REPORT SERIES CLEAN HYDROGEN PROJECTS IN THE GLOBAL SOUTH

Renewable Ammonia: Kenya's Business Case

H2Global Stiftung

Table of contents

About this report

Contributions

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Authors

H2Global
Julian Reul, Leah Mpinga, Hanna Graul

IEE Fraunhofer
Benedikt Häckner, Johann Fetköter, Christoph Zink

Strathmore University
Maryvelma Nafula, Diana Kosgei

Independent expert
Sandra Banda

Publisher

Department—Analysis and Research

Trostbrücke 1
20457 Hamburg

H2Global Stiftung | Fraunhofer IEE | Strathmore University | Federal Ministry of Education and Research

Executive summary

Ammonia plays a critical role in the global economy, particularly in the agricultural sector as a key commodity for fertilizer production. Traditionally derived from natural gas, the price of ammonia—and subsequently fertilizer—fluctuates with global commodity markets, posing challenges for net-importing countries like Kenya. Local ammonia production from renewable hydrogen offers a triple opportunity to traditional ammonia importers: it reduces dependence on global fertilizer markets, fosters the domestic economy, and contributes to the decarbonization of key economic sectors, such as agriculture and shipping.

Kenya is well-positioned to produce renewable ammonia domestically thanks to its abundant renewable energy potential from wind, solar, and geothermal sources. The country's national hydrogen strategy highlights this potential, envisioning the production of hydrogen, ammonia, and competitively priced fertilizer products. However, renewable hydrogen projects face significant economic risks that delay and hinder project development.

This report evaluates the viability of renewable ammonia production in Kenya. Using a fine-grained GIS analysis, the study identifies four suitable regions for renewable hydrogen production: two near Lake Turkana, one near Lake Victoria, and another near Mombasa's port. Simulations of ammonia production costs at these sites, for installed electrolyzer capacities of 10 MW, 100 MW, and 500 MW, produce cost ranges between 999 EUR/ton-NH3 for a 500 MW project near Lake Turkana and 2,437 EUR/ton-NH3 for a 10 MW project near Kisumu.

Production costs of 1,201 EUR/ton-NH3 are calculated for a 500 MW project in Mombasa, which would additionally benefit from existing infrastructure.

While renewable ammonia production costs remain 2—5 times higher than conventional ammonia, locally produced renewable ammonia-based fertilizers can compete effectively within the domestic market. These fertilizers have the potential to achieve production costs 10—30% lower than prevailing prices for key fertilizer products in Kenya.

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Recommendations

Renewable ammonia production offers Kenya an opportunity to stabilize domestic prices, drive economic growth, and decarbonize sectors, such as agriculture and global shipping. To unlock this potential, the following steps are recommended:

- Leverage the domestic fertilizer market to absorb the green premium associated with renewable ammonia production.
- Mitigate price volatilities in the domestic fertilizer market by mobilizing concessional and private financing for tailored hedging instruments.
- Address macroeconomic factors, including inflation and country-specific risks, to reduce the cost of capital.
- Invest in electricity and transport infrastructure, as well as export and bunkering infrastructure at ports, to support project development.
- Proactively demonstrate the social and economic benefits of these projects to secure a social license to operate.

By addressing these challenges and opportunities, Kenya can lead in renewable ammonia production, setting a model for other African countries and the global community.

The hydrogen opportunity for Kenya

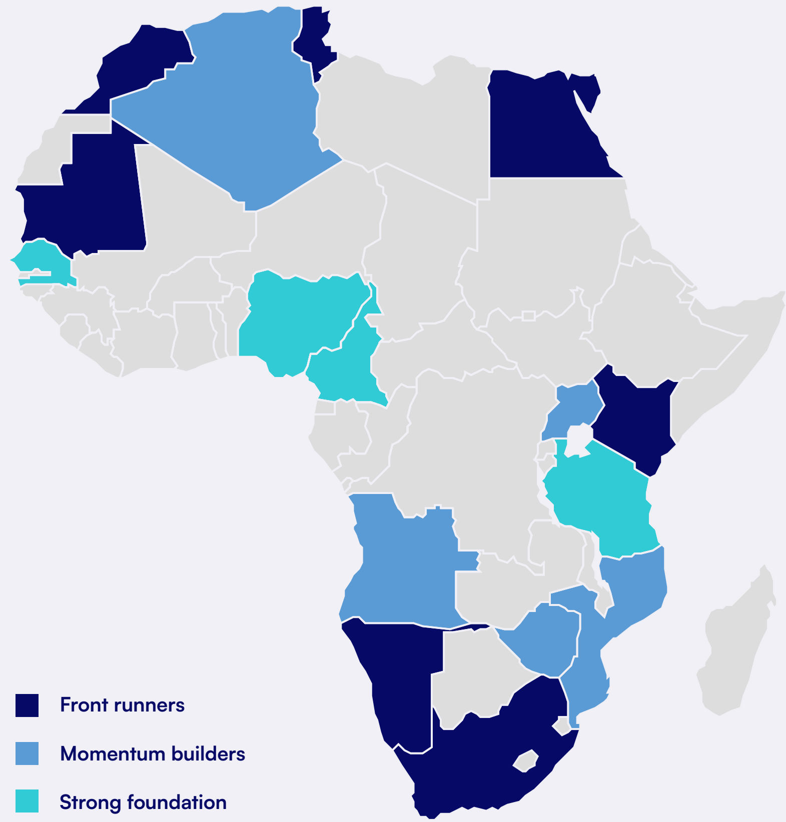
Clean hydrogen and its derivatives are playing a crucial role in the global energy transition.

