer-term feasibility characterizing later stages (Figure 29):

- **Upstream - Mining:** While mining lithium and REEs pose challenges, Namibia can leverage the same strengths that today already uphold its established mining legacy, bolstered by robust policies and safety standards that underpin the country's mineral sectors.
- **Upstream - Concentration/Separation:** Post ore-production, concentrating lithium and separating REEs, although feasible, present greater difficulty. REE separation, in particular, varies in complexity depending on the resource, demanding protracted efforts to formulate tailored procedures. However, these steps remain likely achievable within Namibia.
- **Midstream:** Advancing to the midstream entails addressing three key challenges simultaneously: accessing refining technologies predominantly held by a select few globally (i.e., the knowledge is not widely democratized today), ensuring a stable energy supply for high-temperature processes, and procuring chemical reagents, notably acids, in significant quantities and at reasonable costs. Overcoming these prerequisites poses a challenge not only to Namibia but to other jurisdictions also venturing into these value chains for the first time.
- **Downstream:** Venturing into downstream manufacturing, such as battery or magnet production, presents formidable hurdles. Success likely necessitates first achieving localization in upstream and midstream processes (above), acquiring technological know-how from OEMs of these products who are largely absent today in Namibia and the region, and securing supplies of various additional components beyond lithium and REEs required for the complete manufacture of these downstream products.

Given these challenges, a staged approach seems prudent for Namibia: prioritizing resource- and cost-efficient mine production, followed by localized concentration (lithium) and separation (REEs), should take precedence. Advancing to the midstream will require coordinated efforts at the national level to address energy and chemical requirements while fostering an environment conducive to overseas partners aiding in knowledge transfer and value chain build-up. Only after mastering these steps should Namibia contemplate localizing downstream product manufacturing, such as batteries or magnets. For further insights, refer to Chapter 3.2 detailing these strategic considerations for Namibia.



CRM – Critical Raw Material
Source: Systemiq analysis

Figure 29: The CRM value chain is complex, relying on advanced chemistry and costly reagents. Difficulty of entrance increases further down the value chain.

3.1.3. Seeds of Namibia's lithium and rare earth sectors

Resource Classification Definitions[70]**:**

- Inferred Mineral Resource: An Inferred Mineral Resource is that part of a Mineral Resource for which quantity and grade or quality are estimated on the basis of limited geological evidence and sampling. Geological evidence is sufficient to imply but not verify geological and grade or quality continuity. An Inferred Mineral Resource has a lower level of confidence than that applying to an Indicated Mineral Resource and must not be converted

[70] Canadian Institute of Mining (2014), *CIM Definition Standards for Mineral Resources & Mineral Reserves*

to a Mineral Reserve. It is reasonably expected that the majority of Inferred Mineral Resources could be upgraded to Indicated Mineral Resources with continued exploration.

- Indicated Mineral Resource: An Indicated Mineral Resource is that part of a Mineral Resource for which quantity, grade or quality, densities, shape and physical characteristics are estimated with sufficient confidence to allow the application of Modifying Factors in sufficient detail to support mine planning and evaluation of the economic viability of the deposit. Geological evidence is derived from adequately detailed and reliable exploration, sampling and testing and is sufficient to assume geological and grade or quality continuity between points of observation. An Indicated Mineral Resource has a lower level of confidence than that applying to a Measured Mineral Resource and may only be converted to a Probable Mineral Reserve.

- Measured Mineral Resource: A Measured Mineral Resource is that part of a Mineral Resource for which quantity, grade or quality, densities, shape, and physical characteristics are estimated with confidence sufficient to allow the application of Modifying Factors to support detailed mine planning and final evaluation of the economic viability of the deposit. Geological evidence is derived from detailed and reliable exploration, sampling and testing and is sufficient to confirm geological and grade or quality continuity between points of observation. A Measured Mineral Resource has a higher level of confidence than that applying to either an Indicated Mineral Resource or an Inferred Mineral Resource. It may be converted to a Proven Mineral Reserve or to a Probable Mineral Reserve.

3.1.3.1. Lithium

Namibia's lithium sector, while still in its nascent stages, exhibits significant potential due to various lithium-bearing pegmatite occurrences in the country. These pegmatites are mainly found in the Erongo and Karas regions. The key lithium projects in Namibia with potential outputs include (not exhaustive)[71]:

1. **Soris Lithium Projec**t: Located in the Brandberg West – Goantagab tin belt within the De Rust pegmatite swarm, Montero Mining & Exploration Ltd. oversees this project, holding an 80% interest. The project is at an early stage but has potential targets for drilling with the aim to better define resources currently estimated at 10 Mt with 1% Li_2O, potentially yielding 46,400 t of lithium or 247,000 t of LCE.
2. **Uis Lithium Project**: Operated by Andrada Mining and leveraging the infrastructure from historic tin mining, this project includes lithium-bearing pegmatites with minerals like petalite and spodumene. Andrada Mining controls the tin mine, and Montero Mining & Exploration Ltd. is involved with the tailings project, aiming to recover lithium. Recent estimates from the tailings suggest resources of 81 Mt at 0.73% Li_2O, or about 1.45 Mt LCE[72].

[71] BGR (2023), *Lithium Potential in Namibia – Evaluation of Economic Suitability*
[72] Andrada Mining, Uis Lithium

3. **Karibib Lepidolite Project**: Operated by Lepidico Ltd., this project is in the Karibib – Usakos Pegmatite District. Recent estimates suggest resources of 11.2 Mt at 0.43% Li_2O, or about 120,000 t LCE[73]. Lepidico plans to produce high-purity lithium chemicals using proprietary technologies in the United Arab Emirates (UAE).
4. **Tantalite Valley Project**: Located in the southern part of Namibia within the Namaqua Metamorphic Complex, this project is owned by Kazera Global Investments PLC through African Tantalite Pty Ltd (AFTAN). The recent resource estimate includes 104,800 tons of ore at 0.653% Li_2O, equating to about 315 t of lithium or 1,690 t LCE.

These projects, developed by different companies, highlight the budding nature of the lithium mining sector in Namibia, at various stages of exploration and development and with a variety of intentions for the downstream processing of the mined lithium ore.

3.1.3.2. Rare earths

The REE ecosystem is still nascent in Namibia. Therefore, all current Namibian REE projects are in the exploration phase, meaning none possess proven reserves—a term reserved for active mining operations. Instead, these projects are evaluated based on their mineral resources, classified into three key categories: inferred, indicated, and measured, each reflecting a rising degree of geological confidence as explained in the accompanying inset on resource classification definitions.

Current resource estimates are as follows:

- **Lofdal**: 44.77 million t of ore at 0.17% REO (76,950 t REO content) – indicated/measured
- **Eisenberg**: 570 million t of ore at 0.9% REO (5.1 Mt REO content) – inferred.
- **Eureka**: 310,000 t of ore at 4.8% REO (15,000 t REO content) – indicated
- **Ondoto West**: 213,000 t of ore at 2.59% REO (5,500 t REO content) – indicated/measured

It is essential to recognize that valuing REE projects is intrinsically complex due to the unique mineralogy of each deposit. This complexity means that a lower grade ore could potentially be more economical than a higher grade one, depending on the efficiency of the extraction process. The viability of these deposits can only be assessed after thorough testing.

3.2. Associated challenges for Namibia

3.2.1. Securing more reserves to reach critical mass

As global demand for lithium and REEs rises and the need to reduce reliance on Chinese resources intensifies, companies are increasingly seeking new deposits. This exploration is driven by two positive trends: (i) more lithium and REE resources are continually being discovered, and (ii) mining technologies are continually being improved, partially contributing to point (i). It is crucial to differentiate between 'resources'—an estimated measure of both discovered and potential deposits—and 'reserves,' which are quantities of lithium that can be economically and technologically extracted. For instance, in 2021, the world's lithium resources were estimated at 88

[73] Lepidico, Phase 1 Project

Mt, with 22 Mt of that considered viable reserves[74]. Therefore, following through to convert resources into reserves is critical to ensure the global supply of these critical minerals can be ramped up to meet demand.

Recent data indicates a consistent increase in identified lithium resources and reserves, as illustrated in Figure 30. This upward trend reflects an ability to discover new deposits more rapidly than existing ones are depleted, aided by advancements in technology and market conditions that make more resources economically viable for extraction. This dynamic is crucial for sustaining the supply needed for emerging technologies, especially EVs.

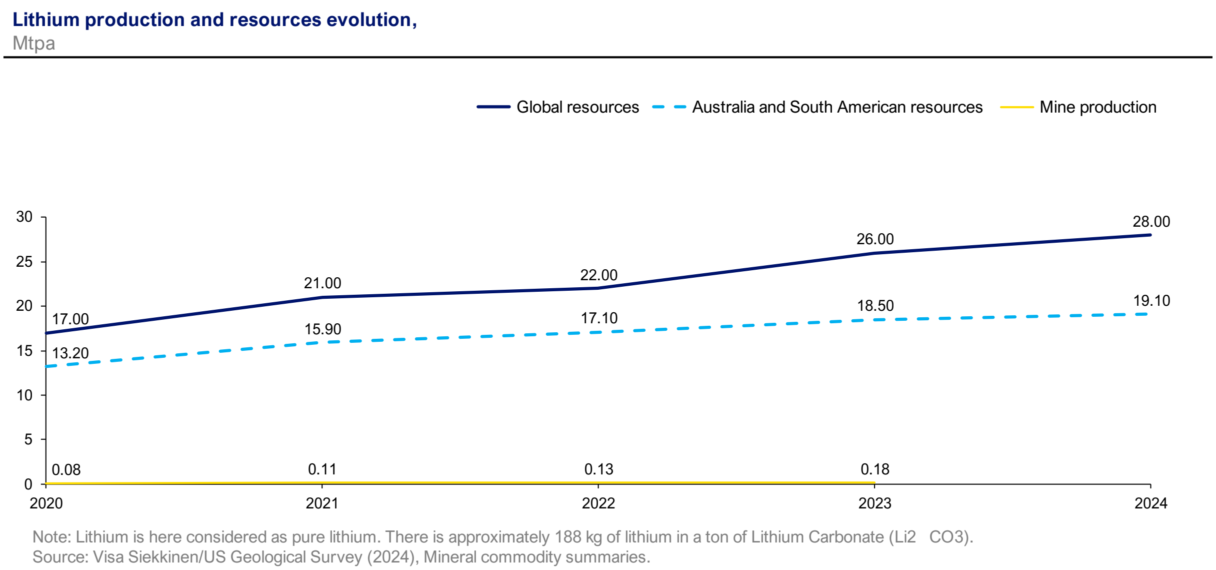


Figure 30: Incentives work: high prices and expectation of rising demand have incentivized more exploration for energy transition materials like lithium.

Looking ahead, neither lithium nor REE supply constraints should pose a long-term issue. Currently, an average EV requires approximately 8 kg of lithium[75]. With the existing 22 Mt of reserves, batteries for 2.8 billion EVs could be produced, and with 88 Mt of resources, up to 11 billion EVs could be supported. However, there is a pressing need to enhance production capabilities by 2030-2035, as limited capacity can cause price volatility and supply constraints. Similarly for REEs, as mentioned in Chapter 3.1.1, although the reserves of neodymium are sufficient to meet the cumulative demand through 2050, estimated at 2 to 4 Mt against reserves of 8 Mt, a supply gap by 2030 remains a critical challenge.

To ensure a stable and expanding supply, continuous exploration is necessary, potentially uncovering more cost-effective deposits. Innovations such as artificial intelligence (AI) have significantly advanced exploration efficiency; a prominent example of this is the AI-driven discovery of substantial copper deposits at the Mingomba site in Zambia by Kobold Metals[76]. In the competitive

[74] U.S. Geological Survey (2024), *Mineral Commodity Summaries 2024*
[75] Castelvecchi, D. (2021). *Electric cars and batteries: how will the world produce enough?*, Nature, 596 (7872), 336-339.
[76] Kobold Metals

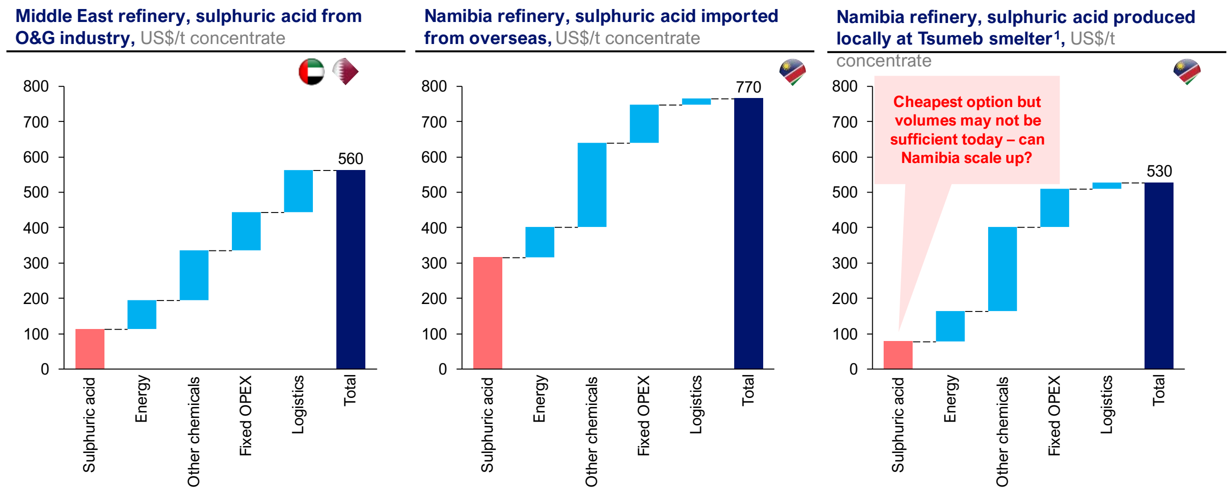
arena of lithium and REEs, new mining technologies like Direct Lithium Extraction are emerging. **For Namibia to stay competitive, proactive governmental support for exploration projects is essential to ensure the potentially long timelines of this phase of a project are kept as efficiently short as possible**. The government can incentivize exploration by reducing taxes, supporting technological innovations, facilitating access to land, and streamlining the permitting process, thereby fostering a conducive environment for sustained mineral exploration.

3.2.2. Securing local sulphuric acid

The production of sulphuric acid, essential in various industrial processes, today faces a paradox. Despite its fundamental role in the green economy, particularly for metal and mineral processing, a key route to sulphuric acid production today is linked to the fossil fuel industry, namely through the desulphurization of fossil fuels to produce sulphuric acid, especially in geographies where the regional energy economy has oil and gas industrial activity. This link poses significant challenges as global decarbonization efforts intensify. Despite a soaring demand projected to rise from the current annual consumption of over 246 Mt to more than 400 Mt of sulphuric acid by 2040, there is a looming threat of a supply shortfall of between 100 and 320 Mt by 2040, depending on how quickly global decarbonisation efforts occur[77].

Availability and cost of sulphuric acid are critical factors for both lithium and REE processing. As shown in chapter 3.1.2., the production of lithium carbonate from spodumene traditionally requires an acid roasting process that consumes significant quantities of sulphuric acid, while sulphuric acid is also required to help separate rare earth oxides from one another. As such, sulphuric acid not only critically enables any lithium refining and REE separation ambitions but could also significantly impact the cost breakdown and therefore regional competitiveness of these parts of the respective value chains, as delineated in Figure 31 in the case of lithium. Importing sulphuric acid into Namibia from overseas can be up to 3 times more expensive than producing it locally, provided there is a route to doing the latter, for example in conjunction with the uranium sector which also requires sulphuric acid in its processes (see below). The availability and cost of sulphuric acid are therefore pivotal considerations for lithium producers in particular (given the quantities of acid required) when selecting refinery locations. For instance, Lepidico is currently considering mining and concentrating lithium ore into spodumene in Namibia, and then exporting this to the UAE for the downstream refinement step, as sulphuric acid is more readily available at lower costs due to the UAE's oil and gas industry[78].

