HYDROGEN ENERGY

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Southern Corridor Development Initiative Namibia

HYPHEN: Project Summary

June 2023

Version 1.0

Deadvlei – Namib-Naukluft National Park Namibia
(www.pexels.com)

Drivers | Several push factors driving alternatives to fossil fuels

EU example on next slide

World is moving to Net Zero

The global direction of the march is undoubtedly towards Net Zero; >90% of the world committed to achieving Net Zero objective. COP 26 highlighted this momentum while emphasising need for national and private sector decarbonisation plans

Energy prices on the rise

Recent developments in the Russia/Ukraine conflict have put energy security and prices in the spotlight. This is especially true for Europe, where the conflict has highlighted the dependence on Russian fossil fuels for energy

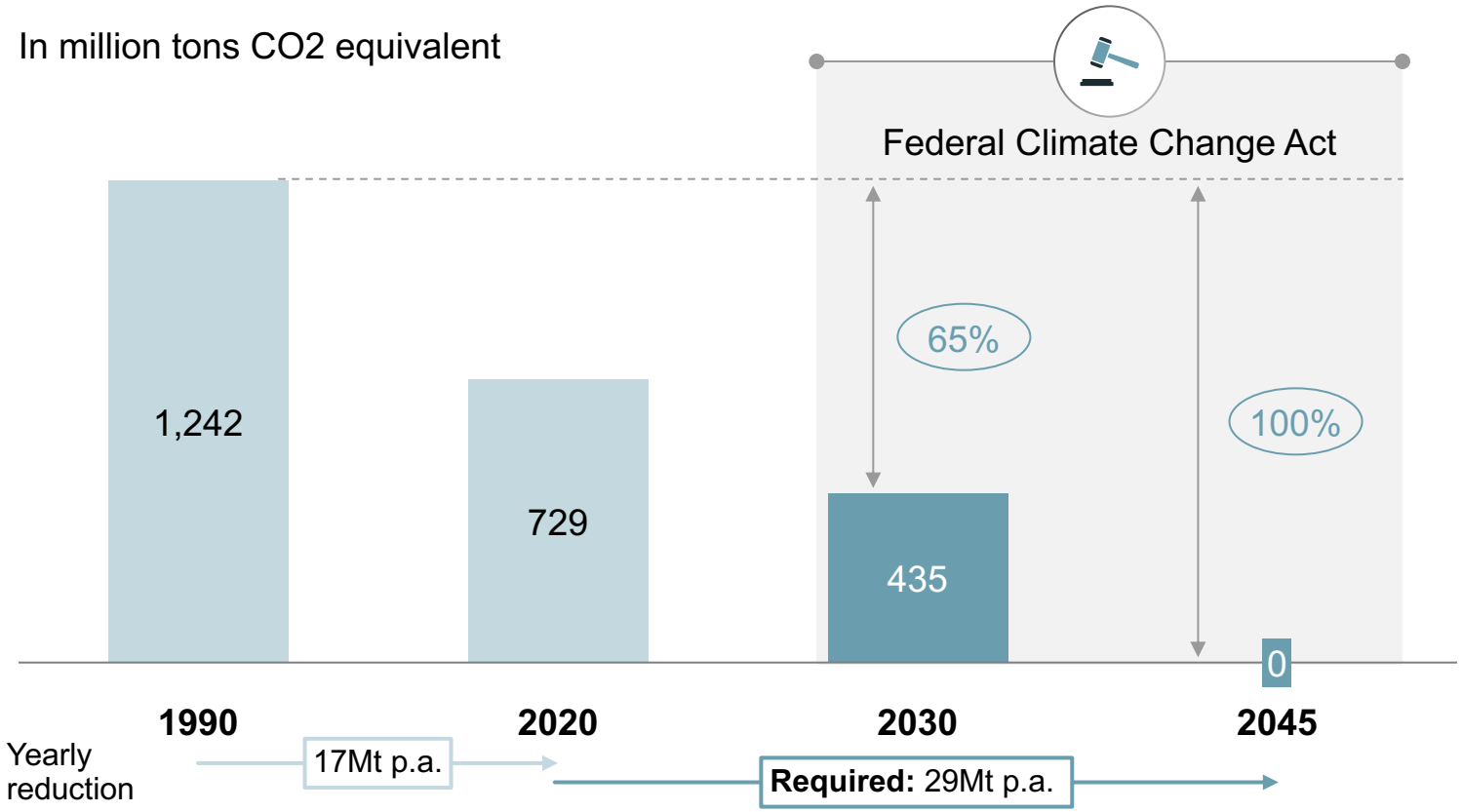
Security of supply in the spotlight

Current geopolitical climate has put security of supply at the forefront of energy policy. The Rus/Ukr conflict has constrained gas supply to Europe, e.g., the Nord Stream 1 pipeline supplying at 20% of its capacity, resulting in significant gas shortages

- As a result, there is a **need to source alternatives** such as H2 and its derivatives
- **Security and sustainability** of supply are key factors driving energy transition policies
- An element of **green ammonia production** is required to fulfil this need

EU Example | Germany legally committed to net-zero by 2045

Germany's greenhouse gas emissions and future reduction targets



Germany legally committed (Climate Change Act 2021) to achieve 65% reduction in 2030[1] and net-zero by 2045

Achieving net-zero by 2045 requires nearly double the yearly decarbonisation rate to 29Mt CO2 equivalent[2]

1. As compared to 1990 emissions 2. Compared to average greenhouse gas emission reduction from 1990-2020 ; Note: Without emissions from land use, land-use change and forestry (LULUCF)
Source: German climate change act 2021; German federal environmental agency, March 2022; BCG analysis

Actuals Targets X% Greenhouse gas reduction target[1]

H2 + derivatives allows for the shipping of sunlight across the world

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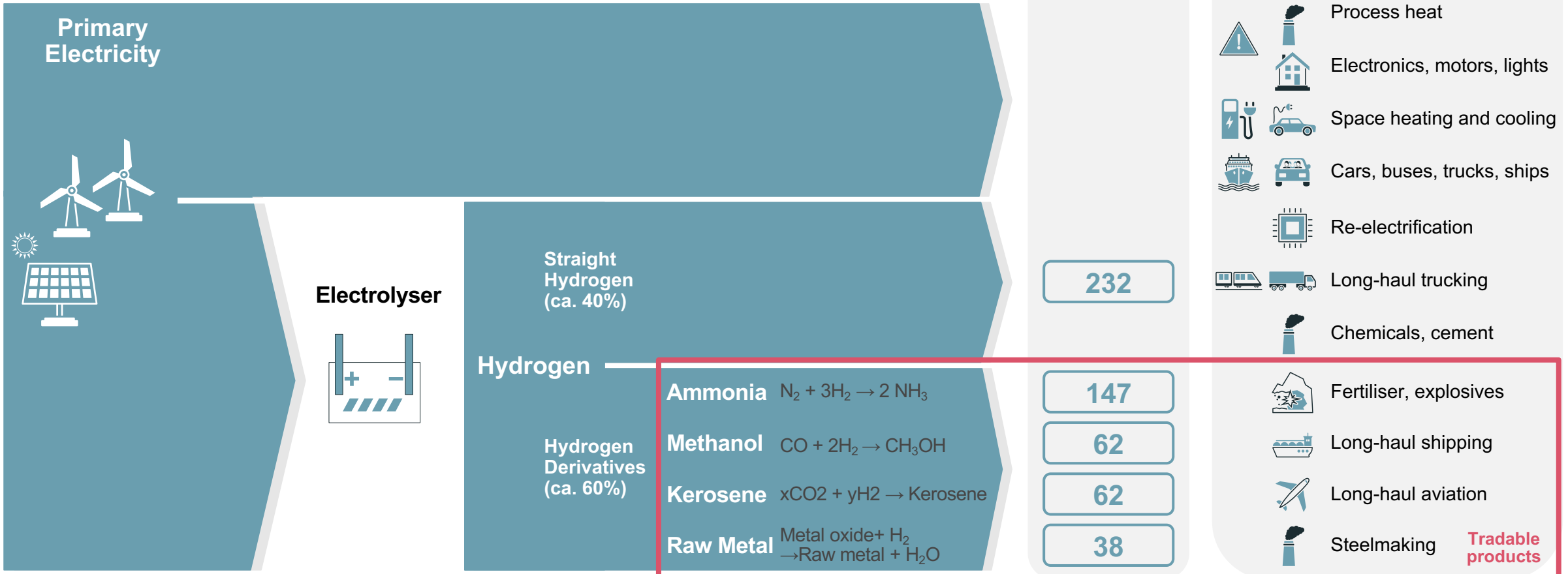
1.5ºC Path

Potential of renewable energy sources are optimised when 1) primary electricity is produced and/or 2) excess is stored; H2 and derivatives provide the ideal storage medium