[77] M. Maslin et al. (2022), *Sulfur: A potential resource crisis that could stifle green technology and threaten food security as the world decarbonizes.*
[78] Lepidico



Notes: Fixed OPEX includes personnel, maintenance materials and miscellaneous. 1. Refers to production of sulphuric acid in N amibia at the Tsumeb smelter and corresponds to 2025 price forecast for sulphuric acid.
Sources: Systemiq analysis from expert interviews

Figure 31: The high cost of importing sulphuric acid is currently a major barrier to establishing a lithium refinery in Namibia but can be overcome by ramping up local production.

Given the vast quantities of sulphuric acid required for lithium refining in particular, in order for Namibia to advance further downstream in the lithium value chain and produce lithium carbonate domestically as part of its green industrialization agenda, a strategic approach to procuring sulphuric acid supply is essential. This will require Namibia to assess its current and future sulphuric acid production capabilities to support and grow its local lithium refining industry effectively.

Today, China has established a significant presence in Namibia's sulphuric acid market, primarily in connection with uranium processing. In 2014, Swakop Uranium, a Chinese subsidiary, commissioned a 500,000 t sulphuric acid facility at the Husab uranium mine[79]. Additionally, in 2024, Sinomine acquired the Tsumeb copper smelter from Dundee Precious Metals for US$49 million, increasing China's involvement in Namibia's copper and uranium sectors[80]. This acquisition is strategically pivotal as the Tsumeb copper smelter also produces sulphuric acid, a byproduct of copper smelting. Rössing Uranium, another Chinese subsidiary, already secured a 5-year contract for 225,000 t of sulphuric acid from the Tsumeb smelter back in 2014[81], a testament to Tsumeb's critical role in producing sulphuric acid for Namibia's uranium sector. With this acquisition and the imposition of new regulations on unprocessed lithium exports in Namibia, **China is strategically positioned to support its existing uranium ventures in Namibia and in parallel emerge as a potentially dominant force in the burgeoning lithium market**.

The strategic importance of sulphuric acid in Namibia's green industrialization and lithium processing cannot be overstated. A well-planned sulphuric acid strategy is essential for Namibia to effectively participate in and benefit from the green industrialization wave and to mitigate foreign

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[79] Namibia Economist (2014), *Sulphuric acid plant for Husab*

[80] Dundee Precious Metals (2024), *Dundee Precious Metals Announces Sale of Tsumeb Smelter for US$49 Million*

[81] Rössing Uranium (2013), *Rössing's new sulphuric acid supply contract supports Namibian economy.*

dominance in critical industrial sectors. This may include plans to scale up local production such as that which already takes place at Tsumeb copper smelter, in order for the volumes demanded from lithium refining to also be met in conjunction with current uranium needs, and/or to consider cost-effective acid imports at scale.

3.2.3. Need for a national CRM strategy

Namibia must prioritize its lithium and REE sectors by establishing a comprehensive national CRM strategy. The country has significant resources that, if effectively leveraged, could substantially boost its economic landscape, particularly through job creation and local industrial development. A crucial initial step has been taken with the 2023 ban on exporting unprocessed critical minerals, aiming to foster local value addition and sustain economic benefits within Namibia, as explained by Mines and Energy Minister Tom Alweendo: "Without some of these minerals being processed on our continent, in our countries, there is no way we are going to industrialize"[82].

The development of a robust CRM strategy is vital for generating employment in Namibia. For instance, the Andrada project targets an annual output of 15,000 tons of LCE[83] and is expected to create nearly 1000 jobs, with 20% dedicated to refining operations. This strategic focus not only retains economic value within the country but also cultivates a skilled workforce, thus fueling long-term economic growth.

Choosing strategic locations and ensuring the availability of essential infrastructure are crucial for CRM project success. A lithium refining facility typically requires approximately 20-25 acres of land, reliable water and constant energy supply[84]. The government should play a key role in streamlining land permitting and the development of supporting infrastructure to facilitate these projects. Governance may also consider including CRM companies in new Special Economic Zones (see more in section 6.2). Strategic thinking around potentially clustering downstream mineral processing facilities in order to achieve economies of scale will also be needed. Localizing a lithium refining facility near the Walvis Bay or the Lüderitz port may provide several advantages, such as streamlining the export of refined lithium products, minimizing transportation costs of imported consumables and ensuring access to a skilled labor pool. In contrast, situating the facility near Tsumeb could capitalize on local sulphuric acid supplies, a critical input in lithium processing, as highlighted in section 3.2.2, although the benefits of port proximity might outweigh this consideration.

Namibia can develop innovative strategies and taxation schemes, similar to those in Chile, to foster a thriving lithium value chain. A primary goal of this value chain is to maximize local value, which can be achieved through specific tax regimes and royalty structures for lithium extraction and processing. For example, Chile has implemented sliding-scale royalties that vary from 6.8% to 40%, depending on the market price of lithium carbonate[85]. Adopting similar policies in Namibia can

[82] Bloomberg (2023), *Namibia Seeks to Tap Resource Potential After Lithium Ore Ban*
[83] Andrada (2023), *Annual Report 2023*
[84] Government of Namibia (2023), *Green Manufacturing strategy for Namibia*
[85] CEPAL (2023), *Lithium extraction and industrialization. Opportunities and challenges for Latin America and the Caribbean*

ensure that the economic benefits of CRM development are maximized and sustained locally in lockstep with market conditions. Encouraging local R&D within designated SEZs can further attract foreign investment and technological expertise. Additionally, supporting exploration projects and refining local regulations to create a business-friendly environment will enhance Namibia's competitiveness in the global CRM market, attracting more investors to contribute to the national economy. Notably, Argentina, Bolivia, and Chile allow immediate deduction of exploration expenditures. Argentina and Bolivia permit tax losses to be carried forward for up to five years, while Chile allows unlimited carry-forwards[85]. More on a potential approach for Namibia to shape its CRM strategy can be found below in Chapter 6.3.

3.2.4. Meeting international standards to secure offtakers

If Namibia were to embark on the lithium and REE value chains, it would not be acting in isolation. As outlined in section 3.1.1, stakeholders are increasingly seeking to broaden their supply chains beyond traditional hubs (see Figure 24), collaborating with governments and project developers to achieve this goal.

However, this geographic diversification does not come at the expense of stringent Environmental, Social, and Governance (ESG) principles and standards. Commodity traders and offtakers are placing responsible sourcing at the forefront of their supply chain strategies, adhering to third-party audit frameworks. Diligent measures are taken to ensure full traceability and mitigate risks across the supply chain. Presently, meeting both low-cost and high ESG standards is no longer seen as a choice between one or the other but rather as a dual necessity by offtakers. Therefore, stakeholders and policymakers in Namibia, already familiar with such standards in the diamond and gold industries, will need to uphold the same high standards in mining practices for lithium and REEs to engage effectively in offtake discussion.

While high ESG standards are already a prerequisite, discussions around low-emissions production for lithium and REEs may also gradually be gaining momentum as part of the commodities' environmental footprint. It remains to be seen whether this criterion will become a standard feature of the market or continue to carry a green premium, as it does currently. Several indicators suggest that low-emissions production may receive increasing attention:

- **In battery material production:** Umicore, a global materials technology group, has set a target of reducing scope 3 emissions intensity by 42% in the carbon intensity of their purchased materials by 2030. For example, their recent supply agreements with Terraframe for low-carbon nickel[86] and with Ganfeng and Vulcan for sustainable lithium aim to support this goal[87].

[86] Press release: Umicore (2 February 2023), *Umicore signs long-term agreement with Terrafame for the supply of sustainable low carbon nickel*.

[87] Press release: Umicore (15 October 2021), *Umicore signs long-term sustainable lithium contracts with Ganfeng and Vulcan*

- **In battery manufacturing:** Swedish battery manufacturer Northvolt introduced a Carbon Roadmap in 2030, targeting 10 kg CO_2/kWh of battery capacity manufactured by 2030. Securing low-carbon raw materials will be instrumental in achieving this target[88].
- **In downstream offtake:** The EU is introducing a Digital Battery Passport mandated by the EU Battery Regulation. This passport will require all large batteries entering the EU market by 2027 to be accompanied by a 'Battery Pass' enabling traceability of its manufacturing footprint[89]. Carbon footprint will be one of the measured metrics, marking the first time it will be required for each battery model per manufacturing plant.

Thus, staying informed about the emerging market for low-emissions lithium and REE materials should be a priority for Namibia to support its growing projects. This approach will enable stakeholders to align with global market trends in low-emissions critical raw materials and be prepared to adapt existing projects or design new ones accordingly.

[88] Northvolt (2022), *Enabling the future of energy – Sustainability and Annual Report 2022*
[89] thebatterypass.eu

4. Cross-Cutting Enabler: Power Infrastructure

4.1. Overview of Namibia's power sector today

Namibia is actively expanding its energy infrastructure to achieve universal electricity access by 2040 and to meet rising demand amidst challenges such as severe droughts impacting imported hydropower. Currently, approximately half of the population lacks access to electricity, with only 55.3% connected to the grid, affecting around 250,000 households. The country's installed power capacity is 654 MW, with peak demand projected to be double this figure by 2040[90]. Over 60% of this capacity currently comes from hydropower, with the remainder largely from underutilized thermal sources, including the aging 120 MW Van Eck coal-fired station and a 22.5 MW heavy-fuel oil (HFO) station, both plagued by high operational costs and low emission controls. To address these issues, NamPower, Namibia's national electric power utility, is diversifying its energy mix: it initiated procurement for the 50 MW Anixas II HFO plant and is increasing renewable energy contributions through 126.5 MW of solar and 5 MW of wind capacity via Independent Power Producers (IPPs). Future projects include bids for a 20 MW solar plant, a 50 MW wind plant, and a 40 MW biomass facility, signaling a shift towards more sustainable and reliable energy sources.

However, despite these developments, Namibia's local energy production remains insufficient to meet its needs, as evidenced by the 2021 peak demand of 616 MW[91]. This shortfall has led to a heavy reliance on electricity imports, which account for 50-60% of the nation's consumption, primarily from coal-powered stations in South Africa and from Zambian hydropower. During peak hours and low generation at Ruacana hydropower plant – when coal-fired electricity imports are necessarily at their highest – Namibian imports can rise to 90%. This creates import dependence and impacts Namibia's fiscal position. With key electricity import contracts set to expire in 2025, Namibia is also facing an increased risk of supply disruptions. In this context, energy security has emerged as a key priority for the Government of Namibia, in addition to electricity access.

In response to these vulnerabilities, the Government of Namibia has implemented strategic policies outlined in the 5th installment of the National Development Plan (NDP5) and the National Renewable Energy Policy (NREP). These policies aim to reduce import dependency by enhancing domestic generation capacities, particularly through renewable sources like solar and wind. NDP5 sets a target for 70% of electricity needs to be met from renewable resources by 2030. To support this strategy, the government introduced a new market structure, the Modified Single Buyer (MSB) Model, which facilitates direct energy transactions between large consumers and IPPs. Under the MSB model, 30% of the annual energy consumption in the power market is open to competitive supply by IPPs. This market liberalization is crucial, enabling IPPs to compete in supplying both NamPower and large customers, such as mines and regional electricity distributors (REDs), who may now procure up to 30% of their annual consumption directly from IPPs.

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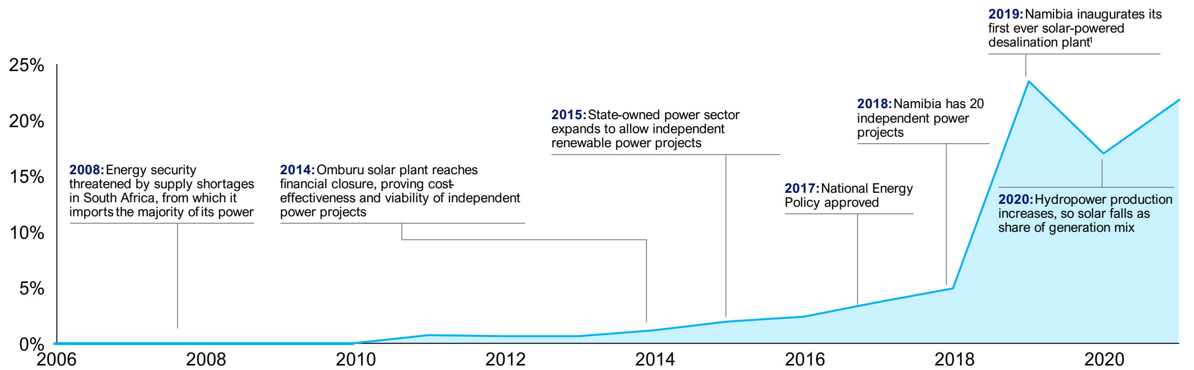
[90] World Bank (2023), *Namibia: Transmission Expansion and Energy Storage*

[91] Namibia Electricity Control Board, Annual Report 2022; Namibia's installed power capacity stands at 654 MW, but due to the improbability of simultaneous operation at full capacity, it falls short of meeting the peak demand of 616 MW, thus necessitating power imports.

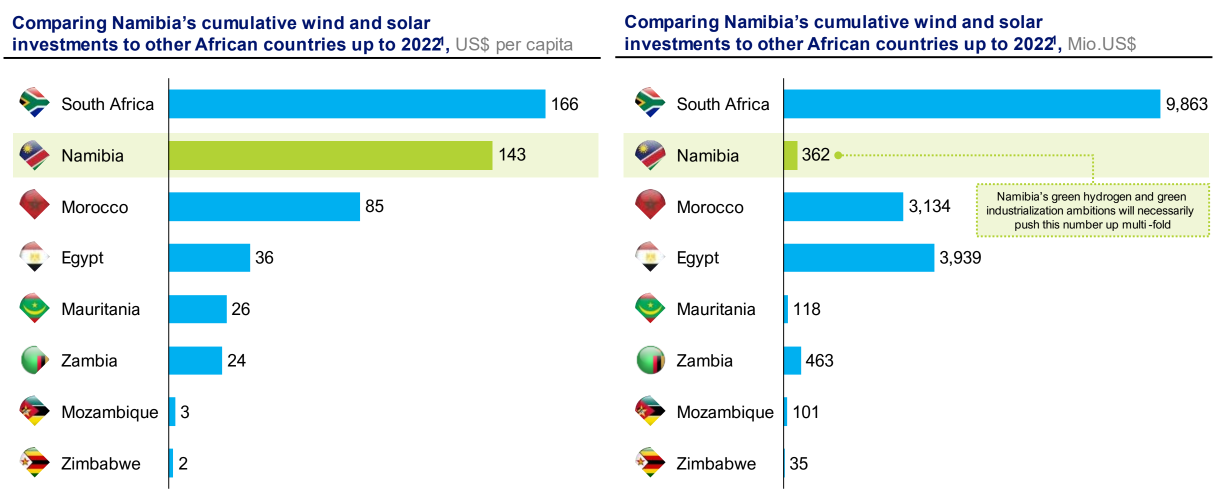
However, these policies have yielded mixed outcomes. On the one hand, the installation of solar panels in Namibia has seen a remarkable increase, surging from virtually zero a decade ago to an impressive 155 MW of installed solar capacity today (Figure 32). This significant growth did not require substantial financial incentives due to the country's exceptional solar irradiation potential. Achievements in this area are primarily attributed to streamlined policies and conducive regulatory conditions with the MSB model. Collectively, Namibia is one of the leading nations in Africa in terms of cumulative investments in wind and solar on a per capita basis (Figure 33, left).

Solar share of electricity generation in Namibia,
%



Note: 1. This desalination plant is a decentralised system and produces 3500 litres of water per hour from the ocean.
Sources: Systemiq analysis from WRI (2023), *These 8 Countries Are Scaling Up Renewable Energy the Fastest*

Figure 32: Namibia is an emerging solar hub in the Southern Africa region...



Note: 1. Up to 2022 means from first ever solar and wind projects until 2022. To calculate investment, we assume 1 MW costs ~US$1Mio. Namibia's population was 2.6Mio. in 2022.
Sources: Systemiq analysis from BNEF (2022), *Scaling-Up Renewable Energy in Africa*

Figure 33: ...and is leading per capita investments in Africa, though lagging in absolute installations.

On the other hand, further advancements in Namibia's energy sector are within reach but face several obstacles. Although renewable energy sources have been incorporated into the domestic supply mix, their integration has been on a limited scale. Challenges such as inadequate storage solutions and delayed investments in transmission infrastructure restrict the capacity for integrating variable renewable energy (VRE) into the system. Between 2018 and 2022, only 20 MW of the targeted 220 MW of new renewable generation was commissioned, primarily due to procedural delays in procurement processes. Additionally, the issuance of 1.2 GW worth of export generation licenses has led to a backlog, with many projects still pending, highlighting the need for enhanced coordination among Namibia's three key energy entities: the Electricity Control Board (ECB), NamPower, and the MME.

Compounding these issues, NamPower, the national utility responsible for generation, transmission, and electricity trading, is now facing changes in demand profiles and consumption patterns, partly due to an increase in solar energy adoption, including self-generation. This shift necessitates significant upgrades to connect new solar PV systems to the grid and adapt to a more decentralized energy model. In the realm of generation, NamPower is competing with private entities that can implement projects more rapidly and at lower costs, especially in the earlier years due to the differing tariff methodologies employed[92]. Regarding grid stability, the introduction of substantial intermittent energy sources adds complexity and may necessitate significant investment in utility-scale battery storage programs.

These challenges are set to intensify with the push towards green hydrogen and green industrialization, which will demand robust grid connections for new industries to both ensure sufficient baseload and dispatchable power capacity as needed, as well as manage their surplus energy effectively.

4.2. What green industries will require of Namibia's power sector

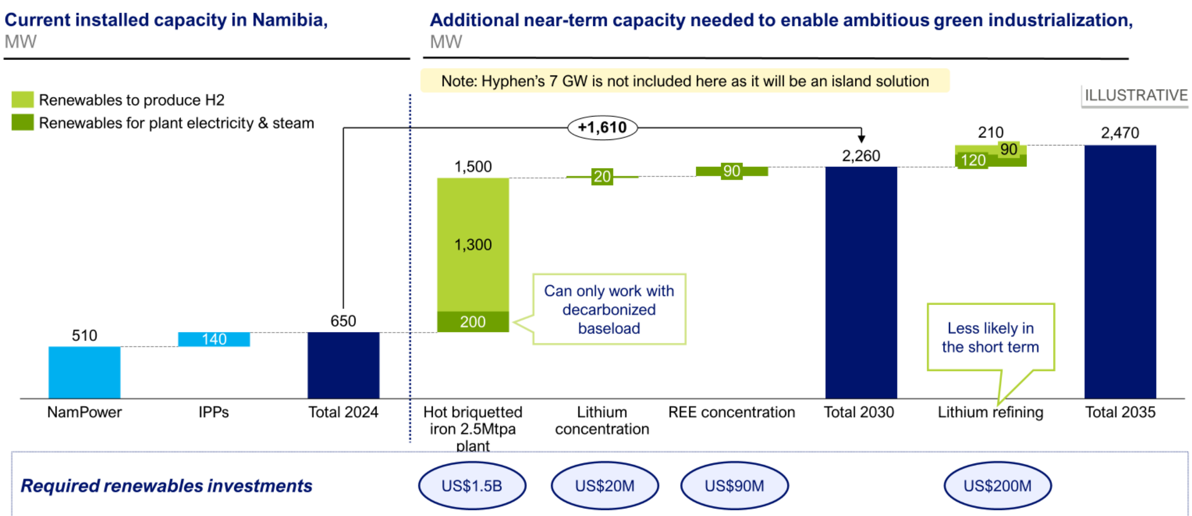
Green industrialization will intensify existing challenges in both generation and transmission sectors by placing extra demands on them. The Hyphen green ammonia project aims to install 7 GW of renewable energy in an isolated "mini-grid" approach. Additionally, other industries in Namibia are exploring decarbonization by leveraging Namibia's solar and wind potential. While these industries are not the primary focus of this report, collectively they encompass Namibia's total industrial complex and could significantly influence energy forecasts in a step-wise, not gradual, manner.

Energy demands for the three industries alone highlighted in this report would already be substantial (Figure 34)**.** As noted in Chapter 2.1.3, a single hot briquetted iron plant would require approximately 1.5 GW of energy—1.3 GW for hydrogen production via electrolysis and 0.2 GW to operate the DRI plant. Given the continuous operation needed for the DRI process, two solutions are

[92] The tariff methodology employed by NamPower typically results in higher tariffs at the beginning that drop in the later years, while the methodology employed by IPPs typically results in a flat tariff over time. This implies that NamPower may not be cheaper than IPPs at the beginning and may end up being cheaper in the later years of a project.

viable: either oversize the electricity production with extensive hydrogen storage capacity, impacting hydrogen costs, or connect the DRI plant to a stable power source (hydropower or gas[93]) either through a power purchase agreement (PPA) or by localizing the power plant close-by, to ensure the iron plant has access to dispatchable power during intermittent periods of low renewable power generation. In both scenarios, the power system will require a comprehensive overhaul, involving either robust, long-distance transmission lines and accompanying substations, or mechanisms to manage energy surpluses during peak times.

Regarding the CRM value chain, as depicted in Figure 34, energy consumption for concentration of all of Namibia's known resources of lithium and REE[94] (including separation for the former) is expected to be significant, potentially accounting for about 25% of Namibia's existing capacity (e.g., 100-150 MW out of 650 MW). If Namibia also refines all of its inferred domestic *lithium* resources in-country, this could add a further 210 MW of energy demands.



Notes: All investments in USD. 1:1 ratio from MW to renewables CapEx cost in million dollars (Mio.) is assumed. For lithium refining, energy required for the kiln is attributed to H_2, while the remaining energy needs are allocated to the electricity category. Hyphen is not included here as it is an "island project".
Sources: Systemiq analysis from GET.Transform (2023), *Namibia ESTO (Sep23);* Mission Possible Partnership (2023), *Steel Sector Transition Strategy*; J.C. Kelly et al. (2021), *Energy, greenhouse gas, and water life cycle analysis of lithium carbonate and lithium hydroxide monohydrate from brine and ore resources and their use in lithium-ion battery cathodes and lithium-ion batteries*

Figure 34: Much greater generation capacity is needed to attract mega-scale projects for iron, lithium and rare earths

Establishing one green iron plant and fully processing the existing lithium and rare earth element (REE) resources[94] in Namibia would require over 2 GW of additional power generation. This expansion presents several challenges. There may be a need to liberalize the market beyond the current 30% rule under the MSB model. Significant investments in transmission infrastructure (lines and substations) and a robust strategy for developing baseload capacity are also essential. Additionally, streamlining the planning and permitting processes and implementing transparent regulations will be crucial for successful implementation.

[93] As detailed in Chapter 2.3, the accepted definition of what constitutes as 'green iron' and therefore whether it will allow for use of power derived from gas has not yet been finalised.
[94] Calculations were made using inferred resources.

The current energy production strategy largely follows a business-as-usual approach, predicated on Gross Domestic Product (GDP) growth without sufficient incorporation of green industrialization nor the goals as laid out in Vision 2030, as depicted in Figure 35. NamPower's three scenarios for forecasting electricity loads until 2046 do not account for MME and MIT's plans for an increasingly industrialized Namibian economy, nor for the development of new activities such as green hydrogen production. It is important to note that these mega-scale projects are expected to impact not only large-scale industrial sectors but also trickle down to small and medium-sized enterprises (SMEs) at smaller industrial scales, which will have their own additional energy demands.

NamPower should therefore consider enhancing its capacity plans. In terms of transmission, the potential for new export or import routes, such as those needed for the Baynes hydro project, will require additional investments. These improvements will enable Namibia's ambitions for green industrialization and are integral to boosting energy self-sufficiency and reducing imports. For export-driven IPP projects, there is also a need to clarify engagement rules to facilitate faster grid connections.

This shift requires a new mindset, moving from a business-as-usual approach to a more ambitious, coordinated paradigm for green industrialization. Further strategic adjustments are discussed in the following section.

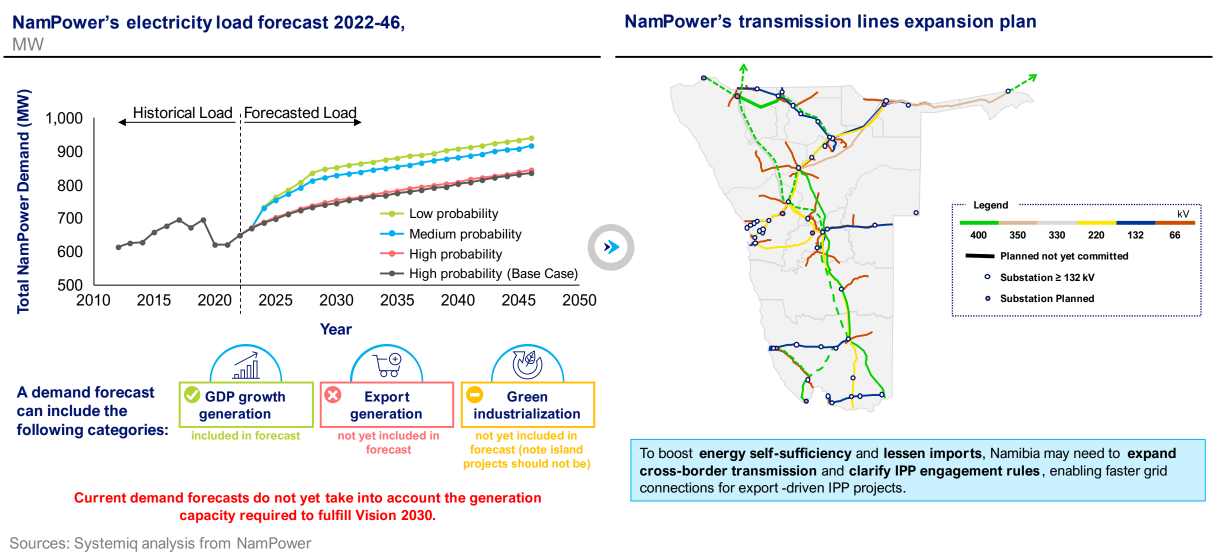


Figure 35: Namibia's energy demand is expected to increase with GDP and population growth, requiring enhanced transmission infrastructure. Current load forecasts do not yet take into account the step changes required to reach Vision 2030 targets nor green industrialization ambitions.

4.3. Potential strategies to evolve Namibia's power system

As previously mentioned, multiple strategies can enhance Namibia's power system to meet green industrialization needs. As shown in Figure 36, successful transformation requires a simultaneous focus on both generation and transmission, beginning with robust planning and forecasting. Once green industrialization is fully integrated into the sixth National Development Plan

(NDP6) with a defined vision for the country's future, the energy sector will enter the forefront of this industrial endeavor.

This chapter aims to explore strategies employed by other countries to adapt their power systems to broader industrialization goals; the potential applicability of these strategies to Namibia is suggested and will require further in-depth and dedicated studies to consolidate. Such discussions will be crucial among key Namibian stakeholders, including the MME, MIT, ECB and NamPower, while also considering the needs of industrial players.

Three strategic options will be detailed below:

1. **Market Structure**: Revision of the current power market structure to reduce potential conflicts of interest and streamline processes. This may involve restructuring the national utility to improve efficiency and adaptability in a market with increasing participation from private entities.
2. **Public-Private Partnership (PPP)**: Strengthening of public-private partnerships to enhance generation and transmission capacities. This could involve increasing the current 30% cap on private contributions to the energy sector and facilitating easier collaboration with IPPs and independent transmission projects.
3. **Intermittent Energy Strategy**: Development of strategies to manage renewable energy intermittency and ensure a reliable, decarbonized energy baseload. This will involve enhancing battery storage technologies, utilizing mini-grids, and coordinating regional efforts to import low-carbon energy from neighboring countries.

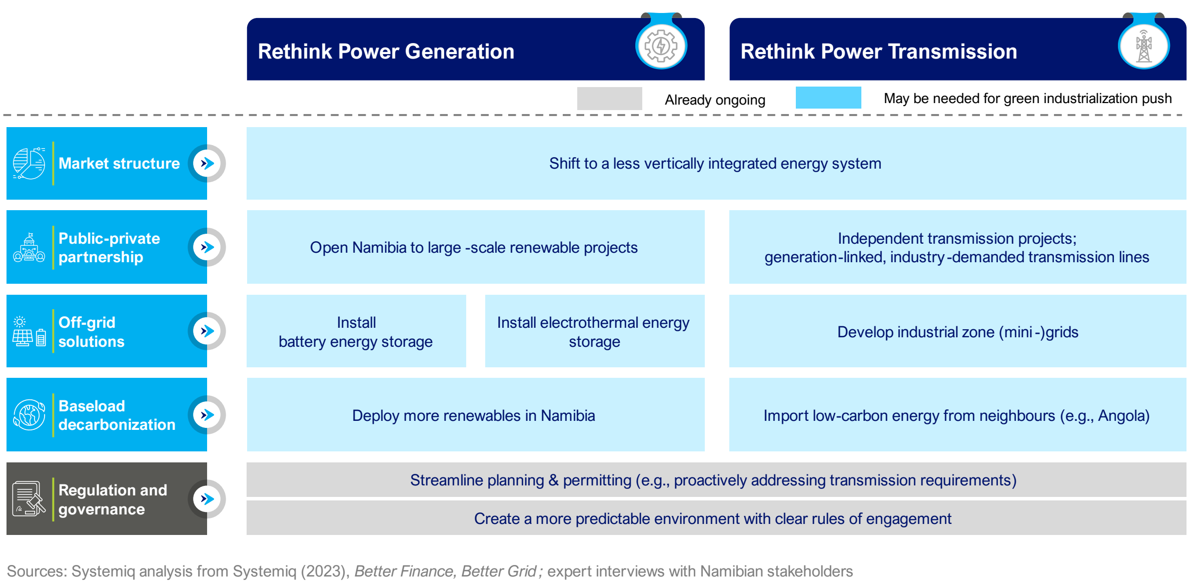


Figure 36: Multiple strategies can evolve Namibia's current power system into a fit-for-purpose sector prepared for new green industries.

To support these strategies, there must also be an ongoing and overarching emphasis on streamlining planning and permitting processes. This includes simplifying regulatory procedures to accelerate project approvals and implementations. Additionally, tackling existing challenges will be critical in creating a resilient and responsive energy sector capable of supporting Namibia's green industrialization goals. These efforts will require close coordination among all relevant stakeholders, including governmental bodies, industry leaders, and energy providers.

4.3.1. Market strategy

In recent years, there has been a growing recognition of the need to reform and modernize the electricity sector in Africa. The traditional model, dominated by large vertically integrated utilities, is being challenged by the global fight against climate change, technological advancements in renewable energy, and the need for competitive pricing**. As a result, several African countries like Zambia, Ghana, Nigeria, Kenya and Uganda have embarked on the path of unbundling and deregulation to increase efficiency, attract private investment and promote competition, setting precedents for reform across the continent**. This overview sets the stage for examining more recent specific examples from Mauritania and South Africa, followed by possible implications for Namibia and NamPower.

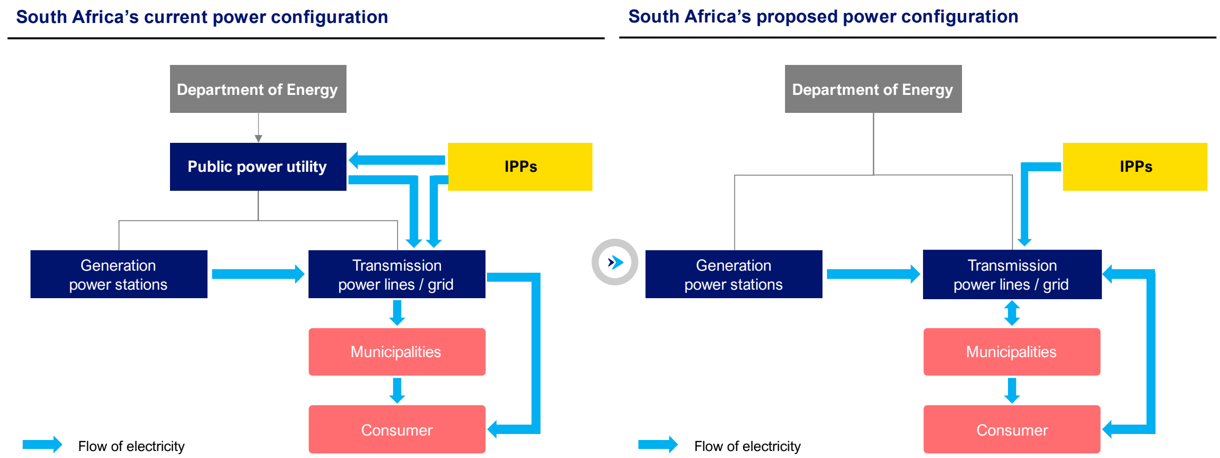
In Mauritania, energy sector reforms, supported significantly by the EU, have initiated the unbundling of state-owned utility SOMELEC. This change would allow independent power producers to generate electricity with SOMELEC as the single buyer. SOMELEC would retain sole responsibility for electricity distribution and regional electricity interconnections for exports. As of mid-2023, the law to reform SOMELEC has been approved but the legal document developed with the support of the EU Technical Assistance Facility with details of the unbundling has not yet been released, illustrating the cautious approach needed when implementing such significant reforms[95]. Mauritania is an example of particular interest given the country's similarities to Namibia and its parallel ambitions for green hydrogen and green industries (see Chapter 1.3).