Future hydrogen demand driven by new H2 use cases

1.5ºC Path

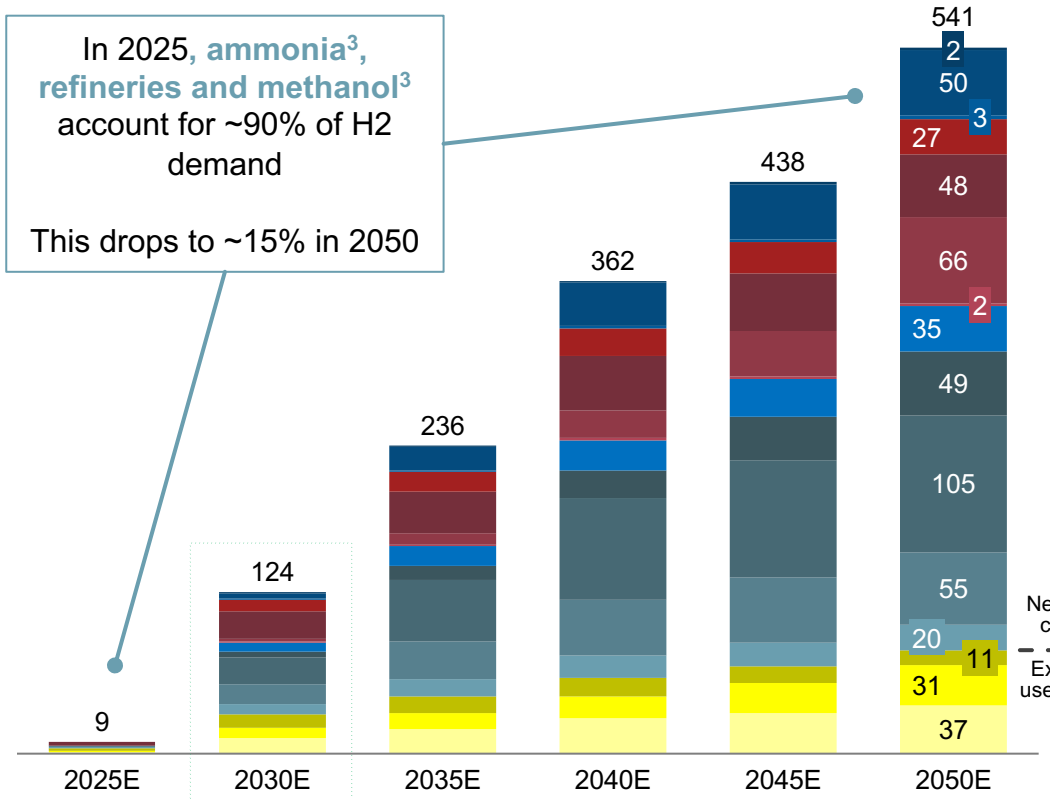
Updated May 2022

Low-carbon H_2 demand by application

2025-2050 total global demand (Mtpa[1])

In 2025, **ammonia[3], refineries and methanol[3]** account for ~90% of H2 demand

This drops to ~15% in 2050



	CAGR 2025-2050	Weighted penetration[2] (2050)	Fuel (Direct use and H_2 derivatives)	H_2	NH_3	MeOH	Other
New use cases	12%	9%	Rail	✓			
	20%	35%	Ocean Shipping		✓	✓	
	15%	10%	Coastal Shipping	✓			
	21%	7%	Light road	✓			
	12%	23%	Heavy road	✓			
	16%	20%	Aviation				✓ E-kerosene
	10%	28%	Off-highway	✓			
	19%	7%	Petrochemicals			✓	✓ Synthetic hydrocarbons
	0%	21%	Reduced metal ores				✓ Raw metal
	24%	3%	Power generation	✓	✓		
	17%	6%	Industry - Heat	✓			
	13%	3%	Buildings - Heat	✓			
Existing use cases	8%	48%	Refineries	✓			
	18%	41%	Methanol			✓	
	14%	50%	Ammonia		✓		

1. Hydrogen-derivative fuels are normalised to hydrogen equivalent. 2. Share of green hydrogen derived energy/feedstock as a % of total sector energy/feedstock demand. 3. Refers to traditional ammonia and methanol use cases

Source: IEA World Energy Balances; IEA WEO 2021; GlobalData; Nexant; BCG Global H2 Demand Model - June2022

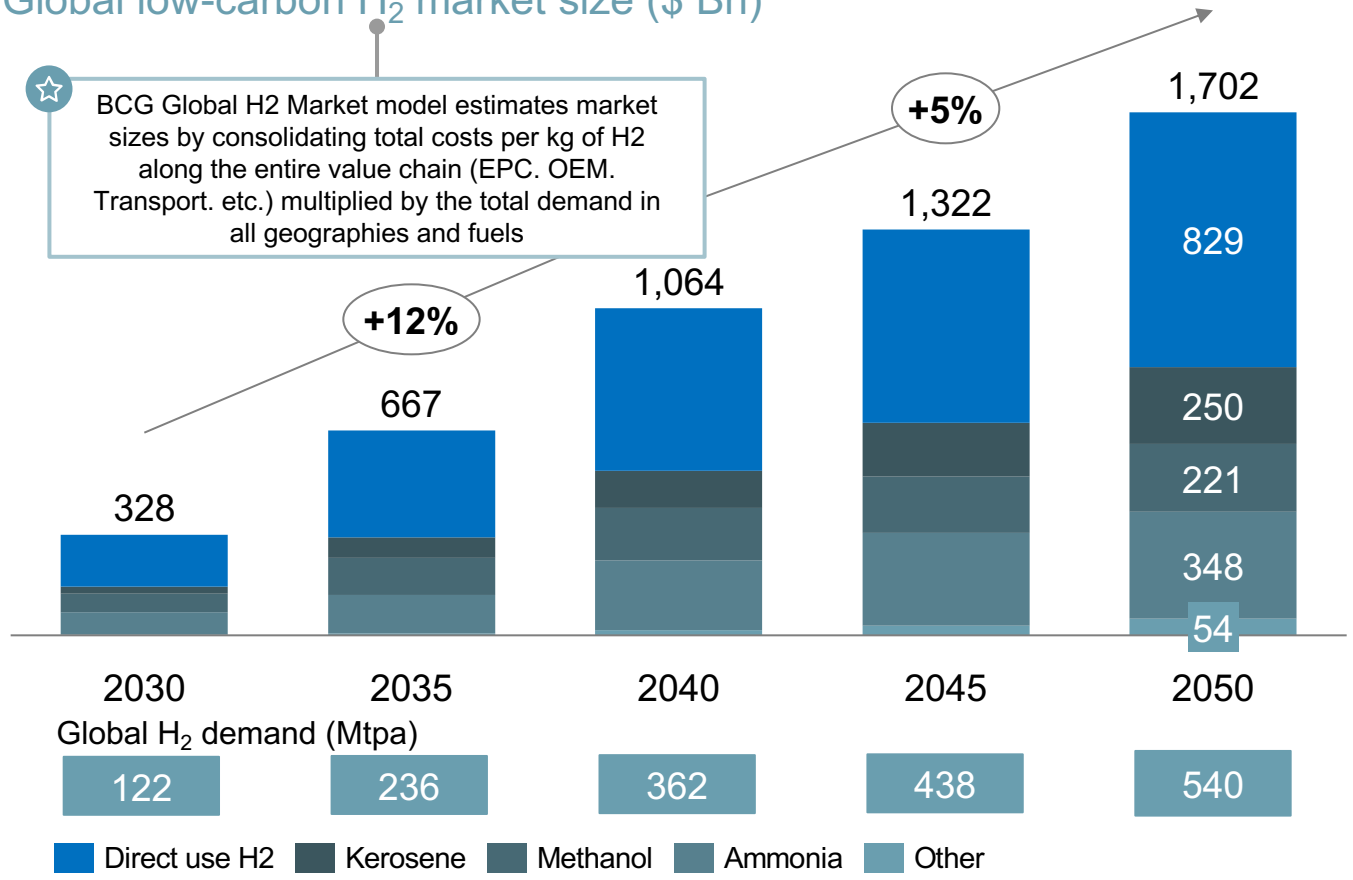
Market for tradable H2 derivatives to be worth ~$870 Bn by 2050

1.5°C Path

Updated Aug 2022

Global low-carbon H_2 market size ($ Bn)

BCG Global H2 Market model estimates market sizes by consolidating total costs per kg of H2 along the entire value chain (EPC. OEM. Transport. etc.) multiplied by the total demand in all geographies and fuels



Direct use H2 production accounts for ~$830Bn, leaving derivatives worth **~$870Bn**

Ammonia worth **~$350Bn** by 2050

- Imported direct use H2 and derivatives **addressable by exporters** worth ~870Bn (~60% of total market)
- However, direct H_2 exports not competitive with local production due to **high transportation costs**
- Derivative markets with potential for export due to **mature shipping technology and economics**

Note: Key financial assumptions of the BCG Global H2 Market Model – WACC: 8%. Grey/blue asset life: 25 years. Pipeline asset life: 40 years; Key hydrogen plant design. operating cost and capital requirement related assumptions based on IEA GHG technical report.
Source: BCG Global H2 Market Model – Feb 2022; BCG analysis

Significant upscale requirements can be expressed in number of Hyphen-sized projects required to reach global Net Zero ambitions by 2050

Estimated

~6 000 Total Hyphen-sized projects required to meet **expected global wind and solar energy supply** by 2050[1]

&

~3 000 Total Hyphen-sized projects required to serve **expected global hydrogen demand** by 2050[1]

OR

~800 Total Hyphen-sized projects required to serve **expected global ammonia demand** by 2050[1]