Despite delays in policy implementation, the electricity sector in South Africa is also in the midst of a major transformation. In 2019, the Department of Public Enterprises shared a roadmap for unbundling Eskom, the national power utility, into generation, transmission and distribution subsidiaries (Figure 37). Separating Eskom into these units would enhance competition, transparency and accountability in the energy sector[96]. Direct privatisation is not the ultimate goal of unbundling, but rather the creation of an independent entity to democratise the energy sector[97]. Despite facing political resistance, the ongoing establishment of the National Transmission Company South Africa (NTCSA) marks a pivotal development in South Africa's energy reform.

[95] RIFS Potsdam (2023), *The Politics of Green Hydrogen Cooperation*

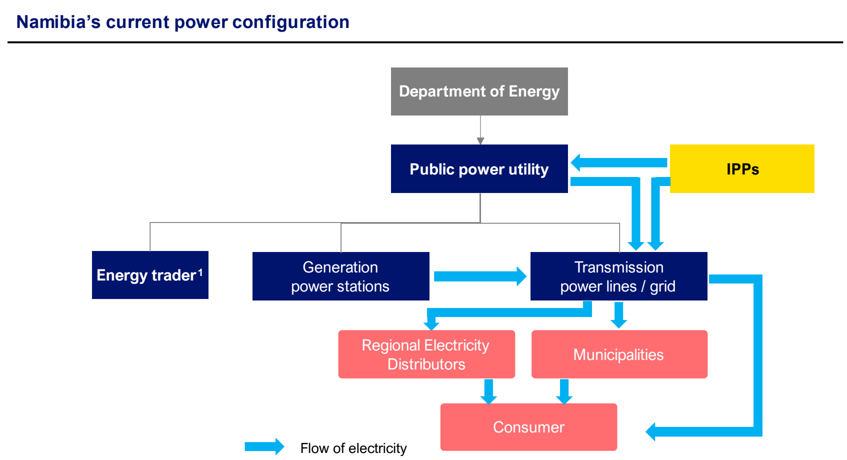
[96] J. Hanto et al. (2022), *South Africa's energy transition – Unraveling its political economy.*

[97] Phenomenal World (2022), *Eskom, Unbundling, and Decarbonization*



IPPs – Independent Power Producers.
Source: Systemiq analysis from Economist Impact (2023), *Powering Progress: Policy shifts and economic frameworks to enable South Africa's energy transition*

Figure 37: To expand its renewable energy capacity, South Africa is in the process of unbundling its public utility.



IPPs – Independent Power Producers; 1. Modified single buyer (MSB)
Sources: Systemiq analysis

Figure 38: Namibia's current power sector configuration.

The examples of Mauritania and South Africa provide valuable insights for Namibia. However, while unbundling has its merits, it is not the panacea. Namibia has already begun to liberalize its market with the Modified Single Buyer System (Figure 38). Any consideration of further unbundling NamPower must be weighed against alternative strategies to enhance the country's power generation system. Given Namibia's small economy and population of approximately 3 million, it is crucial to ensure that any reforms truly benefit the national interest. One of the risks with unbundling to consider in Namibia's context is the breaking up of a proper but not large asset base, upon which NamPower today relies upon to receive decent development loans and enter negotiations effectively with IPPs. Also at risk is a misdiagnosis of the causes leading to the stumbling blocks observed today: as emphasised above, the trifecta of NamPower, ECB and MME must be better coordinated in a concerted manner to enable smooth integration of IPPs into the power market, even without vertical unbundling. Finally, upholding the market should also be the assurance that the market trader office (i.e., that managing the MSB market) carries out its audit function independently of NamPower.

4.3.2. Public-private partnerships and transmission strategy

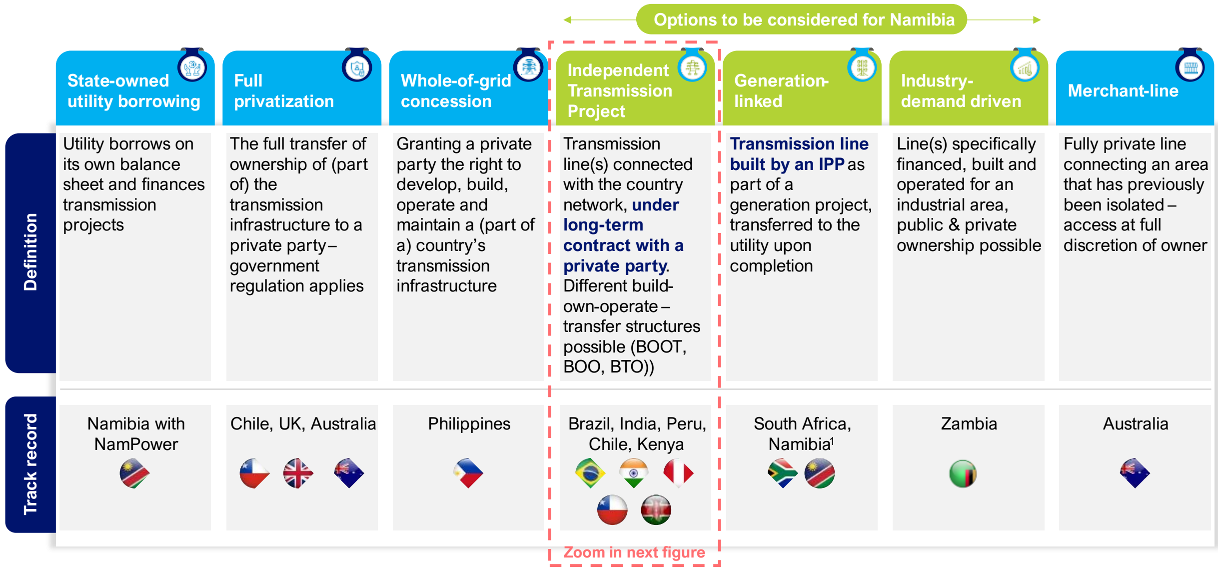
Instead of going as far as unbundling NamPower, another viable option could be to enhance public-private partnerships. As previously mentioned, further opening up the MSB model is a potential strategy. This could include raising the existing 30% cap on private sector contributions to the energy sector and streamlining collaboration with IPPs and independent transmission initiatives. This approach would leverage private sector efficiencies while maintaining strategic oversight.

In Namibia, Independent Transmission Projects (ITPs) could serve as another efficient public-private partnership model for developing transmission infrastructure, as shown in Figure 39. Given the long lead times typically associated with transmission projects and the emerging industrial requirements in Namibia, ITPs present a viable solution. These projects have demonstrated success in various countries, including Brazil, India and Peru, and can be implemented without significant disruptions to existing systems or extensive regulatory reforms with much shorter timeframes than other models[98].

NamPower could draw upon valuable lessons from ITPs in other countries. ITPs allow for varying models of ownership, risk sharing and division of responsibilities, and give optionality to cater to local desires and requirements. For example, asset ownership within an ITP could be transferred to NamPower directly after completion, after a predefined period, or maintained by the ITP entity indefinitely. As shown in Figure 39, there may also be a role for generation-linked models. This particular model is particularly conducive to harness renewable energy sources in remote areas or connect an industrial player to the grid. It usually involves joint projects for renewable generation capacity and transmission lines.

Cost efficiency is another compelling argument for adopting ITPs in Namibia. As observed in other regions, off-balance sheet financing can lead to substantial cost reductions. For instance, competitive bidding and a diverse pool of lenders in Peru and India led to project cost reductions of up to 36%[98]. Such financial efficiencies could be critical for Namibia, where cost-effective infrastructure development is necessary to support economic growth and energy security.

[98] Blended Finance Taskforce (2023), *Better Finance, Better Grid*



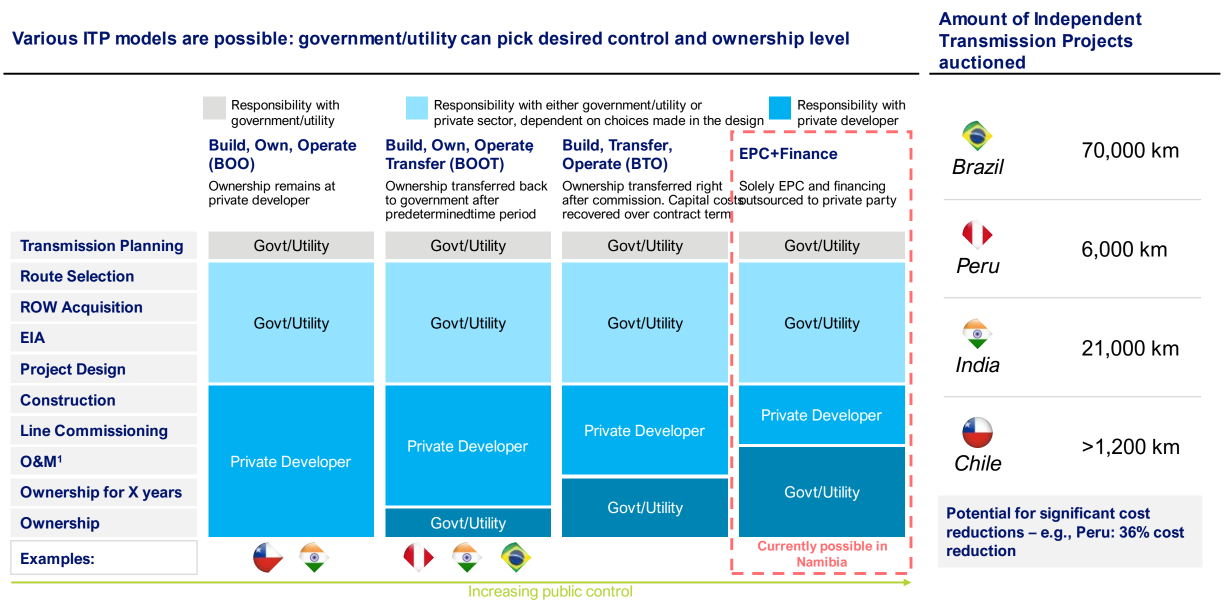
Notes: 1. The uranium mine in Trekkopje exemplifies a scenario where infrastructure was developed by a private entity and later transitioned to NamPower for operation and maintenance.
Sources: Systemiq analysis from Blended Finance Taskforce (2023), *Better Finance, Better Grid*

Figure 39: In the long term, different types of financing mechanisms can accelerate installation of new transmission infrastructure.

By leveraging ITPs, NamPower could maintain flexibility in financing models, choosing between various ITP arrangements or traditional balance-sheet financing depending on the project's specific requirements and risks. This approach allows for tailored control and ownership structures (Figure 40), fitting well with Namibia's strategic energy and industrial goals. Interestingly, this model has already been tested in Namibia as highlighted in the below box.

<u>Example of ITP in Namibia:</u>
NamPower has already facilitated Independent Transmission Projects in Namibia using a Build, Transfer, Operate (BTO) model. An example is Areva SA's construction of a transmission line and substations for its Trekkopje uranium mine. After construction, these assets were transferred to NamPower for operation and maintenance, enhancing power supply reliability in the Erongo region. This project exemplifies effective public-private partnerships supporting Namibia's industrialization goals[99].
Such partnerships are crucial for accelerating infrastructure development and enhancing the stability and reliability of the national energy grid.

[99] AllAfrica (2010), *Namibia: NamPower takes over Areva's power lines.*



O&M – operation and maintenance; EPC – engineering, procurement and construction firm; ITP - Independent Transmission Projects
Sources: Systemiq analysis from Blended Finance Taskforce (2023), *Better Finance, Better Grid*

Figure 40: Independent transmission projects are likely the most successful for financing new infrastructure in the near term.

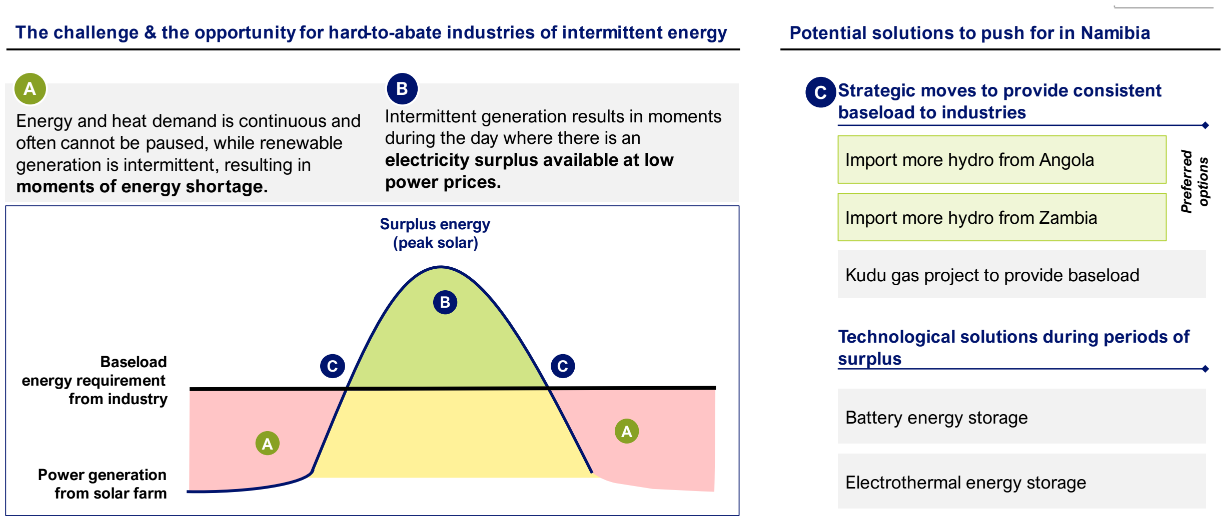
4.3.3. Baseload strategy

Intermittent renewable energy presents significant challenges due to the mismatch between the continuous demand for energy and heat, and the variable nature of renewable energy generation (Figure 41, left). This intermittency often leads to periods of energy shortage when demand cannot be paused to match the fluctuating supply. Conversely, there are times during the day when excess electricity is generated, resulting in a surplus that is available at lower prices. This variability complicates the management of a stable and reliable energy supply.

To ensure a sustainable baseload, Namibia could consider several strategies (Figure 41, right). **One approach is to enhance non-intermittent power sources** by either increasing the import of baseload energy, such as hydropower from Angola—which possesses substantial hydro reserves in its central region that could be connected to Namibia through transmission infrastructure investments—or by developing gas combined cycle gas turbine (CCGT) projects like the Kudu Gas Field, although this carries certain challenges that could be at odds with green industrialization[100].

[100] Greening Namibia's grid will be more difficult if Kudu gas is developed, as NamPower will most likely have to become the anchor customer to Kudu. If 200 MW from Kudu is connected to the national grid, this may force out some renewables, with private sector probably forced out first. Additionally, costs will be high due to the lack of a flat offtake. A capacity factor of minimum 80% must also be considered in order for costs to be managed, meaning that, although off-peak renewable power during the night will be much cheaper than gas-fired power, NamPower as anchor customer would be forced to purchase 80% of Kudu gas power even during these periods of cheap renewables.