Solar PV land requirements

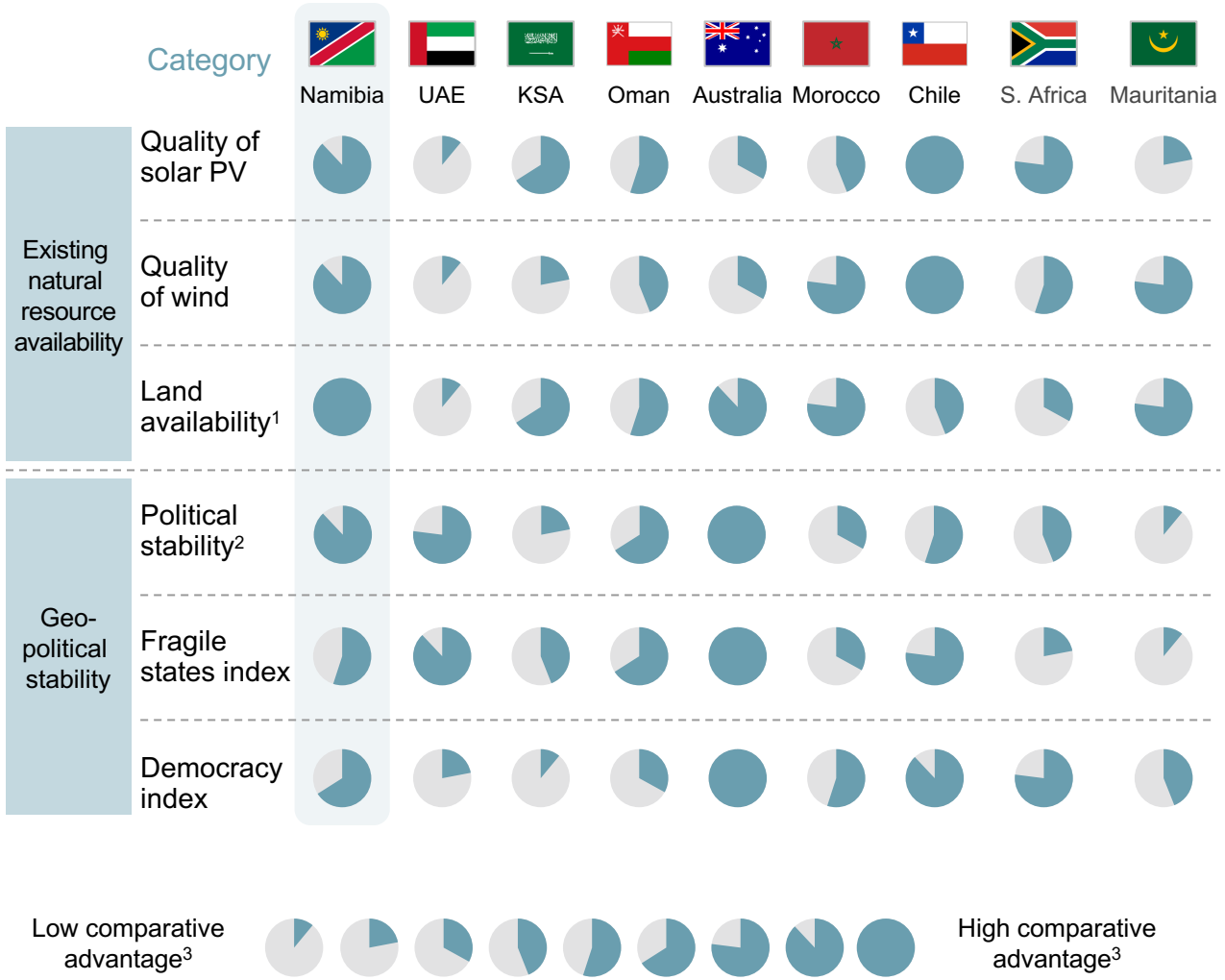
~170 000 km² of land required in 2050

Wind land requirements

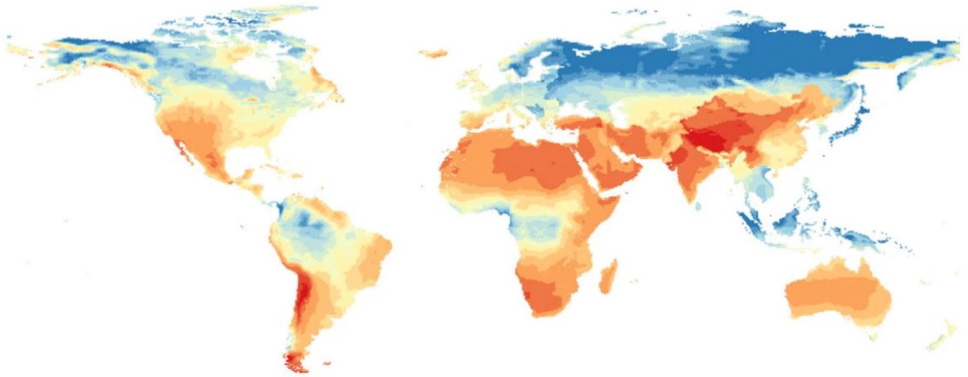
~510 000 km² of land required in 2050

1. IEA World Energy Outlook NZE scenario for Energy Supply:World
Note: Based on global annual average conditions
Source: IEA, BCG analysis

Namibia competitively positioned compared to high potential regions



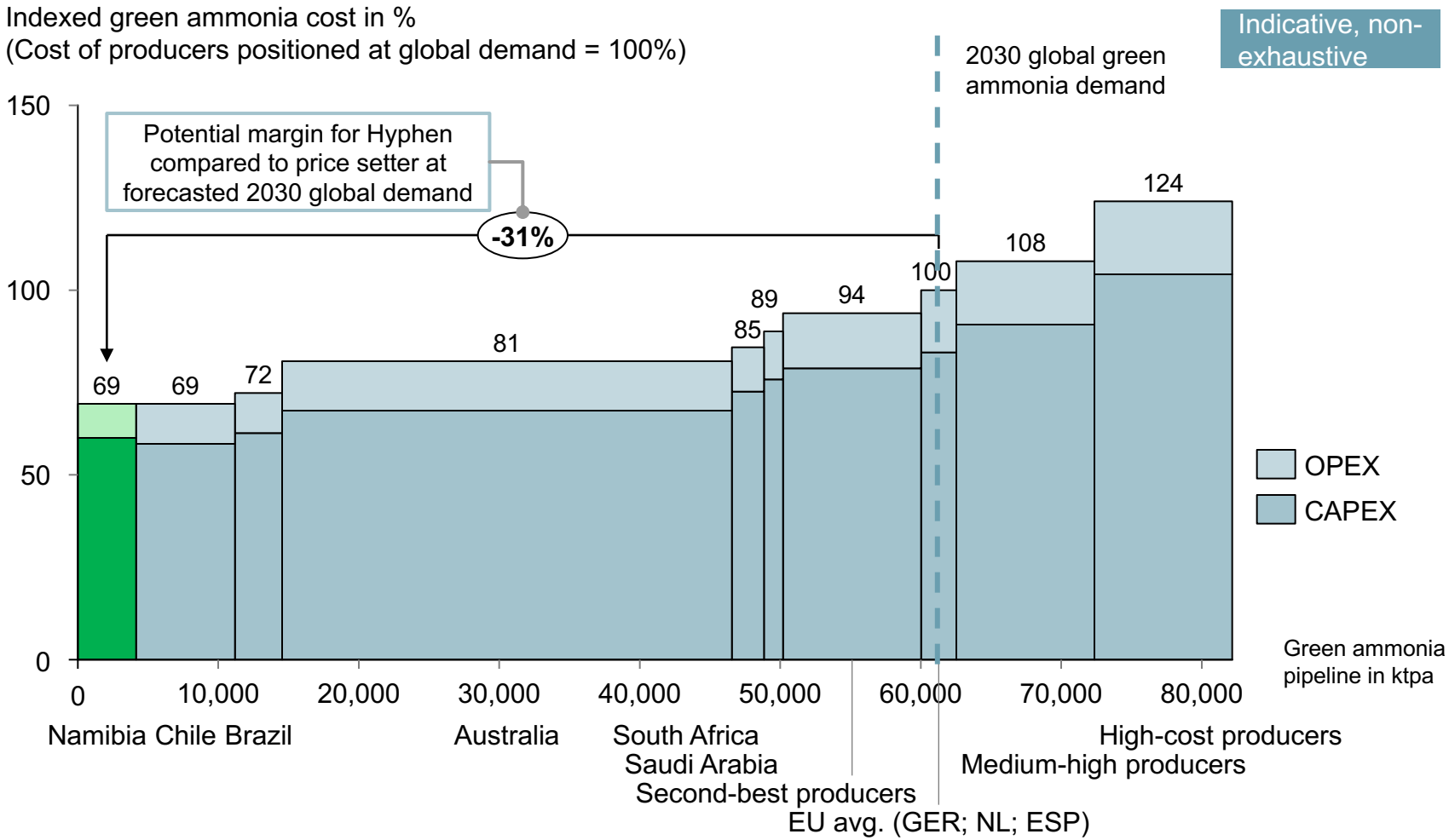
Resource comparison



Namibia holds a **competitive advantage in natural resources geopolitical stability and democratic values**. However, as it is a **developing country**, it lacks the financial resources to kick-start the industry and would be reliant on foreign direct investment

1. Uses population density as a proxy 2. Political Stability and Absence of Violence/Terrorism 2020 index. 3 Relative to other countries in this set
Note: Chile's resources not collocated
Source: Global Solar Atlas; : BCG H2COST model; data.un.org; World Bank (WGI); Fragile States Index; Economist Intelligence Unit;

Namibia (TKNP) positioned far left on world cost merit order (normalized) of green ammonia in 2030



Note: Green ammonia pipeline is based on announced projects
Note 2: Costs were calculated based on best location within a country. It does not consider restrictions on the size/availability of that location
Source: GlobalData, Nexant, IRENA Innovation Outlook Ammonia 2022, BCG H2 model, Enertrag

Two **differentiating cost drivers** between countries:

1. **Cost of capital**: Namibia has relatively high cost of capital. This can be offset to some extent by superior renewable resources, but driving down cost of capital remains top priority
2. **Government charges**: the green H2 and derivatives industry has the potential to dominate the Namibian industrial landscape. To benefit first movers, government is incentivised to keep charges as low as possible

Strong resources must be deployed to reach global decarbonisation goals with existing limited production capacity

Illustrative

Wind | Land & equipment requirements assuming equal energy output

Resource comparison

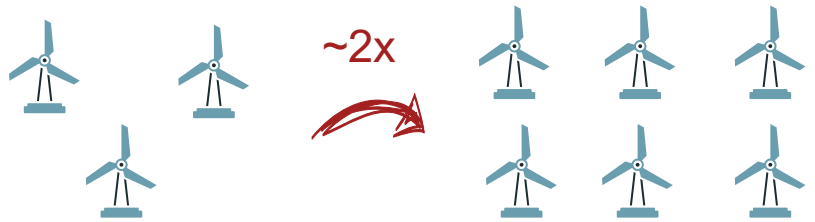
Wind intensity (W/m^2)

Namibia	~1150
Germany	~590

~2x

Land & equipment resources required in Germany

Namibia (T/K) **Germany (Bremen)**



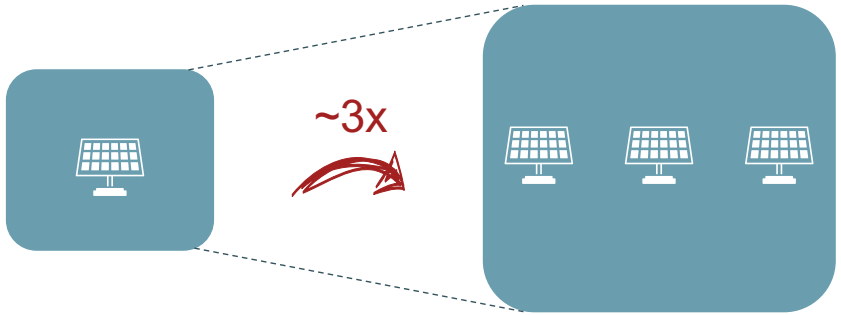
Solar | Land & equipment requirements assuming equal energy output

Solar intensity (kWh/m^2)

Namibia	~2800
Germany	~880

~3x

Land & equipment resources required in Germany



Source: Global wind atlas; global solar atlas

Investment should be made in areas where 2 objectives are reached:

- Implementation is quick and **speed to output maximised**
- Total **capital spend** to achieve set output is **minimised**

Thus, production in high-potential area like **Namibia is more suitable** than production closer to demand centres (e.g., Europe)

Hyphen is one of largest, furthest developed NH_3 projects worldwide

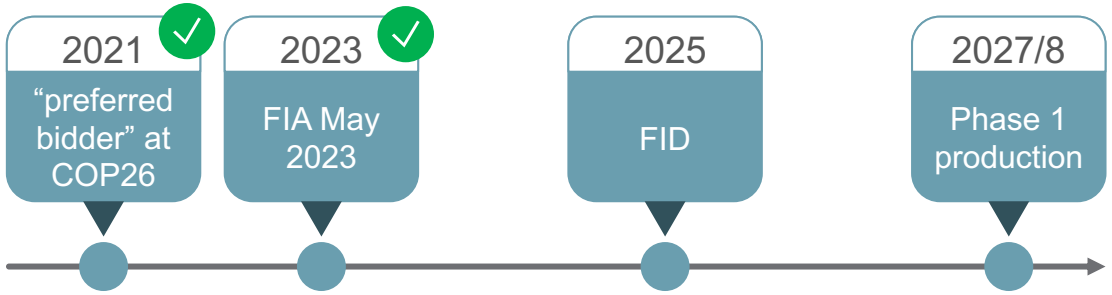
Key facts about Hyphen

Phase one & two

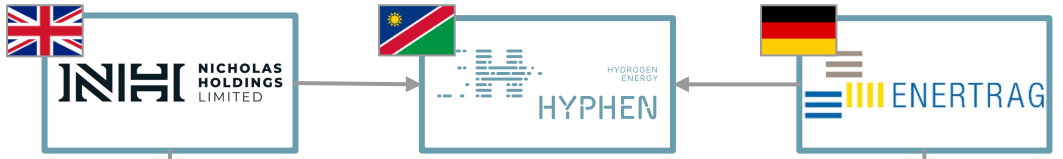
Installed capacity	6-8 GW renewables 2.5-3.5 GW electrolysers
Total investment	USD $10BN
Green hydrogen/ammonia	350 kt/a H_2; 2 Mt/a NH_3 *(4-5 Mt/a CO_2 avoided)*
Construction jobs	15,000 for 4-5 years
Operational jobs	3,000 permanent jobs

- GDP of Namibia: ca. US$10 billion
- 1 large steel plant: 350 kt/a H_2
- NH3 demand Germany: ~3 Mt/a

Hyphen currently on track to reach major milestones



Two complementary shareholders for an ideal shareholder setup



Nicholas Holdings
- > 30-year track record as infrastructure investor in sub-Saharan Africa
- Owner of largest private train operator in Africa (Traxtion)

ENERTRAG
- One of the largest renewables players in Germany (800 staff, 1 GW assets) with global footprint
- Green H2 production since 2011
- 10 GW development pipeline

Hyphen is currently working with a broad range of actors including the Namibian Government to launch the project

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- Preferred bidder
- Close cooperation with the Govt (on legislation, tax framework, etc.)

Advisors

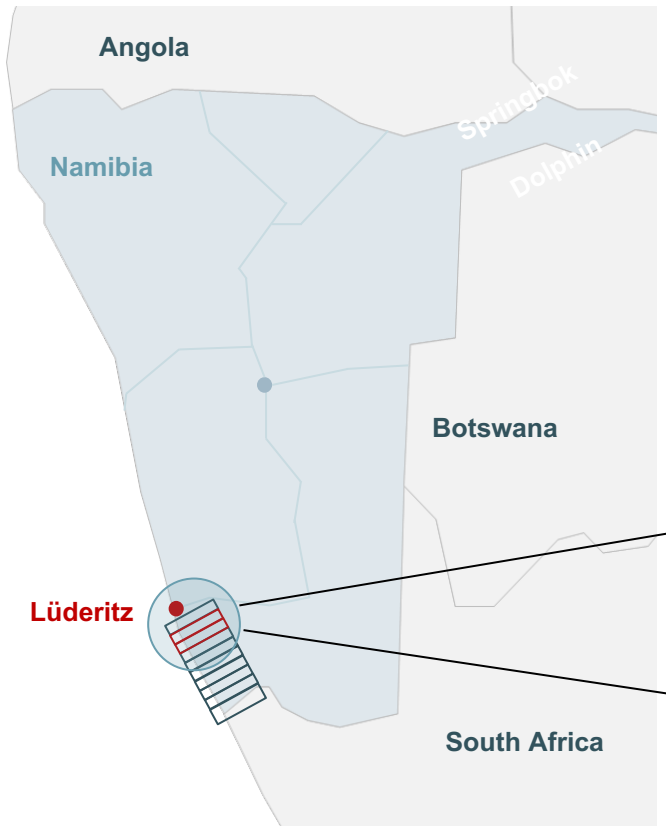
SLAUGHTER AND MAY / pwc
LAZARD
ENS africa
BCG
FTI CONSULTING

Hyphen shareholder ENERTRAG a pioneer in green hydrogen

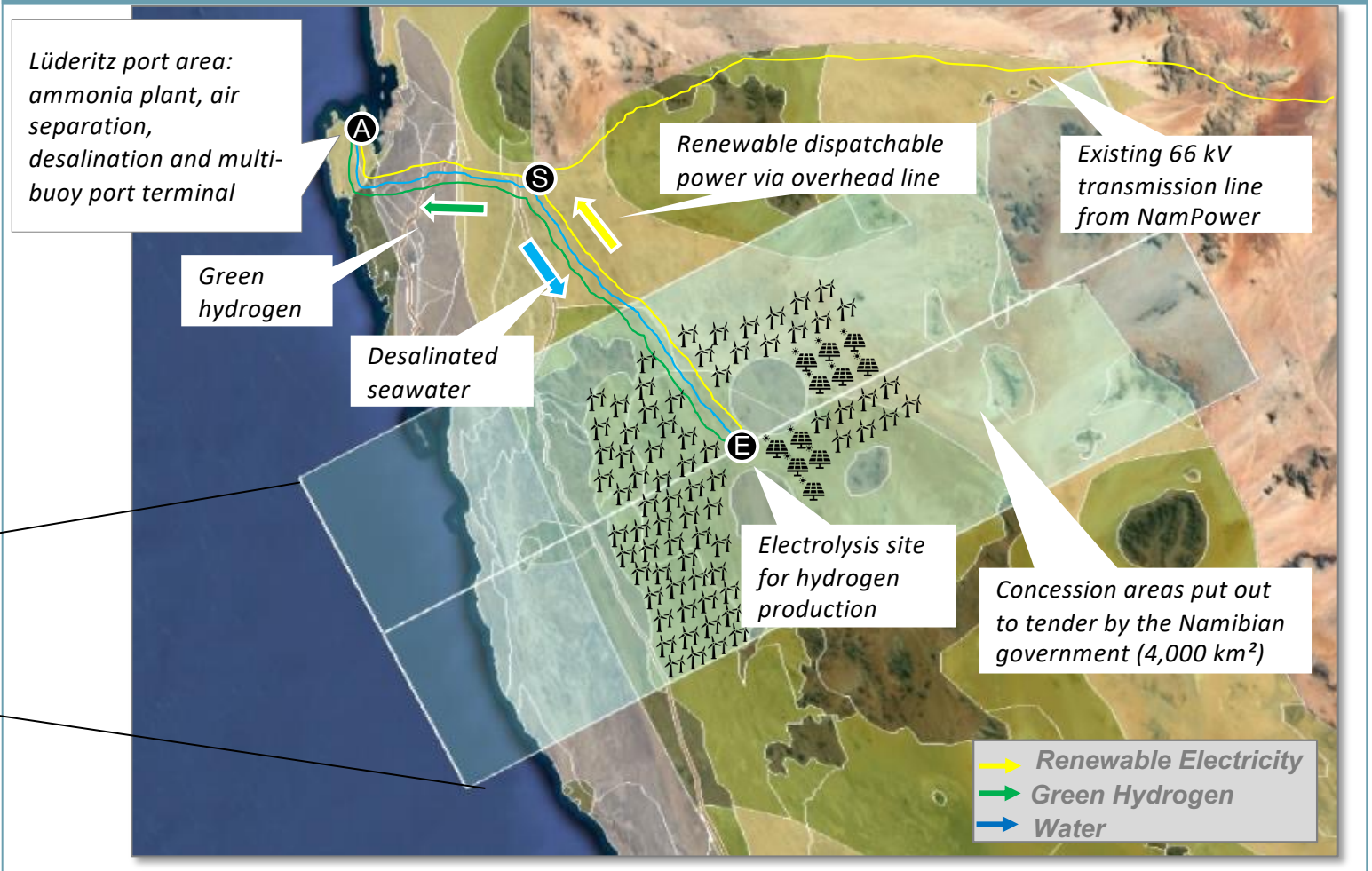
Commissioning Date: October 25, 2011
Total Investment: 21 M. EUR
Nominal Capacity Wind: 6.9 MW (3 x 2.3 MW)
Nominal Capacity BioGas: 732 kW (2 x 366 kW)
Nominal Capacity Electrolysis: 560 kW
Gas Storage Capacity: 1,186 kg
Maximum Annual Production H2: 94,000 kg/a
Annual Power Production: 16 GWh/a
CO2-Avoidance: 9,600 t/a