Alternatively, investing in battery energy storage systems is a viable solution, especially as their costs have decreased by 90% in less than 15 years and are expected to continue declining[101].



Source: Systemiq analysis

Figure 41: Given renewable intermittency and some industries' 24/7 energy needs, investigating baseload and dispatchable power solutions is crucial.

The strategic importance of these energy solutions is emphasized by the demands of energy-intensive industries such as green iron production. Namibia's carbon footprint was recorded at 64g CO_2/kWh in 2022, a figure that, though low, can vary significantly depending on the source and proportion of energy imports. This footprint can escalate substantially when relying on coal-based imports, rendering it non-competitive compared to regions like Tasmania, Northern Sweden and Quebec, which boast low grid carbon intensities of 27g, 13g and 28g CO_2/kWh, respectively, and are regions of interest for green iron project developers like H2 Green Steel[102]. This variability, compounded by Namibia's reliance on imports and its limited grid capacity, presents a considerable challenge for major iron projects. Kajsa Ryttberg-Wallgren, Head of Growth and Green Hydrogen Business for H2 Green Steel, starkly emphasizes the critical role of green power: "*No green power, no project"*[103].

To successfully attract green industrial projects such as a green iron project, Namibia faces many decisions. These include pairing intermittent renewables with battery storage—impacting capital expenditures—or oversizing renewable capacity for hydrogen production alongside investments in hydrogen storage, which would influence the economics of hydrogen. Another viable option involves tapping into hydropower from neighboring countries like Angola and Zambia. While

[101] International Energy Agency (2024), *Batteries and Secure Energy Transitions*
[102] Electricity Maps, display data for 2022 from Renew Economy (2024), *"No green power, no project:" Can Australia compete on green steel?*
[103] Bloomberg (2023), *Swedish Industrialists Explore US$6 Billion Green Steel Project in Canada*

promising, this approach demands long lead times, concerted efforts, PPAs, and robust regional relationships, plus the development of necessary transmission infrastructure.

In summary, securing a reliable generation capacity to provide both baseload and dispatchable power is essential not only for energy independence and sovereignty but also for supporting green industrialization, particularly in continually operated and energy-intensive industries such as iron reduction. Moreover, it is crucial to monitor the evolving definitions of "green iron" in this global industry in order to potentially adapt strategic choices, including reassessing options like Kudu gas that may prove to be too carbon-intense.

5. Cross-Cutting Enabler: Rail Infrastructure

5.1. Overview of Namibia's rail sector today and what green industrialization will demand of it

Transport infrastructure is crucial for supporting industrialization. Namibia benefits from well-maintained roads, widely regarded as some of the best in Africa, which currently support the country's mining industries. Should Namibia's CRM industry materialize, these existing roads could facilitate its development. For overseas exports, ports play a vital role, and Namibia is well-equipped with Walvis Bay, a major port linking it to European and Asian markets. Discussions are already ongoing to upgrade Walvis Bay and develop the Lüderitz port for new industries. **The objective of this subchapter is therefore to assess whether the existing rail infrastructure can meet the demands of Namibia's green industrialization, particularly for green hydrogen and green iron**. This evaluation will determine if the current rail system is adequate or if significant enhancements are needed to support the anticipated industrial growth.

The first misconception to clarify concerns the logistics of commodity transportation for developing a direct reduced iron (DRI) industry in Namibia. Namibia has two primary options:

1. Transporting iron ore from the mine to an industrial hub near an export port, where green hydrogen and the DRI plant would be co-located; or
2. Transporting green hydrogen to the iron ore mine, where the DRI plant would be set up, and subsequently exporting the reduced iron from the mine to the offtaker (e.g., to a port for overseas steel producers).

In both of the above options, the transportation of iron ore/iron is better done by rail rather than by road trucking: it is widely recognized in the scientific community that rail is more competitive, efficient, safer, and economical to transport heavy commodities like iron ore than by trucks, reducing the carbon footprint by 75%[104] and cutting transportation costs by 20-40%[105].

Additionally, there is a consensus that transporting industrial commodities by rail is more advantageous than moving hydrogen through pipelines, the latter of which involves risks such as embrittlement and leakage, and requires extensive maintenance due to the molecular thinness of hydrogen[106].

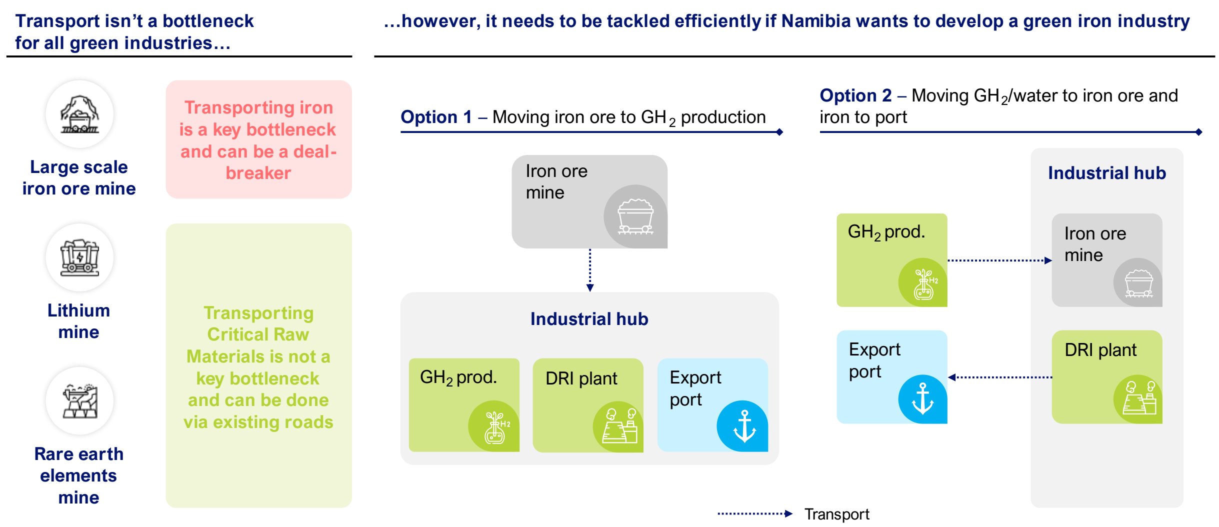
For these reasons, it is advisable for Namibia to ensure that hydrogen production is co-located with its eventual transformation into hydrogen derivatives such as green ammonia or green iron. Consequently, the first option outlined above and in Figure 42—co-locating the DRI plant near an export port and using rail for iron ore transport—is preferable. **This choice underscores the need for**

[104] Association of American Railroads (2024), *Freight Rail & Climate Change*

[105] BCG (2023), *Benefits of applying advanced technologies to rail freight shipping*.

[106] L. Giannini (2024), *Embrittlement, degradation, and loss prevention of hydrogen pipelines*

a robust and well-adapted rail infrastructure in Namibia to support efficient iron ore transportation[107].



Source: Systemiq analysis

Figure 42: Different transport options are optimal depending on the green industry sector – rail is crucial for iron.

Currently, Namibia's railway system is at a crossroads, urgently requiring upgrades to accommodate the anticipated increase in demand. One key element that requires urgent attention is the availability of suitable rolling stock. The rail system currently handles 1.6 million tons of goods per year[108], and needs to scale up significantly to support potential increases of 2 to 5 million tons by 2026. This surge can be expected if projects such as the Lodestone iron ore mine begin producing and if partnerships with regional sources of iron ore – e.g., South African iron ore mines – move ahead, as described in Chapter 2.2.1. Interestingly, this aligns with TransNamib's current 5-year plan, which forecasts moving around 4 million tons by 2030. The plan includes purchasing 25 new locomotives and around 300 units – ranging from flat wagons for mining commodities to fuel tankers and asset tankers – and refurbishing some existing locomotives. These upgrades are essential for leveraging emerging opportunities and supporting the sustainable growth of Namibia's green industries, and must be prioritized with haste given the 18-24 month lead time typically needed between ordering and receiving a new locomotive.

Beyond rolling stock, several key improvements to the rail line infrastructure itself are also critical to meeting the demands of an expanding industrial sector. While TransNamib maintain the rail lines and own the rolling stock assets, the rail lines themselves are owned by the Ministry of Works and Transport; the Ministry of Finance and Public Enterprises is the third stakeholder in Namibia's rail governance. All three parties therefore will need to work together to align on the

[107] If the route to the offtaker, such as an export port, is not situated near the industrial hub, the additional utilization of rail transport may become necessary to convey the green iron from the DRI plant to the port. This requirement arises when distances are too substantial to warrant road transport as a viable option.
[108] TransNamib (2019-2020), *Integrated annual report*

necessary priorities to facilitate Namibia's green industrialization. Firstly, modernizing the signaling and train control systems will enhance safety and efficiency across the network. Secondly, increasing the axle load capacity from 16.5 tonnes/axle load to international standards (e.g., 18.5 tonnes/axle load in Southern African Development Community (SADC) countries) is essential for accommodating heavier freight loads; currently, only around 25% of the Namibian national rail network meets that standard. Thirdly, developing new rail lines to connect mining sites to hydrogen hubs and ports, and possibly extending or upgrading existing lines to integrate with regional mining activities (below) will be critical. Regarding maintenance, resolving ongoing issues is crucial for ensuring the longevity and functionality of the rail infrastructure. This step is vital for preventing disruptions in service, which could impede industrial operations.

Potential extensions of the rail network are also under discussion to bolster Namibia's connectivity with neighboring countries and enhance its role as a transport corridor. One proposed extension is a new rail line to South Africa, specifically designed for the transport of iron ore and manganese. Another significant proposal is the TransKalahari line connecting with Botswana, which would serve as an alternative route to South Africa for transporting CRM (copper, nickel, manganese) from Botswana to Namibian ports. Similarly, discussions include enhancing connections with Zambia for the efficient movement of copper to the coast. These extensions would significantly strengthen regional trade links and support the industrial sector's growth in Namibia and beyond.

Most of these rail infrastructure upgrades and extensions are already under discussion, but their significance will be magnified under the new green industrialization paradigm and a concerted effort will be needed to prioritize "no-regret" actions, including solving the issue of investment.

Finally, decarbonizing rail transport is also essential for Namibia, as the sector heavily relies on diesel-powered locomotives, significantly contributing to its carbon footprint. Several promising methods are available for achieving zero emissions in rail transport: electrification via overhead catenary systems, hydrogen fuel cells, and battery-powered locomotives. Electrifying the rail network through overhead lines, commonly used in western countries like France, involves high capital expenditures and faces risks such as copper cable theft, a challenge recently highlighted in South Africa[109]. Meanwhile, hydrogen fuel cells are gaining traction in Namibia, where TransNamib is advancing a pilot project for dual-fuel locomotives that utilize both hydrogen and diesel[110]. However, the zero-emission potential of hydrogen depends critically on its production source and the efficiency of the extraction process. Another viable option for TransNamib may be **battery-electric locomotives**, supported by the recent advancements in battery technology, falling battery costs, increased energy densities, and the availability of affordable renewable electricity in Namibia[111].

[109] Bloomberg (2023), *Theft of Hundreds of Miles of Cable Hits South Africa Rail Route*
[110] H2TECH (2022), *A consortium receives funding for a green H2 dual-fuel locomotive pilot project in Namibia*.
[111] N.D. Popovich et al., *Economic, environmental and grid-resilience benefits of converting diesel trains to battery-electric*, Nature (2021), 6, 1017-1025.

5.2. Potential strategies to evolve Namibia’s rail system

Similarly to opening access to its power sector, Namibia could look into opening access to its rail system through public-private partnerships and innovative financing models, as recently demonstrated by neighboring countries for upgrading and extending their rail infrastructure to support green industrialization.

For instance, Zambia is opening its rail access to Chinese and American stakeholders with vested interests in its copper sector:

- **Chinese Investment in the Tanzania-Zambia Railway**: A US$1 billion-plus initiative by China plans to revitalize the railway connecting Zambia's copper heartland to the Tanzanian port of Dar es Salaam, with the deal expected to conclude by September 2024[112]. Negotiations are driven by a state-owned Chinese company.
- **Lobito Corridor Project**: This US-backed venture aims to link Zambia's copper mines to the Atlantic Ocean port of Lobito in Angola. It involves a significant US$250 million loan from the International Development Finance Corporation to upgrade the 1200 km Benguela rail line in Angola, with advisory support from the Africa Finance Corporation[113]. The project, expected to exceed US$2 billion in total costs, includes US$455 million in Angola, US$100 million in the Democratic Republic of Congo (DRC), and US$1 billion from the US and its partners for an additional 800 km of rail linking Zambia to the network. The Lobito Atlantic Railway consortium, in connection with this project, plans to acquire 1555 wagons and 35 locomotives for the Angolan segment to fully harness the railway's capacity.

There is already momentum for such cross-border projects in Namibia. Botswana has received unsolicited bids from international investors, including firms from the UAE, Qatar, China, and India, to develop a new railway line through Namibia, bypassing the deteriorating South African rail network[114]. TransNamib is also in talks with a client operating on the southern route from Northern Cape in South Africa into Namibia regarding their provision of rolling stock and operation on TransNamib lines, a business model that TransNamib are amenable to exploring in other instances in order to unlock additional volume that they otherwise would not be able to move using their existing assets (see section 5.1 above). Investments in rail infrastructure by players in the metals and minerals space is not a new phenomenon and may be explored in Namibia’s context[115].

[112] Bloomberg (2023), *China Railway to Negotiate Tanzania-Zambia Line Concession*

[113] Mining.com (2024), *Zambian president calls rail link connecting copper mines to Angolan port ‘once-in-lifetime’ break*.

[114] Bloomberg (2023), *Crumbling South African Rail Prompts Botswana to Forge New Route*

[115] Two examples in the iron ore industry: (1) In 1960, the World Bank granted a US$66 million loan for high-grade iron ore development in Mauritania alongside a 415-mile railway; (2) Rio Tinto and the Winning Consortium Simandou are currently supporting the Government of Guinea with US$6.5 billion for the construction of a heavy haul rail system in Guinea to shift iron ore from the Simfer Simandou mine (the size of which is an estimated 1.5 billion tonnes of ore reserves).

6. Cross-Cutting Enabler: Policies

6.1. Overview

To effectively drive green industrialization, it is essential to forge robust public-private partnerships and strategically align all elements of industrial and regulatory planning. So far, this report has emphasized the importance of establishing well-defined strategies, including implementing a comprehensive CRM strategy, adapting rail and power infrastructure to meet new industrial objectives, and anticipating regulatory changes and specifications in partner markets such as the CBAM and Battery Pass in Europe and standards for green steel and sustainable mining globally. **Achieving green industrialization will require well-designed policies to support operationalization of all components of these strategies in a seamless and integrative manner**.

Dr. Humavindu's introductory keynote speech at the "Localizing Green Industries in Namibia" workshop on 10th April in Windhoek provided a comprehensive overview of Namibia's industrial policy trajectory and its strong alignment with green industrialization objectives, reflecting considerable progress already made. Namibia launched its green industrial journey with its first National Industrial Policy in 2012, followed by the Execution Strategy for Industrialization (Growth at Home) in 2014, focusing on local value addition and aligning with regional industrial goals such as those of SADC.

The policy landscape transformed significantly in December 2020 with the withdrawal of existing manufacturing incentives, leading to the October 2022 introduction of the National Sustainable Special Economic Zones Policy. This policy aims to supplant the Export Processing Zone regime by December 2025, alongside efforts to finalize the SEZ Bill, National Informal Economy, StartUps, and Entrepreneurship Policy, with a new Industrial and Productive Development Policy expected by early 2025.

Sectorally, the Ministry of Industrialization and Trade is looking to integrate green technologies in areas such as steel manufacturing, charcoal production, and seafood, adapting existing policies to support this transition, including the automotive sector policy and the Mineral Beneficiation Strategy. This adaptation is part of a broader commitment to sustainable industrial practices, also seen in Namibia's ratification of the Kigali Amendment to the Montreal Protocol, enhancing the sustainability of the energy sector.

On a global scale, Namibia is fostering strategic partnerships on Green Hydrogen and Critical Raw Materials with international entities like the EU, Germany, and Japan. These collaborations form a key component of Namibia's strategy to embed green industrialization within its national policy framework, demonstrated by initiatives like the 2021 SD Investor Roadmap developed with the UNDP to attract investments in solar and other green technologies.