Hyphen project area and connection to Lüderitz port

Project is located in the south of Namibia on the coast line, close to Lüderitz



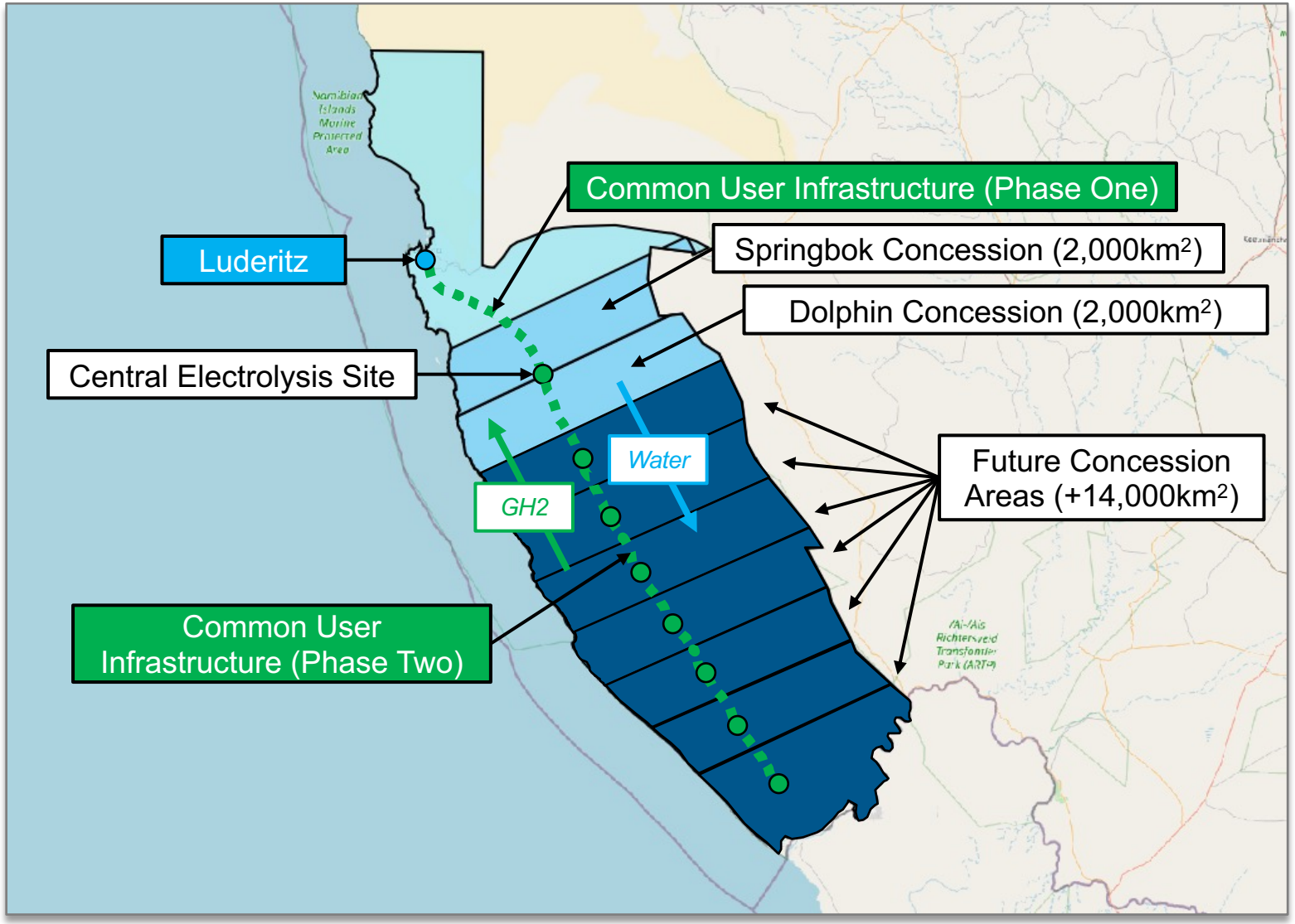
The Namibian Tsau//Khaeb region is a global top three co-located wind and solar resource with land entirely owned by Government



Project – Summary video

Source: https://hyphenafrica.com/

First project will unlock ‘CUI’ for future projects



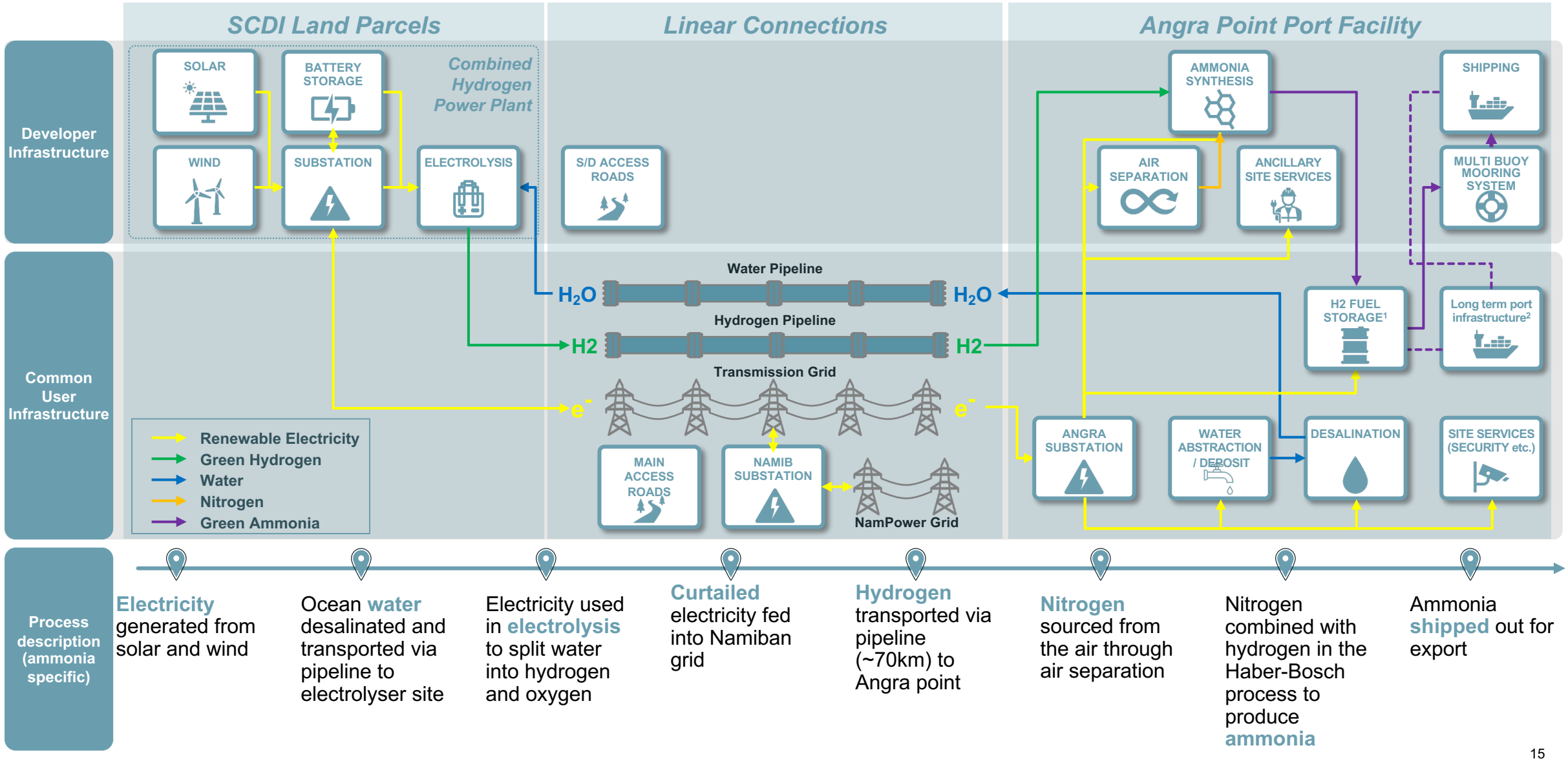
Common User Infrastructure (“CUI”) Corridor

Green Hydrogen Gas Pipelines

Water Pipelines

Transmission Lines

Hyphen Common User Infrastructure (CUI) approach



1. Could also store other synthetic fuels. The product stored as part of the first project is ammonia 2. Long term physical port infrastructure to be build in the future, with exact ownership and operating structure to be determined

“Moving molecules” is the optimal technical solution

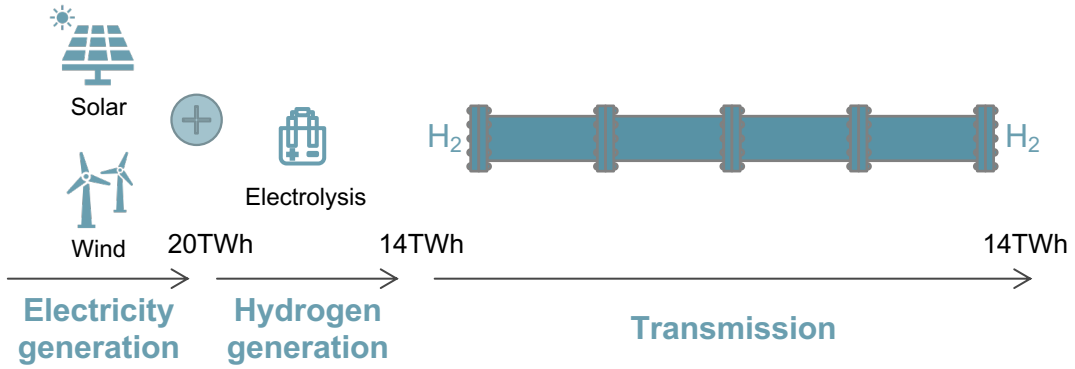
Theoretical project from scaling perspective