At its core, Namibia's approach to green industrialization seeks to transform the national economy towards a sustainable growth path. This transformation encompasses a shift from fossil fuels to renewable energies, heightened resource efficiency, and the embrace of a circular economy, principles that resonate with the environmental sustainability commitments enshrined in Namibia's Constitution since its independence.

Traditionally, Namibia has formulated its policies by benchmarking against neighboring countries and partners, primarily within the SADC region and South Africa in particular. However, the new agenda for green industrialization necessitates an expansion of the lens to include a broader array of regions. This lens should encompass the perspectives of both understanding what competitors are doing, but also how Namibia may align with potential partners in these new value chains. Figure 43 highlights global competitors across our three key industries of focus: hydrogen, iron, and critical raw materials. For hydrogen, notable competitors include countries in the Sahara, Brazil, the U.S., China, India and Australia. In the sectors of lithium and REEs, competitors are China, Argentina, Bolivia, Chile, the Democratic Republic of the Congo (DRC), Zimbabwe and Australia. For iron, existing and upcoming producers are located in Mauritania, South Africa, Brazil, Australia and China. This list is illustrative rather than exhaustive, and serves to suggest that a broader perspective could inform the development of robust, globally competitive policies for Namibia.

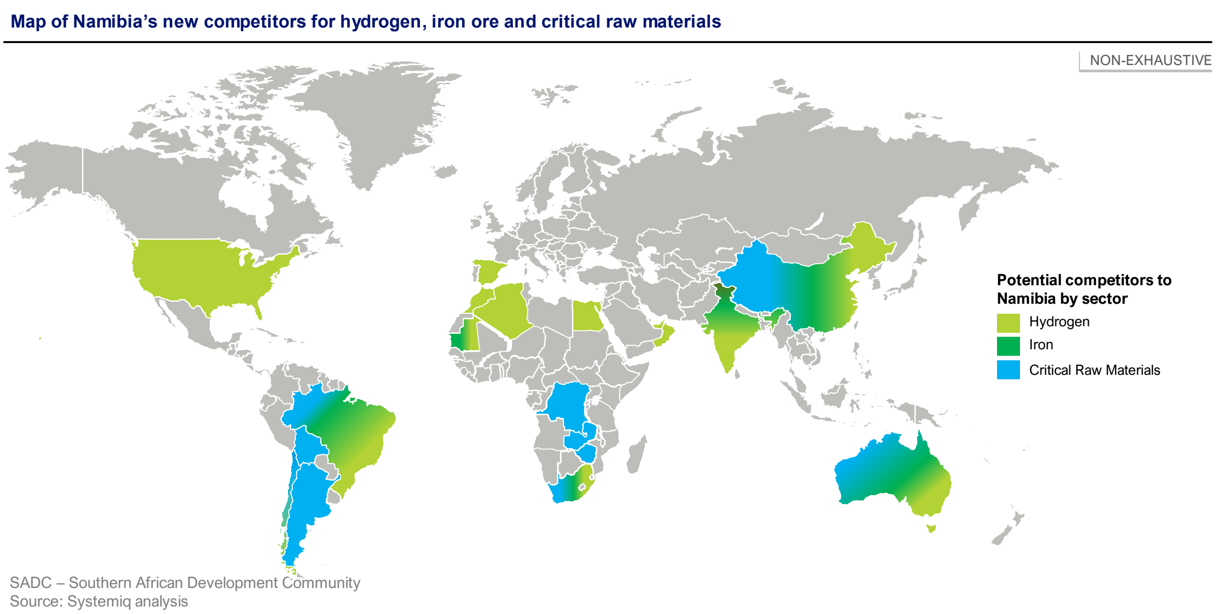


Figure 43: Namibia's green industrialization competition expands globally beyond its traditional benchmarks in the SADC region, offering policy insights worldwide to draw inspiration from.

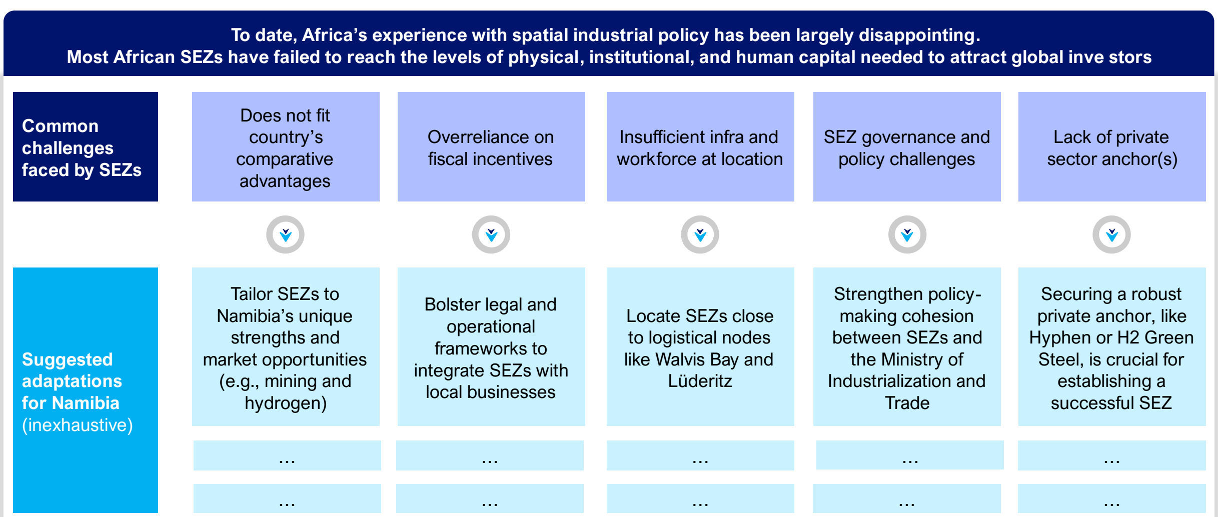
This chapter will focus on key policy priorities to accelerate green industrialization in Namibia, building upon existing momentum in industrial policy reform as described above. Firstly, the crucial role of green special economic zones in fostering green industrial growth will be examined. Secondly, the potential impact of CRM policies in supporting the nascent lithium and REE markets within Namibia will be explored. Lastly, the importance of certification and policy adaptation to meet the requirements of major offtake markets such as the EU, the US and Asian countries will be briefly covered. These strategic elements are essential for integrating green industrialization into Namibia's broader economic framework.

Note that a green iron-specific lens has not been taken in this chapter, given that several enabling components for green iron have been covered in Chapter 4 on power and Chapter 5 on rail above. Any overarching industrial policy discussed below will also naturally affect green iron, as it will other sectors.

6.2. Green industrialization priority: Special Economic Zones

A pivotal piece of legislation for green industrialization is currently under discussion: the national Special Economic Zone policy. SEZs are defined as geographically delimited areas where governments enhance industrial activity through a blend of fiscal and non-fiscal incentives, infrastructure improvements, and superior services. These zones have become a popular tool for economic development globally, with their use expanding dramatically from 80 zones in 1975 to approximately 5400 globally by 2019[116]. While Africa accounts for only a small fraction of these zones, their growth on the continent is accelerating as countries aim to revitalize existing programs or launch new ones[117].

Despite their growing number, SEZs are not a silver bullet and must be thoughtfully implemented. They were originally established to capitalize on the consolidation of global value chains and the emergence of global production networks, allowing for the concentration of production stages in cost-effective locations. Successful examples, predominantly in China and the so-called Asian Tigers (e.g., Shenzhen), have demonstrated their potential to spur innovation, productivity, and economic dynamism. **However, Africa's experience with SEZs has been mixed, with many not achieving desired levels of foreign direct investment, company attraction or job creation**. Common challenges include mismatches between the SEZs' sectorial focus and the host country's comparative advantages, over-reliance on fiscal incentives, insufficient infrastructure, lack of coordinated political support, and the absence of a robust private sector anchor, as illustrated in Figure 44.



Sources: Systemiq analysis from ECONSTOR (2017), *Industrial clusters: The case for Special Economic Zones in Africa;* Andres Rodriguez-Pose et al. (2022), *The challenge of developing special economic zones in Africa: Evidence and lessons learnt*

Figure 44: Ineffective policy design is limiting the success of African SEZs to date and should be pitfalls to avoid as Namibia designs its SEZ approach.

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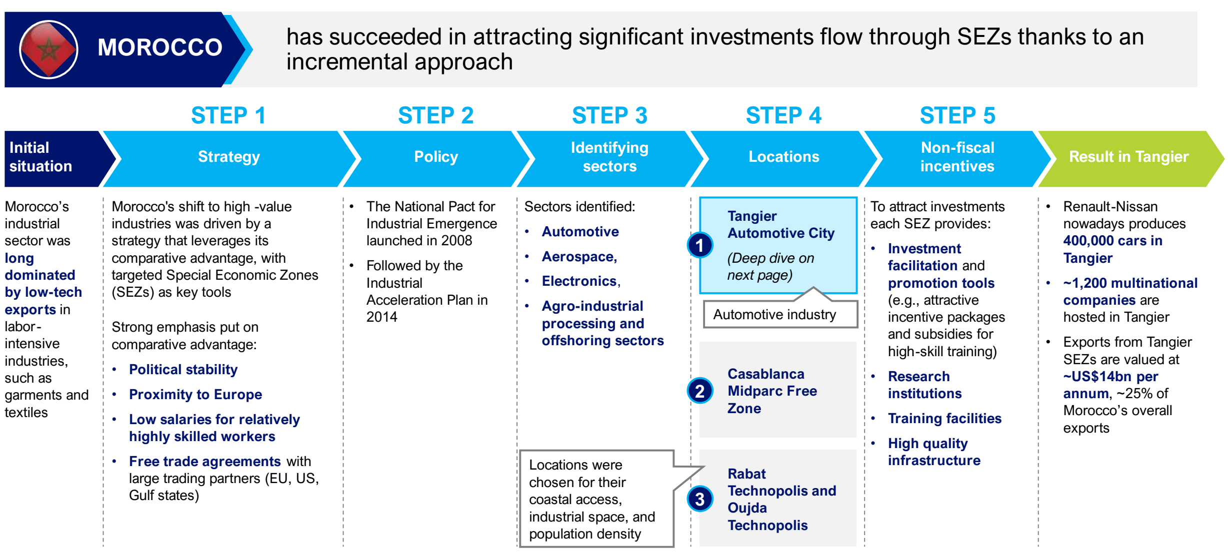
[116] United Nations Conference on Trade and Development [UNCTAD], 2019

[117] Andres Rodriguez-Pose et al. (2022), *The challenge of developing special economic zones in Africa: Evidence and lessons learnt.*

Namibia's approach to SEZs should take these lessons and adapt them to its specific context, particularly in sectors where Namibia has strengths like hydrogen and mining, or around a potential private anchor such as Hyphen or a green iron company like H2GS. Success stories, such as that of Morocco, illustrate the benefits of a well-crafted SEZ strategy.

Morocco has transformed its industrial sector from low-tech, labor-intensive industries to higher value-added industries like automotive and aerospace through targeted SEZs (Figure 45)[118,119]. The shift to high-value industries was primarily driven by a strategy that leveraged Morocco's comparative advantages, with SEZs playing a crucial role. Early on, strong emphasis was placed on Morocco's political stability, proximity to Europe, and competitive labour costs. Following this strategic direction, Morocco implemented two key policies: the National Pact for Industrial Emergence in 2008 and the Industrial Acceleration Plan in 2014, with a particular focus on the automotive industry. To attract foreign investments, Morocco offered multiple non-fiscal incentives, including high-skill training subsidies and high-quality infrastructure. An example of the result of this approach can be found in Morocco’s Tangier Automotive City, where Renault-Nissan now produces 400,000 cars annually in Tangier and approximately 1200 multinational companies operate. Exports from Tangier SEZs are now valued at approximately US$14 billion per annum, representing about 25% of Morocco's total exports.



Sources: Systemiq analysis from Andres Rodriguez-Pose et al. (2022), *The challenge of developing special economic zones in Africa: Evidence and lessons learnt*; The Africa Report (2023). *What can Africa learn from Morocco’s thriving economic zones?*

Figure 45: Success of Morocco’s SEZs are due to a step-wise design.

Namibia can draw valuable insights from Morocco's experience, keeping in mind the differences in developmental stages. A well-targeted SEZ strategy in Namibia should not just replace old models but should leverage the country's unique advantages and secure strong

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[118] Andres Rodriguez-Pose et al. (2022), *The challenge of developing special economic zones in Africa: Evidence and lessons learnt.*

[119] The Africa Report (2023), *What can Africa learn from Morocco’s thriving economic zones?*

partnerships, ensuring that SEZs are well-placed logistically and supported by comprehensive policies that are fit for purpose. Crucially, avoiding an over-reliance on fiscal incentives alone would ensure that Namibia's SEZs attract high quality investors and do not contribute to a regional 'race to the bottom' on the fiscal front. This holistic approach will help avoid the pitfalls observed in other geographies and maximize the benefits of green industrialization for Namibia's economy.

6.3. Critical raw materials: Learnings from other jurisdictions

Chapter 3.2.3 outlined how Namibia could define its approach to lithium and REE by drawing lessons from the policies of countries such as Chile, Argentina, Bolivia and Mexico. A policy revamp can be categorized into five key initiatives, as illustrated in Figure 46:

1. **CRM Policy Framework:** Establish CRM as a strategic asset. Consider the creation of a state-owned enterprise to oversee CRM activities and prohibit the export of raw, unprocessed materials.
2. **Value Maximization**: Enhance local benefits by adopting adaptive royalty rates linked to CRM market prices and providing tax incentives for investments in sustainable technologies and recycling efforts.
3. **ESG**: Strengthen environmental and water use regulations and ensure that mining projects secure local community consent before proceeding. Align with international standards adhered to by the lithium and REE markets today, incorporating them into MME policy where needed (see point #5 below).
4. **Investment in Technology and Innovation**: Allocate a percentage of CRM-derived revenues to fund research and development in CRM processing technologies and green innovations.
5. **International Collaboration and Trade**: Develop strategic partnerships within the CRM sector and align with international standards, such as those required for Battery Pass certification, to expand market access.

Namibia, with its extensive mining expertise, has been proactive in implementing ESG practices in its diamond, uranium, or gold industries. It now needs to effectively adapt to the emerging lithium and REE markets. **This adaptation should primarily focus on maximizing local value and job creation, while ensuring that Namibian ventures are strategically positioned to meet market demands and develop projects that are fit-for-purpose.**

Some policy models adopted in other regions for their own CRM sectors should be carefully analyzed for their applicability to Namibia to understand if they may or may not yield the same efficiency in the local context. One example of Namibia following in the steps of other jurisdictions has been the critical step of banning the export of unprocessed goods, aligning with other African countries that also have lithium reserves, such as Zimbabwe and its Base Minerals Export Control Act[120]. Here, the impact of this ban may be measured by investments in Zimbabwe along the lithium value chain: according to a recent Bloomberg report, Chinese companies have secured investments totaling US$2.79 billion in Zimbabwe, predominantly in the mining and energy sectors[121]. An

[120] Zimbabwe, Base Minerals Export Control Act

[121] Bloomberg (2023), *China to Invest US$2.8 Billion in Zimbabwe in Lithium, Energy*

increasing number of these initiatives are centered around processing plants. For example, in May 2023, Chengxin Lithium Group launched a lithium concentrator with the capacity to produce 300,000 t of spodumene annually, highlighting a significant shift towards local processing and value addition[122]. Notable other policies from the so-called 'lithium triangle' in South America (Chile, Bolivia and Argentina) that are worth exploration in the Namibian context include the establishment of a public company in Bolivia, the implementation of variable sliding-scale royalties in Chile—ranging from 6.8% to 40% based on lithium carbonate prices—and the formation of numerous private-public partnerships across Bolivia, Chile, and Argentina[123]. These partnerships have facilitated the creation of research centers focused on advanced materials and battery technologies, indicating a strategic approach to industrialization and innovation in these countries. Indeed, some of these latter strategies echo the possible incentives that a SEZ may provide (see section 6.2), suggesting the need to coordinate multiple policy strands among potentially multiple policy-making bodies within the government of Namibia.