Two distinct options technically possible…

Preferred option

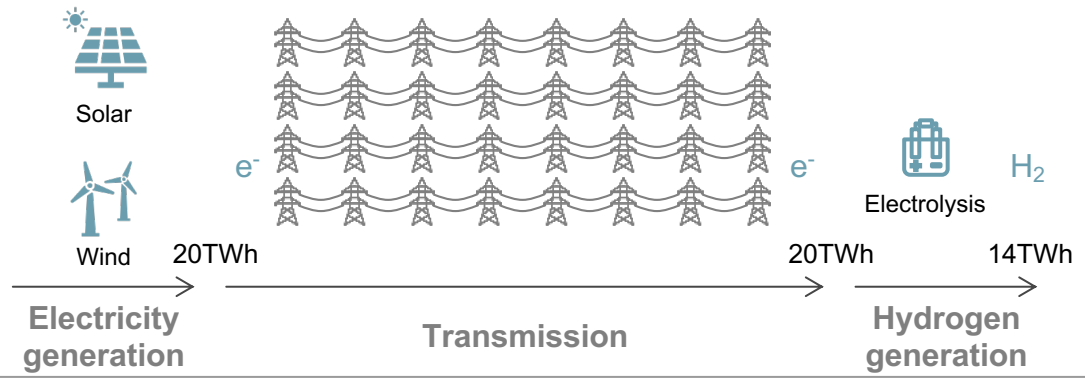
1 Moving molecules

“**Moving Molecules**” — Electrolysers positioned in the renewables corridor



2 Moving Electrons

“**Moving electrons** ” – Electrolysers positioned at the port



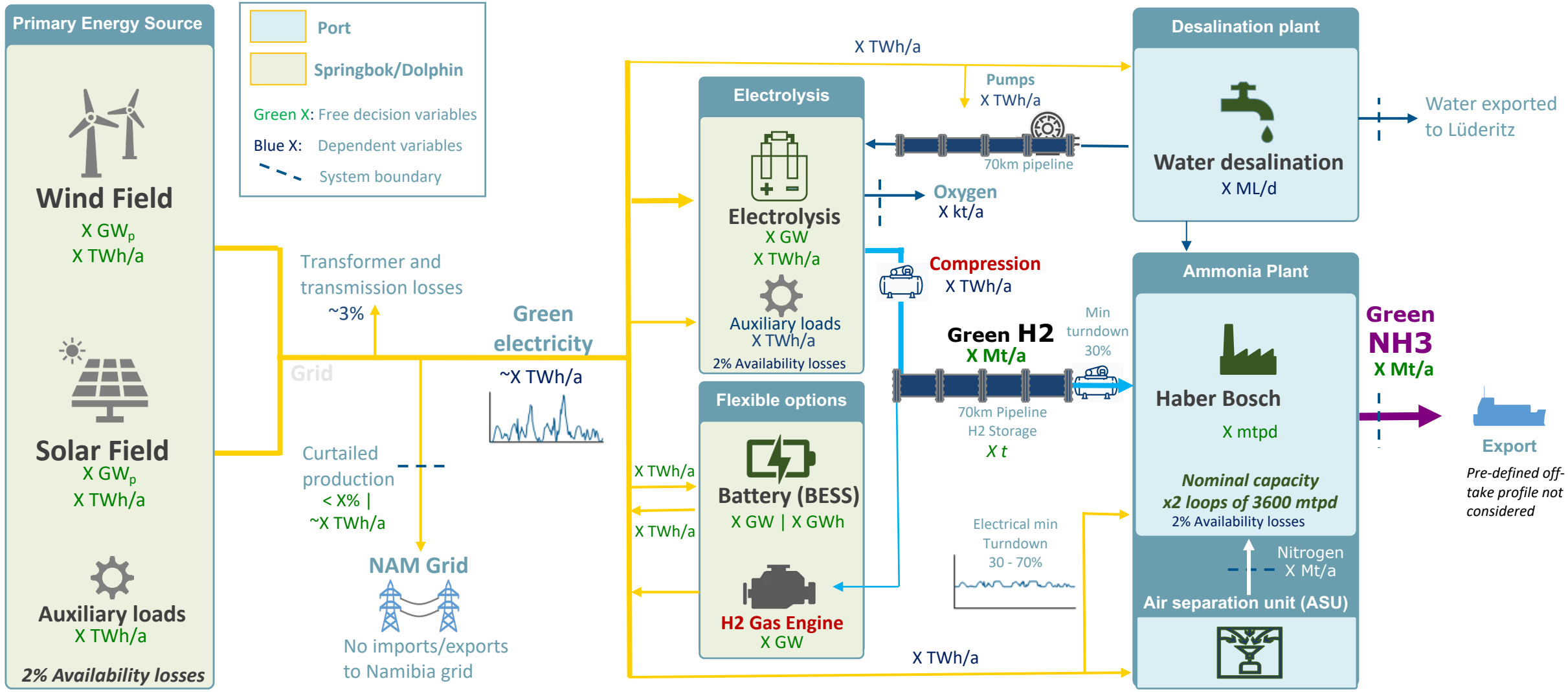
Hydrogen demand (300ktpa H2 equivalent)

… with “moving molecules² ” being the preferred solution

Environment	1x 1,400mm hydrogen pipeline can accommodate 3Mtpa of GH2, equivalent to approximately 50 GW of RE. This would be equivalent to 48x 400kv lines
Cost	Pipeline cheaper per unit energy and length: Capital cost of pipeline is $c 6-10 per kg/100km and for transmission it is $c 11-15 per kg/100km
Energy Transport	Transmission losses[1] associated with both options, because of electrolyser inefficiencies, the pipeline requires 30% less "energy" to be moved, resulting in more effective deployment of capital and improved overall system efficiency
Operability	Pipeline offers buffer capacity to smooth out variability and optimize potential uptime of downstream processes and equipment
Land availability	Area around Angra Point in Lüderitz is limited & would not be sufficient to accommodate transmission line infrastructure, as well as electrolysers associated with the full development potential of the SCDI, when choosing "Moving electrons"

1. Transmission losses, pipeline leakages and compressor energy usage have not been shown explicitly. 2. A parallel grid will still be required to run downstream RE systems on green electricity, but this is of small scale. Generally, between 5% - 10% of total installed RE capacity depending on the downstream derivative process. Source: RMI, Linde, Enertrag and BCG expert