CRM – Critical raw materials
Sources: Systemiq analysis from United Nations (2023), *Lithium extraction and industrialization Opportunities and challenges for Latin America and the Caribbean*

Figure 46: Namibia could benefit from crafting CRM policies, potentially drawing on successful models from Latin American countries.

6.4. Traceability and environmental certificates

Namibia's diplomatic strategy of being "*friends to all and enemies to none*" uniquely positions it to leverage international relations in advancing green industrialization. This approach has been effective, attracting diverse foreign investors from Chinese firms in the uranium sector to Western companies like Anglo American in diamonds, and German involvement in green hydrogen through the Hyphen project. Looking ahead, Namibia should continue to adapt to its potential markets and

[122] Foreign Policy (2023), *Zimbabwe's 'White Gold'*
[123] United Nations (2023), *Lithium extraction and industrialization Opportunities and challenges for Latin America and the Caribbean*

maintain as many open doors as possible. As highlighted in this report, both Chinese and U.S. players are capable of constructing significant cross-cutting infrastructure for their projects, which could substantially aid Namibia's growth if it successfully navigates between these global giants. The same holds true for partnerships with the EU. However, partnering with these regions also presents certain challenges, as detailed in Figure 47.

Regulations to adapt to · Risk premium diversification

		Trade Status and agreements w. Namibia	Relationship to Namibia	Opportunities / Challenges	Adaptive measures in Namibia
Current trading partners	EU	MoU with the EU on CRM and GH	• Offtaker for both CRM and GH2 derivatives	• Carbon Border Adjustment Mechanisms • Battery Pass	• Need to **adapt to CBAM and certification requirements** • Need to **adapt to Battery Pass requirements**
	Japan	MoU with JOGMEC	• Offtaker for both CRM and GH2 derivatives	• Potential new partners for Namibia	• The Japanese government desires to pursue decarbonized hydrogen wherever is cheapest. **No specific measure required in Namibia.**
Potential future trading partners	Middle East[1]	MoU work in progress with QatarEnergy	• Offtaker for CRM • Competitor on GH2	• Potential new partners for Namibia	• Partner in both CRM and GH projects • Create integrated value chains
	USA	No single free-trade-agreement, co-launched Mineral Security Partnership Morocco is the only African country w/ a US-FTA today	• Offtaker for CRM and GH2 • Competitor on both	• Inflation reduction act • Potential new partners for Namibia	• **Green export** opportunity if **free-trade-agreement** signed with the US • Need to **adapt to IRA requirements**
	Canada	Work in progress	• Offtaker for both CRM and GH2 derivatives	• Potential new partners for Namibia	• No specific measure required in Namibia

Note: 1. e.g., UAE, Qatar; CRM = Critical Raw Materials; GH: Green Hydrogen; FTA: Free -Trade-Agreement; MoU: Memorandum of Understanding
Source: Systemiq analysis

Figure 47: Namibia needs to proactively craft a comprehensive strategy for its strategic export markets.

To optimize Namibia's strategy in forming partnerships that promote green industrialization, it is crucial to recognize the dual nature of each partnership, where each ally may also be a competitor. Intelligent strategies must be devised to ensure these partnerships lead to substantial value creation and job opportunities within Namibia, while allowing alignment with partner markets especially around the growing standardization worldwide of traceability and environmental certification to ensure smooth and fair trading of green products.

Firstly, adapting to the regulatory environments of partner nations, particularly around product life cycle traceability and environmental certification, is essential. For instance, engagement with the European Union requires navigating specific regulations such as the CBAM (see inset box below) or the trade of green commodities like iron or ammonia to supply these European industries looking for low-cost green inputs. Additionally, the EU Battery Passport mandates rigorous standards for critical raw materials essential for battery production (see section 3.2.4). These regulations necessitate strategic alignment and compliance to facilitate trade and cooperation.

Secondly, partnering with the United States presents its own set of challenges and opportunities. Currently, Namibia does not have a free-trade agreement with the U.S., which may limit certain economic interactions. Moreover, the U.S. Inflation Reduction Act (IRA) imposes specific requirements, which can be particularly selective for industries like renewable energy and technology[124]. Namibia must evaluate these requirements carefully to determine how best to adapt and capitalize on potential opportunities.

Finally, while some regions may pose fewer barriers, MoUs are still essential for formalizing partnerships. These agreements should be strategically focused on attracting foreign investments effectively. Namibia should pursue these MoUs with a clear agenda, ensuring that they align with national interests and contribute to sustainable economic growth.

In conclusion, Namibia's approach to international partnerships in green industrialization should be nuanced and strategic, emphasizing compliance, strategic alignment, and targeted negotiations to maximize the benefits of each international relationship.

<u>What the EU's Carbon Border Adjustment Mechanism could mean for Namibia's own certification policies</u>:

Despite facing criticism as a market distortion and a financial drain on African countries, the EU's CBAM offers a strategic opportunity for Namibia and other nations looking to export to Europe. By implementing a domestic carbon tax that aligns with the EU's Emissions Trading Scheme, Namibia could create added value for its carbon-intensive exports, destined for the EU, as depicted in Figure 48. This alignment would enable Namibia to capitalize on the EU's mechanism, which adjusts import prices based on the carbon pricing of the exporting country. Consequently, by matching or exceeding the EU's carbon price, Namibia's exports could avoid additional CBAM tariffs, retain more revenue domestically, and use these funds to support its transition to greener industrial practices.

However, the introduction of a carbon tax is a complex decision with far-reaching implications. It could increase local production costs significantly, impacting the competitiveness of Namibian industries both domestically and globally. This could deter investment and slow economic growth, especially in sectors where profit margins are already thin. Therefore, a detailed, sector-specific analysis is essential to assess the potential economic impacts. This analysis should consider the direct costs to businesses, the potential for passing these costs onto consumers, and the broader effects on Namibia's economic landscape. The findings will guide whether the benefits of aligning with CBAM outweigh the risks and costs to Namibia's industrial sector.

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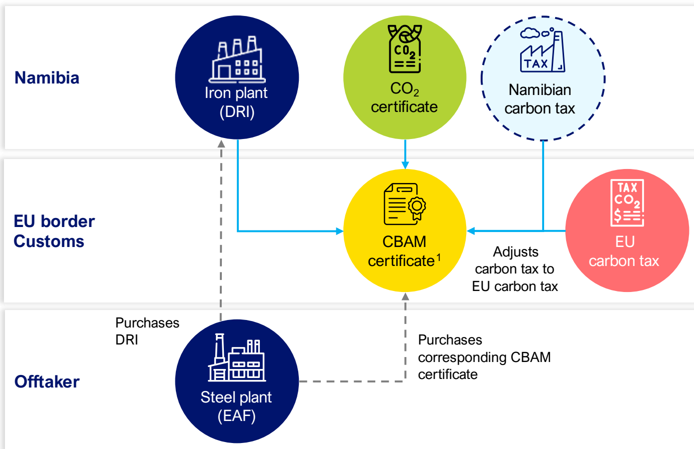
[124] Example: Inflation Reduction Act 2022: Sec. 13401 Clean Vehicle Credit: The IRA established a Clean Vehicle Credit of up to USD 7500 per vehicle to incentivise and accelerate the adoption of electric vehicles.
Eligible battery-powered electric vehicles must meet the Critical Mineral and Battery Component Requirement, which establishes the following conditions:

- A baseline for the percentage of the value of the applicable critical minerals contained within the electric vehicle battery that were (i) extracted or processed in the United States or in a country with which the United States has a free trade agreement; or (ii) recycled in North America. This baseline begins at 40% for vehicles placed in service before 1 January 2024 and escalates to 80% for vehicles placed in service after 31 December 2026.
- A baseline for the percentage of the value of the components contained within the electric vehicle battery that were manufactured or assembled in North America. This baseline begins at 50% for vehicles places in service before 1 January 2024 and escalates to 100% for vehicles placed in service after 31 December 2028.

Illustrative example of CBAM on iron

How does CBAM concretely work?



1. The bureaucratic burden of the CBAM would mostly be borne by EU importers, the EAF plant in our example .

Source: Systemiq analysis from PtX Hub (2023), *CBAM implications for PtX imports to the EU.*

Description of the CBAM mechanism

The proposed mechanism is relatively straightforward:

- **Assessment**: Determine the carbon content of imported goods
- **Comparison**: Compare the carbon price paid by EU producers with that paid by the producer of the imported good
- **Adjustment**: If the imported product has not incurred a carbon cost equivalent to the EU's Emissions Trading System price, a CBAM will be levied to make up the difference

If Namibia plans to export carbon-intensive products to the EU, implementing a Namibian carbon tax could keep tax revenues within Namibia, preventing European benefit at its expense.

Figure 48: The EU's carbon border adjustment mechanism could motivate Namibia to establish its own carbon tax

7. Cross-Cutting Enabler: Unlocking Capital

Background on Namibian dollar:
The Namibian dollar is pegged at par to the South African rand and developments in Namibia's real exchange rate largely reflect changes in the nominal exchange rate of the rand and inflation differential with South Africa, Namibia's main trading partner[125].

Namibia's robust natural resources could herald a new era of prosperity, with significant potential in oil exploration and green hydrogen production.

Historically, sectors like mining, fishing, and tourism have drawn considerable foreign direct investment (FDI). Key investors include China in uranium mining, South Africa in diamonds and banking, and Canada in mining for gold, zinc, and lithium. Other global investors from Spain, France, Russia, the UK, the Netherlands, the US and Qatar are active in various sectors, notably in oil exploration off the Namibian coast, where promising results have been reported from the offshore Orange Basin[126].

Namibia maintains a largely positive investment climate, despite facing challenges such as the COVID-19 pandemic and inflation, thanks to several key strengths. These include the country's political stability, an independent judicial system, and robust protections for property and contractual rights. The quality of Namibia's transport infrastructure is also a major asset, with ongoing upgrades to roads, ports, and rail networks enhancing connectivity. Furthermore, Namibia benefits from access to the Southern African Customs Union (SACU) and the SADC Free Trade Area, as well as markets in the EU and Asia. Additionally, Namibia's rich natural resources, including offshore oil reserves and some of the world's highest solar radiation levels, alongside vast land and wind resources, position it as a potential global leader in renewable energies and green hydrogen production.

Despite a history of rapid economic expansion and important levels of FDI, Namibia currently faces potential barriers to attracting new FDI and may be experiencing a "middle-income trap"[127]. Several factors contribute to this stagnation, including Namibia's small domestic market, low and declining productivity, high transport and energy costs, a limited pool of skilled labor, and increasing threats from climate change, such as water scarcity. Additionally, while corruption is not widespread, a 2019 scandal in the fishing sector significantly damaged public trust and financial stability[126].

In this context, oil exploration and developments related to prospective green hydrogen production have gained momentum, attracting new FDIs and presenting an upside potential, although final investment decisions are yet to be announced. Despite the significant activities in

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[125] IMF (2023), *Namibia 2023 Article IV consultation—press release; and staff report*
[126] U.S. Department of State (2023), *2023 Investment Climate Statements: Namibia*
[127] Government of the Republic of Namibia (2024), *A Blueprint for Namibia's Green Industrialization*

the oil and gas industry, the focus of this report will remain exclusively on the capital requirements for green industrialization, deliberately excluding the oil and gas sectors. According to the Government of Namibia's *Blueprint for Green Industrialization*, which focuses on eight shortlisted sectors as priorities for green industrialization (as referenced in Chapter 1.2), **Namibia could require a cumulative investment of up to US$55 billion by 2040 to grow these eight industries**. This translates to approximately US$3.7 billion annually, about 4x the FDI recorded in 2022 or 7x the average annual FDI between 2010 and 2022, as illustrated in Figure 49 below. These investments, crucial for Namibia's sustainable development and economic growth, would include both infrastructure investments (e.g., rail, ports, electricity, desalination plants) and industrial investments related to these eight industries (e.g., solar panel manufacturing plant, wind turbine manufacturing plant, DRI plant, etc.).

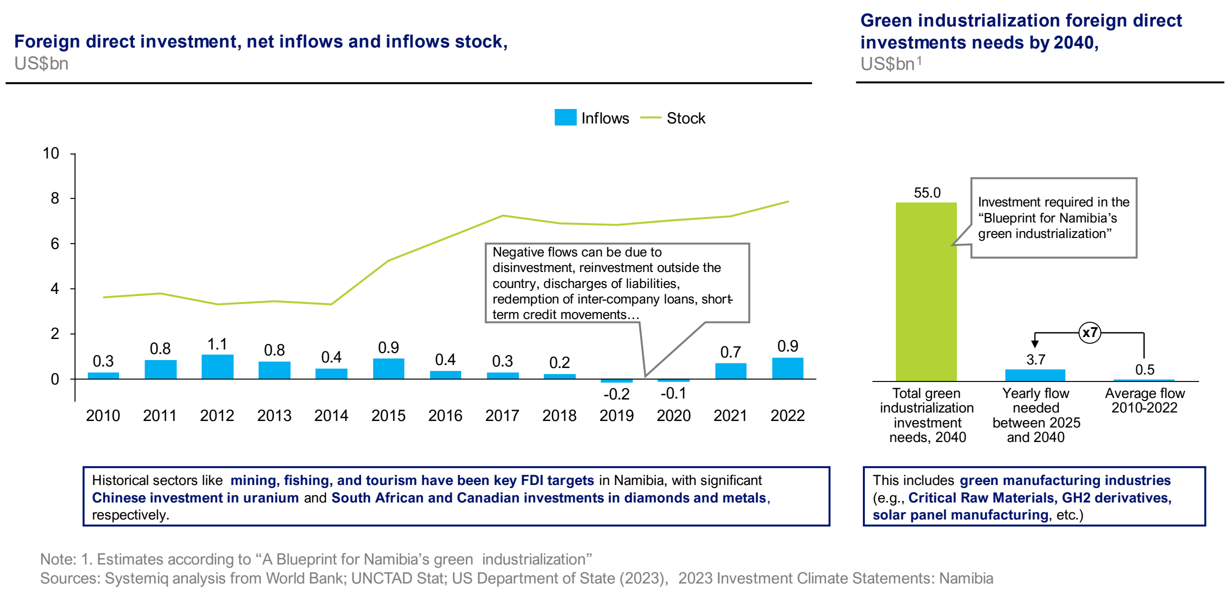

Figure 49: Green industrialization will require ~7X more foreign direct investments annually than Namibia's average in the past decade.

Reducing uncertainty in project parameters is crucial for attracting substantial FDI in Namibia. When pursuing the tender route in Namibia, selecting strong, reliable partners is crucial. Identifying long-term collaborators and developers with a proven track record is essential, as is fostering cooperation with local governments and municipalities for project success. For instance, most existing green hydrogen derivatives projects taking place around the globe are being developed by companies with robust balance sheets, equipped to initiate and scale megaprojects from the ground up. **On top of this, fostering public-private partnership is key to narrowing the uncertainty parameters and cultivating success of the projects**. While achieving a perfect ideal scenario—with a 100% offtake agreement, clear regulatory frameworks, definite ownership structures, and pre-established supporting infrastructure—is difficult, strategizing with the government and sponsors to align as many elements as possible beforehand can significantly reduce uncertainty.

The inclusion of potential buyers as shareholders could enhance project viability. As highlighted in Chapter 2.1.1, a successful example of this strategy is H2 Green Steel, which incorporates its offtakers as equity partners. These partners are motivated by the need to green their supply chains and participate responsibly in the market. This arrangement not only secures a buyer but also ensures investment from stakeholders who are directly interested in the success of the project. Additionally, securing government support, as seen with Sasol in South Africa's production of sustainable aviation fuel in response to a German government tender, can validate the project and attract further investment[128]. More broadly, this approach can be described as vertical integration of green value chains within the ecosystem, where different stakeholders in the system can be included as part of the funding mechanism.