Systems modelling – Energy system overview

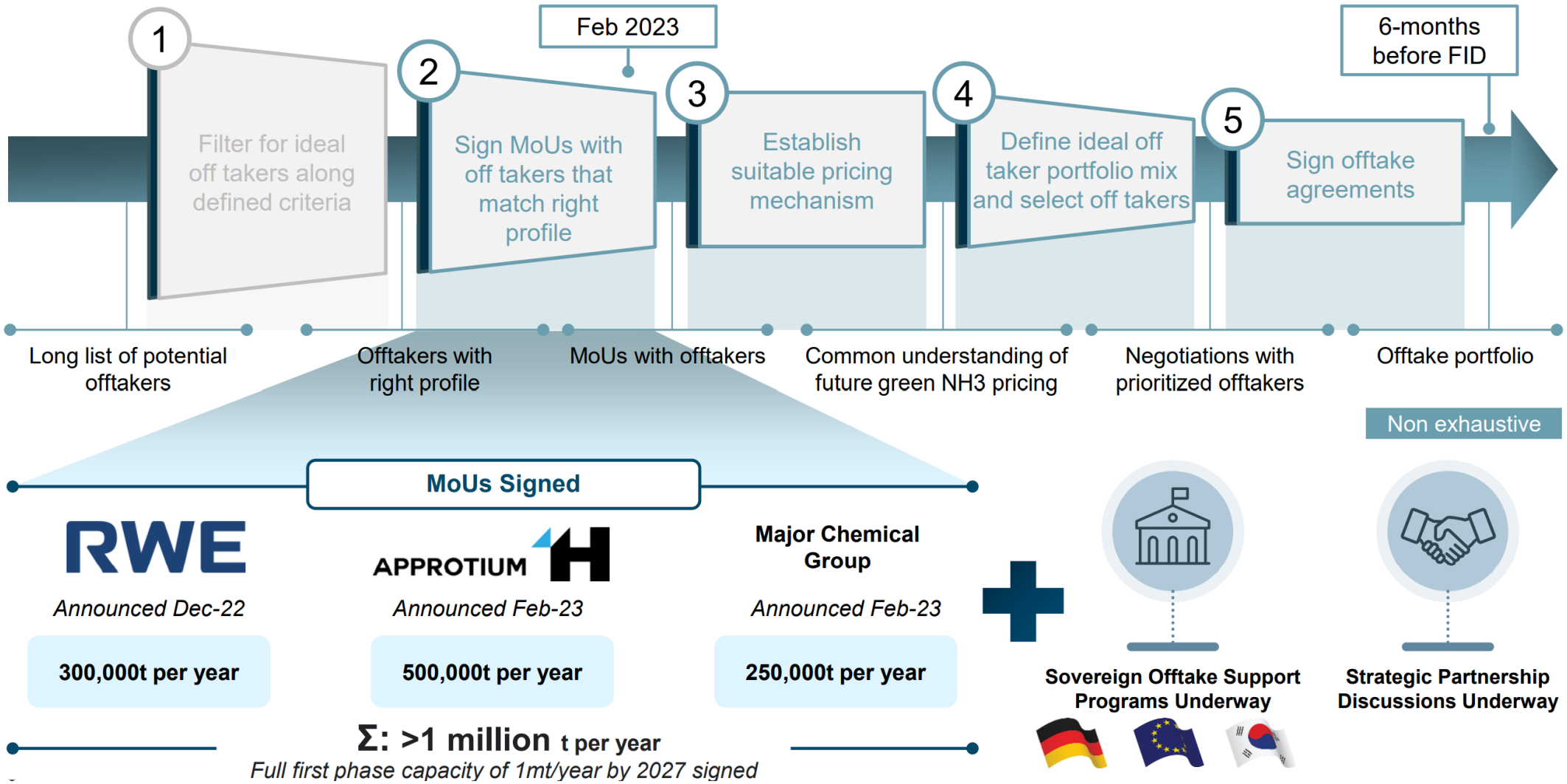


Technologies have an associated CAPEX, OPEX and availability

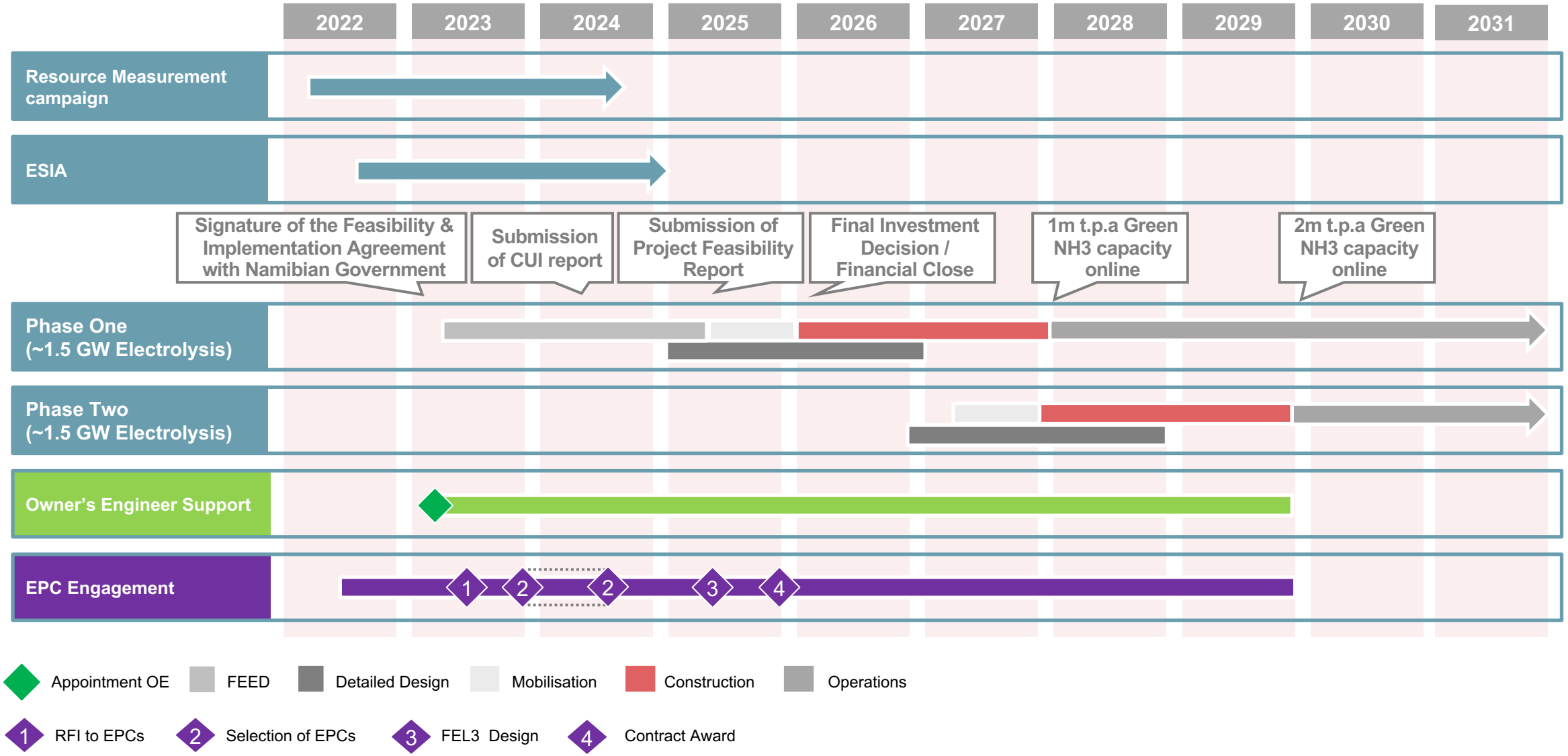
Water infrastructure and H2 pipeline sizing excluded from optimization

Proxy H2 storage cost included in optimisation to ensure viable H2 storage volume (pipeline limits)

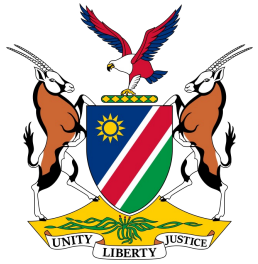
Offtake – Offtake agreements signed for 1Mtpa of NH3



Project timelines – High-level



Close working relationship with Government



- **Green hydrogen strategy for H2 valleys & implementation roadmap**
- **Implementation Authority Office as implementing authority**
- **Provision of land for implementation of the Project and tendering of additional land**
- **Enabling legislation**
  - Amendments to existing legislation
  - Establishment of sectoral specific legislation
- **Approval and administration of licences / permits**
- **Owner of 24% equity interest in the Project**

&

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- **Southern Corridor Development Initiative infrastructure master plan (3MTPA H2)**
- **Common use infrastructure sizing & access regime design**
- **Technical engineering studies (FEED)**
- **Environmental permitting and other licencing / permits**
- **Socio economic development (people & procurement)**
- **Commercial development**
  - Offtake (including sovereign support)
  - Project financing

FIA – Umbrella agreement

Feasibility & Implementation Agreement

- The FIA is the umbrella agreement between Hyphen and the GRN regulating all aspects of their relationship in respect of the development and implementation of the Project.
- The FIA is for a minimum term of 40 years following the completion of feasibility and the validation of the Project, with a potential for further extensions of that term.

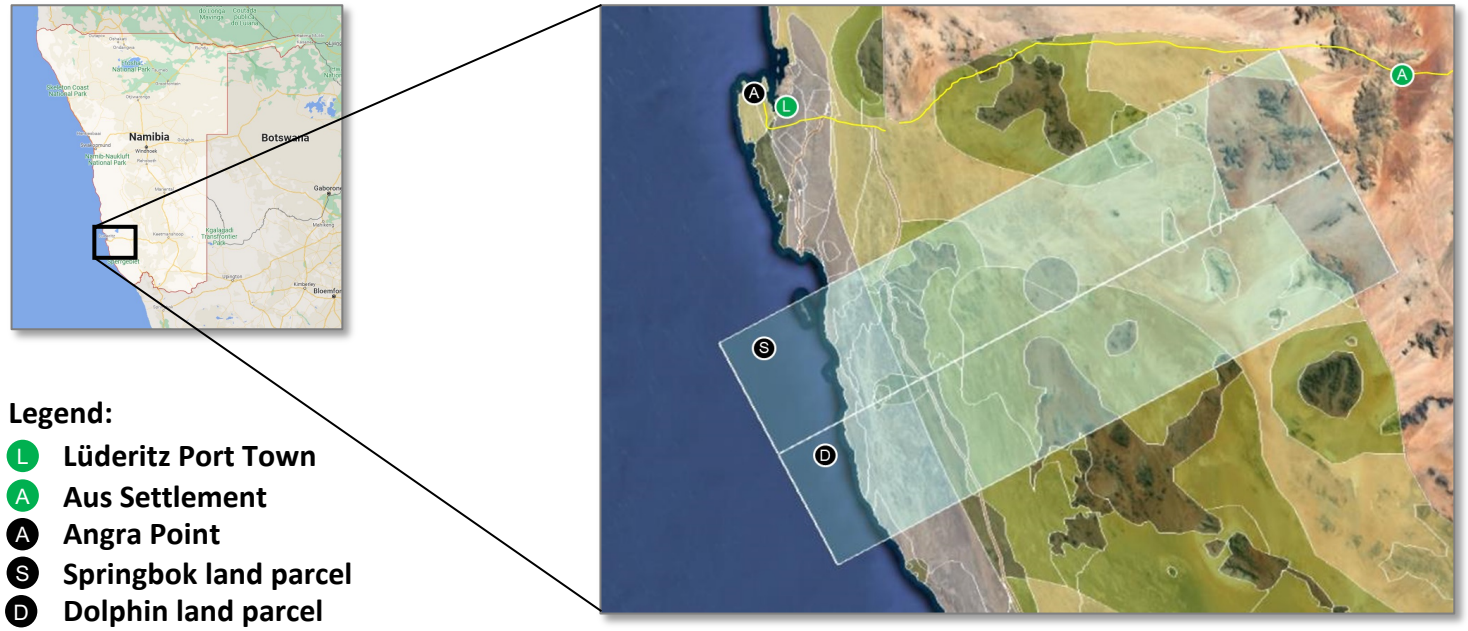


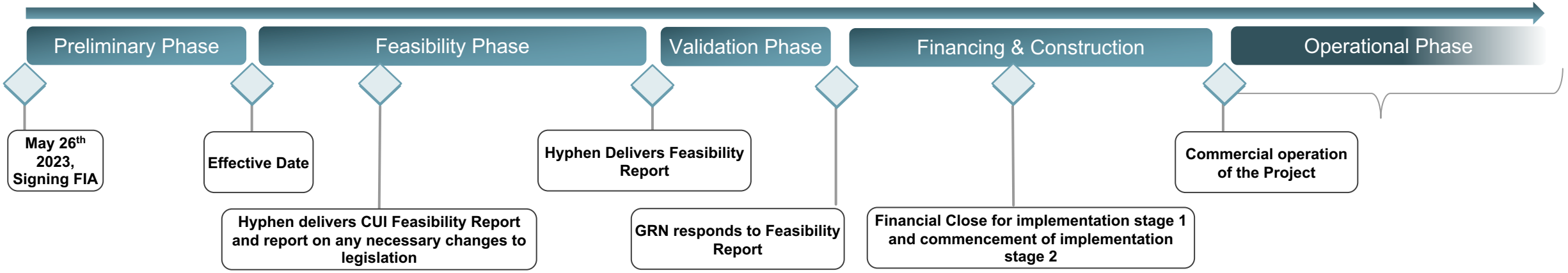
Photo: Signing of the FIA on May 26th, 2023.

Conclusion

- The FIA was signed on May 26th 2023 between the GRN (represented by the Ministry of Environment, Forestry and Tourism, the Ministry of Finance and Public Enterprises and the Ministry of Works and Transport) and Hyphen.

FIA – Project timeline

Milestone planning under the FIA



The FIA is split into five phases:

- The **Preliminary Phase** covering the period from the signature of the FIA until all conditions precedent to the FIA becoming effective have been met.
- The **Feasibility Phase** during which Hyphen is tasked with assessing the technical, financial, environmental, social and commercial viability of the Project, including the potential establishment of common user infrastructure, and the output of which is the production by Hyphen of a comprehensive feasibility report setting out Hyphen's proposed Project design and commercial structure.
- The **Validation Phase** during which the GRN is required to assess Hyphen's feasibility report and validate the Project (which the GRN is required to do if the Project meets all pre-agreed minimum criteria).
- The **Financing and Construction Phase** during which Hyphen is required to raise the necessary finance for the Project and for constructing and commissioning it.
- The **Operational Phase** during which Hyphen is responsible for the operation and maintenance of the Project.

Future –H2 should lead to >200,000 direct jobs in wind/solar alone

Potential End State - Namibia

150 GW electrolyser

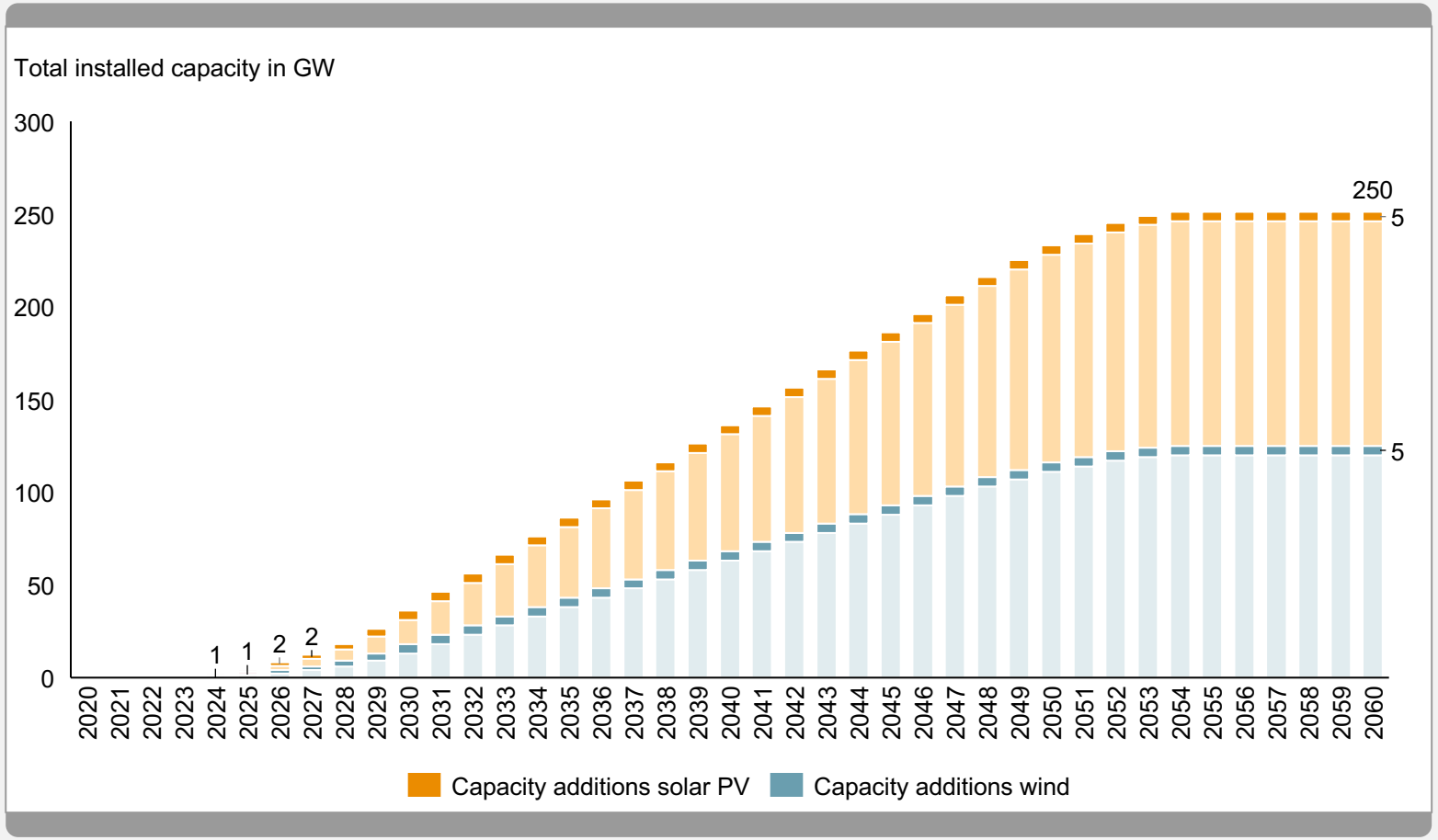
250 GW Wind/Solar PV
- 10 GW p.a. of new wind/solar PV and
- 5 GW p.a. electrolyser in perpetuity

Namibia's domestic demand decarbonized in the 2020s

→ 10-15 Mt/a green-H2-based export

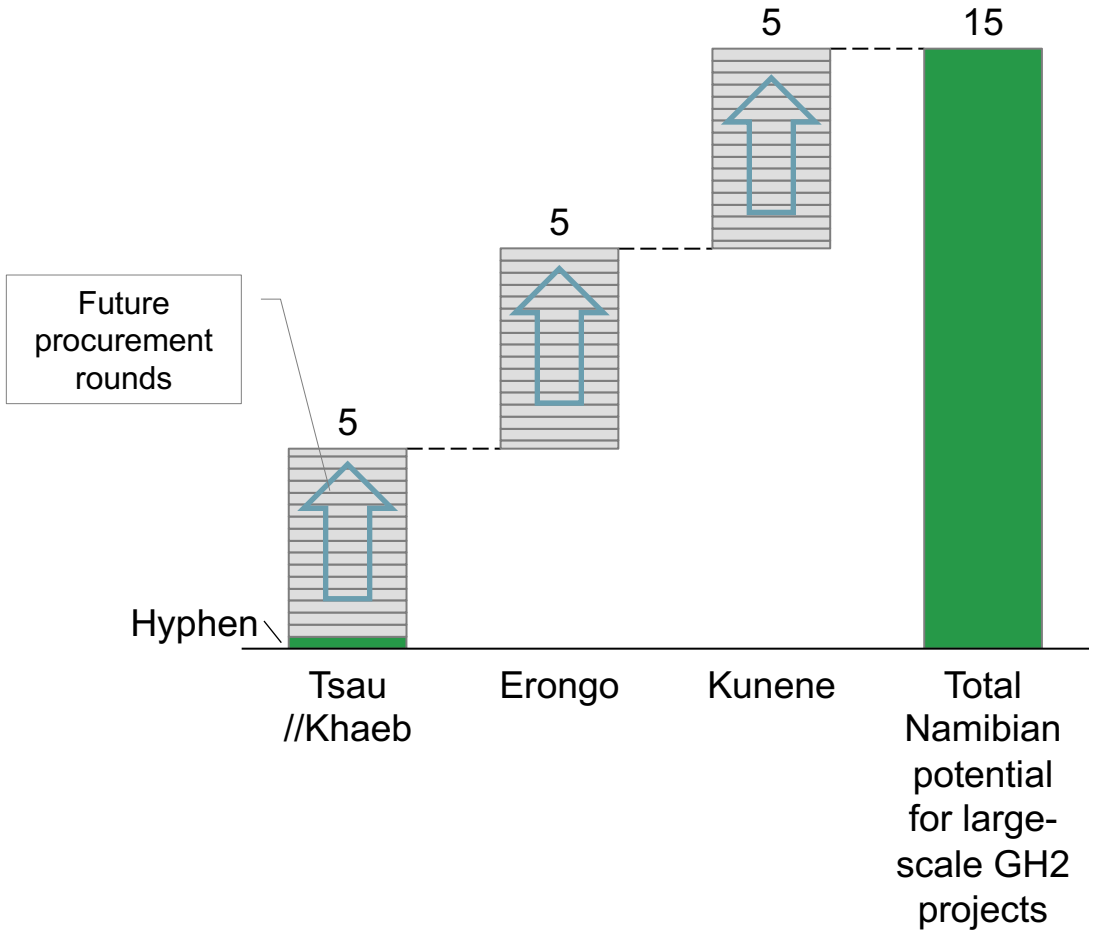
→ > US$35 billion H2-based export potential

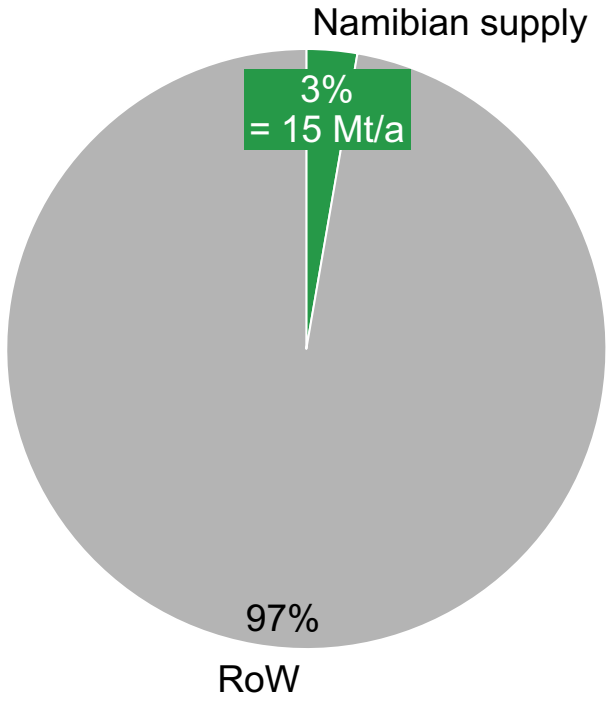
→ > 200,000 permanent jobs in wind and solar alone



Hyphen is the first large-scale GH2 project in many to come

GH2 production in million tons per year





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