Exploring guarantees from multilateral or development finance institutions is a viable last resort for projects unable to secure sufficient offtake agreements. While traditionally cautious about ascending too far up the risk curve, the push towards energy transition is compelling these institutions to reconsider their investment strategies. This shift could potentially open up new funding avenues, especially for ventures that are pioneering in nature but carry higher risks. These guarantees can serve as critical financial backstops that enable the realization of innovative projects in challenging markets. More broadly, it has been acknowledged that a smarter use of public capital in guarantee products that address credit and currency risks, are streamlined to reduce transaction costs and which are structurally linked to project development can help meet the 5x scale up in climate finance which is needed in emerging markets for sustainable and inclusive growth[129].

Namibia is poised to benefit from the growing global interest in green infrastructure investments, driven by an increasing supply of projects and a shifting investment preference among developed markets. As the demand for infrastructure projects such as renewable energy, storage solutions, and ancillary services such as ports and transmission lines rises, these low-risk, stable-return investments become particularly attractive and funds exist today that enable infrastructure transactions to be structured in such a way to bring the overall risk of such projects down. For instance, renewable energy projects offer the security of long-term purchase contracts and minimal operational risks once established, making them ideal for investors in developed markets with lower risk appetite (e.g., pension funds as the demographic ages) to transition from growth assets to income assets. However, the challenge remains in alleviating developed market investors' concerns about emerging market risks. **To attract these investments, Namibia can enhance its market appeal by demonstrating low country risk and promoting regulatory reforms that open the market to private players and facilitate green industrialization**. By focusing on these achievable reforms and showcasing real progress, Namibia can effectively reduce uncertainty and draw in critical foreign investment needed to advance its green energy sector.

[128] Reuters (2021), *South Africa's Sasol forms consortium to produce sustainable aviation fuel*.
[129] Blended Finance Taskforce (2023), *Better Guarantees, Better Finance*

8. Navigating Dynamic Landscapes: Critical Recommendations for Policymaking in Namibia

The policy-making landscape in Namibia is a dynamic tapestry, woven with threads of various initiatives, strategies, and objectives. Among these, the emergence of green hydrogen as a focal point has added a new dimension to the ongoing discourse. However, it is crucial to acknowledge that the realm of policymaking for green industrialization necessarily extends beyond green hydrogen, encompassing a myriad of sectors and concerns, as described in the preceding chapters.

Amidst this complexity, synthesizing the plethora of information and distilling it into actionable recommendations becomes imperative. This section endeavors to encapsulate the essence of the insights garnered from the comprehensive analysis conducted in preceding sections. It serves as a compass, guiding policymakers through the labyrinth of possibilities and illuminating pathways toward the foundation of Namibia's green industrialization.

8.1. Policymaking approach

A critical shift from business-as-usual to a mindset of green industrialization is the first priority for national alignment, where the default assumption should evolve to consistently interrogate how ongoing and future policy designs intersect and align with key green industrialization priorities (see section 8.2 below). These priorities serve as guiding beacons, illuminating the path towards a sustainable and resilient future.

Achieving this alignment may require embracing a more integrated and agile approach to policymaking, with some of the following characteristics:

- **Embracing the Interconnectedness:** One of the overarching themes emerging from the green industrialization transition – not only Namibia but worldwide – is the interconnectedness of various sectors and initiatives. Policies formulated in isolation risk falling short of their intended impact. Therefore, a holistic approach that acknowledges the symbiotic relationship between different domains is paramount. For instance, while green hydrogen holds promise as a renewable energy source, its integration into existing energy frameworks must be carefully calibrated to maximize synergies and mitigate potential conflicts.

- **Strengthening Institutional Capacity:** Effective policy implementation hinges upon robust institutional capacity. Enhancing the capabilities of relevant government bodies and agencies is essential to ensure coherence, efficiency, and accountability in the execution of policies. While MIT and MME are key for obvious reasons, green industrialization requires an all-of-government approach, as already indicated by the diverse representation on the Green Hydrogen Council; green industrialization will be necessarily as broad, if not even broader. This entails investing in human resources, bolstering technical expertise, and fostering collaboration both within and across governmental departments.

- **Fostering Innovation and Collaboration:** Innovation thrives in environments that encourage experimentation and collaboration. Policy frameworks should incentivize research and development activities, facilitate knowledge exchange platforms, and promote public-private partnerships. By fostering a culture of innovation, Namibia can leverage its intellectual capital to drive sustainable growth and competitiveness.

- **Empowering Local Communities:** Sustainable development cannot be realized without the active participation and empowerment of local communities. Policies should be designed to overemphasize the need to communicate the benefits of green industrialization to the wider population and 'raise the tide' of ambition across a national level. This will ensure inclusive decision-making processes and the needs of communities are discussed at an informed level. By harnessing the collective wisdom and resourcefulness of its citizens, Namibia can build resilient communities that are active agents of change.
- **Adaptive Governance and Continuous Learning:** The pace of change in today's world demands adaptive governance structures that are responsive to evolving realities. Policymaking should embrace principles of flexibility, adaptability, and continuous learning. Regular monitoring and evaluation mechanisms should be put in place to assess the efficacy of policies, identify emerging challenges, and recalibrate strategies accordingly. This also reflects the need for strengthening institutional capacity (as above).

8.2. Policy imperatives

In alignment with the transition to green industrialization, several policy imperatives emerge:

- **Evolve Energy Planning:** A national energy masterplan that takes into account targets as outlined in Vision 2030 and ongoing green hydrogen and green industrialization ambitions – in terms of both inputs and outputs thereof – is of paramount urgency. Establishment in national plans of renewable energy in dispatchable and stored forms, and transmission infrastructure (lines and substations) as the foundational elements of any industrial project is key. This will only succeed if the trifecta in charge of Namibia's power landscape today – MME, NamPower and ECB – work together to solve ongoing coordination bottlenecks.
  [Key chapters for reference: 4]

- **Leverage Public-Private Partnerships:** Public-private partnerships and increasing market liberalization in sectors such as power generation, power transmission, and rail infrastructure are viable options on the table worth exploring to ensuring that supply can keep up with the demand that green industrialization will pose on the nation for such infrastructure. These collaborations foster innovation, efficiency, and inclusivity in industrial development. This lens should be front and centre of ongoing discussions around reforming the power and rail sectors, and any efforts to do so should be supported by the Government where possible (e.g., TransNamib's openness to engaging with a private player on the southern rail line connecting to South Africa).
  [Key chapters for reference: 2.1, 2.3, 3.1, 3.2, 4.3, 5.2]

- **Enhance Vertical Stakeholder Engagement:** Deepening partnerships with offtake markets and integrating offtakers as potential project shareholders from the outset enhances stakeholder engagement and project finance derisking.

[Key chapters for reference: 2.1.1, 3.1.1, 7]

- **Strategic Planning for Value Chains:** Precisely dissecting the iron, lithium, and rare earth value chains and engaging in long-term planning in a phased approach according to these dissections are essential. In particular, supporting mines in the iron and CRM space to reach a stage of efficient production should be an immediate priority. Policies should acknowledge the indispensable roles of baseload and dispatchable power for green iron, as well as the significance of sulphuric acid in enabling critical mineral processing, ensuring alignment with foundational needs of these industrial projects.
  [Key chapters for reference: 2.1.3, 2.2, 3.1.2, 3.2]

- **Learn from Global Best Practices:** Engaging in information-gathering roadshows to learn from global best practices is invaluable. Policies should facilitate knowledge exchange with regions excelling in areas such as power transmission market reform (e.g., India), CRM value maximization (e.g., Latin America), mineral processing (e.g., Australia, China) and hydrogen production (e.g., Morocco). Alignment with global expectations on ESG, in particular for CRM, is fundamental.
  [Key chapters for reference: 1.3, 3.2.3, 3.2.4, 4.3, 6.2, 6.3, 6.4]

- **Empower Regional Authorities:** Recognizing and addressing the critical roles of regional councils in land acquisition, planning, and permitting for projects they may host is imperative. Policies should support and foster industrialization by empowering local authorities to facilitate streamlined processes, thus aligning with efforts to empower local communities.
  [Key chapters for reference: 7]

- **Diversify Partnerships:** Diversifying partners while vigilantly safeguarding national interests and competitiveness is essential. Policies should emphasize pragmatism and strategic alignment, particularly in engagements with partners already in-country such as China in the critical raw materials space, reflecting the need for continuous learning and collaboration. Government should also help bolster direct engagements with interested stakeholders in the SADC region (e.g., iron ore mines in South Africa).
  [Key chapters for reference: 1.3, 3.2.3, 3.2.4, 4.3, 6.2, 6.3, 6.4]

- **Navigate Financial Challenges:** Exploring opportunities to leverage the balance sheets of emerging industries to finance common user infrastructure needed in a green industry (port, rail, power) or large-scale hydrogen/power storage projects. Policies should facilitate strategic partnerships and innovative financing mechanisms, addressing financial challenges in the transition to green industrialization.
  [Key chapters for reference: 7]

- **Design SEZs with Purpose:** SEZs should not solely rely on fiscal incentives but should instead focus on complementing them with non-fiscal incentives and establishing private

sector anchors, all the while designing this with Namibia's competitive advantages in mind. This echoes the call for holistic approaches to policy design.
[Key chapters for reference: 6.2]

- **Embrace Foreign Policies:** Viewing initiatives like the EU's Carbon Border Adjustment Mechanism (CBAM) as strategic opportunities (e.g., for developing a parallel revenue stream in Namibia) rather than threats, and keeping abreast of industrially-set standards such as the evolving definition of green iron, fosters proactive engagement to maintain in lockstep with dynamic changes in the global landscape, mirroring the call for adaptive governance structures.
[Key chapters for reference: 2.2.4, 6.4]

Conclusion:
In conclusion, the recommendations outlined herein represent a synthesis of the multifaceted insights gleaned from the diverse array of topics explored in this report. While they are tailored to the specific context of Namibia, their underlying principles of interconnectedness, capacity building, innovation, adaptive governance and global alignment with key markets and industries hold universal relevance. It is our hope that these recommendations serve as a catalyst for informed dialogue, strategic action, and enduring progress in the realm of policymaking in Namibia for sustainable industrialization.

9. Appendix

9.1. Abbreviations

BF-BOF	Blast Furnace-Basic oxygen furnace
CBAM	Carbon Border Adjustment Mechanism (EU)
CCS	Carbon capture and storage
CRM	Critical raw material
CS	Crude steel
DRI	Direct reduced iron
EAF	Electric arc furnace
ECB	Electricity Control Board (Namibia)
ESG	Environmental, social, governance
ETES	Electrothermal energy storage
ETS	Emissions Trading System (ETS)
EV	Electric vehicle
FDI	Foreign direct investment
FID	Final investment decision
GHG	Greenhouse gas
GW	Gigawatt
HBI	Hot briquetted iron
HFO	Heavy fuel oil
IAO	Implementation Authority Office (Namibia)
ICMM	International Council on Mining and Metals
IPP	Independent power producer
ITP	Independent transmission project
kt	Thousand tonnes
ktpa	Thousand tonnes per annum
LCE	Lithium carbonate equivalent
MIT	Ministry of Industrialization and Trade (Namibia)
MME	Ministry of Mines and Energy (Namibia)
MoU	Memorandum of Understanding
MSB	Modified single buyer model
Mt	Million tonnes
Mtpa	Million tonnes per annum
MW	Megawatt
NDC	Nationally Determined Contribution
OEM	Original equipment manufacturer

PPA	Power purchase agreement
PPP	Public-private partnership
PtX	Power-to-X
PV	Photovoltaics
RED	Regional electricity distributor
REE	Rare earth elements
REO	Rare earth oxide
SADC	Southern African Development Community
SEZ	Special economic zone
SME	Small and medium sized enterprise
t	tonne
TWh	Terawatt-hours
VRE	Variable renewable energy

9.2. Key assumptions

The below assumptions provide a structured basis for the calculations and estimations discussed in the corresponding figures of the report.

Figure 12: The quantum of green power and hydrogen required to drive a single green iron plant are immense.

- **Plant capacity and input**: The minimum viable size for a DRI plant is an annual input of 2.5 Mt of iron ore with a 64% iron content, resulting in an output of 1.6 Mt of reduced iron.
- **Hydrogen and electricity input**: For a plant outputting 1 Mtpa of DRI, the hydrogen requirement is 55 ktpa. Assuming 1 kg of hydrogen consumes 52.5 kWh of electricity at an average load factor of 40%, the corresponding electrolyzer capacity is approximately 1.3 GW, intentionally oversized to accommodate the intermittency of Namibian renewables.
- **Electricity for DRI production**: DRI production consumes 380 kWh of power per tonne, necessitating ~0.2 GW of green power capacity for a 2.5 Mtpa DRI plant.
- **Cost assumptions**: The cost of renewable power sources is estimated at approximately US$1 million per MW, equating to US$1.5 billion for 1.5 GW total renewable capacity. Capital expenditures are estimated at US$1.5 billion for a 1 GW hydrogen electrolyzer and US$1 billion for a 3 Mtpa DRI plant. These have been scaled for a DRI plant with 2.5 Mtpa iron ore input.

Figure 14: Levelized cost of hydrogen from key producing countries.

- **Cost basis**: Hydrogen cost estimates shown here are on the optimistic end and grounded in the renewable energy potential of each country. Each dollar increase in hydrogen price results in a US$55 increase in the cost per tonne of DRI and will therefore have an important impact on overall DRI cost. The key takeaway from this chart is the relative cost ranges of different regions compared to one another, though absolute costs are likely to be higher (see point above about being optimistic).

Figure 15: Comparison of shipping costs from iron ore export countries to Port of Hamburg as destination.

- **Methodology**: Shipping costs are based on an assumed cost of approximately US$0.002 per tonne per kilometer. For example, for a distance of 12,700 km between Lüderitz (Namibia) and Hamburg (Germany), the total cost amounts to US$25.4 per tonne.

Cross-Cutting Enabler: Policies

- **Rail and shipping distances:** The analysis includes rail transport costs for Dordabis-Lüderitz and Sishen-Lüderitz routes (700 km and 1000 km, respectively), along with shipping from Lüderitz to Hamburg, covering a distance of 12,700 km.
- **Investment and equipment costs:** Investment for rail upgrades is based on a capital expenditure of US$1.3 million per kilometer. Costs include diesel locomotives and US$65,000 per unit of rolling stock.
- **Transport capacity:** The total volume of iron ore transported is estimated at 2.5 Mtpa for the Namibian route and 5 Mtpa for the South African route.
- **Cost per transport and hydrogen:** The assumed levelized cost of hydrogen (LCOH) is US$2.4 per kg of H2. Transportation costs are estimated at US$0.02 per kilometer for rail and US$0.002 per kilometer for shipping.
- **Exclusion of carbon costs:** The calculation does not include carbon costs in the estimation of other expenses.

Figure 19: Investing in green HBI is a strategic move with a long-term outlook, with EU CBAM levelling the playing field by 2030-2035.

- **Price estimates:** The 2030 estimated prices are US$435 per tonne for pig iron and US$355 per tonne for DRI using natural gas. For green HBI, the input cost is set at US$198 per tonne of iron ore, leading to a cost of US$309 per tonne of HBI (assuming an iron content of 64%).
- **Additional costs:** The calculation incorporates hydrogen costs, logistic costs, miscellaneous costs, and electricity costs.
- **Carbon tax:** A EU carbon tax of US$120 per tonne of CO_2 in 2030 is estimated to render green HBI from Namibia competitive.

Figure 34: Much greater generation capacity is needed to attract mega-scale projects for iron, lithium and rare earths

- **Energy consumption**: It is assumed that 3 MW is needed to produce 60,000 tonnes of concentrate, 20 MW of power and 15 MW of green hydrogen are required to refine 5,000 tonnes of LCE[130]. This has been scaled for a production target of 30,000 tonnes of LCE per year. For REE, calculations are based on inferred resources and only the concentration step has been considered. It is assumed that on average, approximately 15 MW are required to produce 5,000 tonnes of REO, which leads to a need for 90 MW to concentrate Namibia's potential annual output of 33,000 tonnes of REO.

[130]Table 5 Material and energy flow summary per tonne of $LiOH \bullet H_2O$ and Li_2CO_3 produced in China from Australian spodumene concentrate from J.C. Kelly et al. (2021), *Energy, greenhouse gas, and water life cycle analysis of lithium carbonate and lithium hydroxide monohydrate from brine and ore resources and their use in lithium ion battery cathodes and lithium ion batteries*