The production of clean hydrogen is set to aid the decarbonization of energy-intensive sectors such as transport, buildings and industry.[1] In addition, hydrogen is a commodity that is used as an input, for example for the production of ammonia.[2] Ammonia is the primary feedstock for nitrogen fertilizers, accounting for 70% of global ammonia demand.[3] As per International Renewable Energy Agency (IRENA), ammonia accounts for 15—20% of the chemical sector's carbon emissions and 1% of total global emissions.[4] The decarbonization of ammonia in the chemical sector has been identified as a "low hanging fruit" in the energy transition, due to the existence of an already mature ammonia market.

In Africa, renewable hydrogen production is promising due to the continent's high renewable energy capacity.[5] The continent holds 60% of the world's solar resources but only 1% of installed capacity.[6] It is estimated that by 2035, more than 500 Mt per year of cost-competitive renewable hydrogen can be produced in Africa.[7] Producing renewable hydrogen in Africa can help create and strengthen local value chains i.e., renewable ammonia, methanol and green steel production.[8] Producing renewable hydrogen and its derivatives in Africa can also reduce the continent's exposure to market price fluctuations and reduce supply risks.[9] Most importantly, developing the hydrogen economy in Africa presents opportunities such as job creation, increased food security, new fiscal streams, and improved access to clean energy.[10] Beyond domestic implications, the production of hydrogen in Africa is set to establish new global trade relationships. For countries with high renewable energy capacity, export of renewable hydrogen and its derivatives to high-energy-demand regions such as Europe and South-East Asia can foster economic development.[11]

The H2Global Foundation conducted a country clustering analysis to assess the potential of African countries to produce renewable hydrogen and create value for the local economy (H2Global Stiftung, 2025 - *Forthcoming*). The assessment considered an array of dimensions, including renewable energy potential, water stress levels, public and private commitment to clean hydrogen, existing domestic industries with a potential demand for renewable hydrogen, country risk factors, and existing export infrastructure for hydrogen and its derivatives. Kenya was identified as one of six **front runners** in Africa's emerging hydrogen economy.

Figure 1: Clustering analysis of the hydrogen market potential of African countries.



Kenya's emerging hydrogen sector

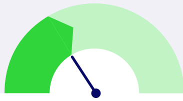
The opportunities for renewable hydrogen development in Kenya are comprehensively outlined in Kenya's Green Hydrogen Strategy and Roadmap.[12]

This policy document emphasizes renewable hydrogen's potential to improve the balance of payments, enhance food security, drive green industrialization, support decarbonization efforts, and attract increased investments. From a techno-economic perspective, renewable hydrogen offers diverse use cases across multiple sectors. These include developing nitrogen-based fertilizer value chains, producing clean fuels for aviation and shipping, manufacturing methanol as a chemical feedstock for plastics production, supporting power system balancing, and offering grid services. In addition to its techno-economic potential, renewable hydrogen development promises socio-economic benefits. These opportunities include developing a skilled workforce, improving food security, and enhancing regional and international trade.

Kenya's Green Hydrogen Strategy and Roadmap is aligned with national strategies such as the Kenyan Energy Transition Investment Plan that identifies hydrogen as one of six key decarbonization technologies for Orderly Transition.[13] The roadmap foresees three implementation phases of Kenya's green hydrogen strategy: **Phase 1 (2023—2027)** focuses on launching the hydrogen economy and building domestic demand; **Phases 2 (2028—2032)** and **3 (2032 and beyond)** focus on scaling up direct investments, reducing hydrogen production costs, and tapping into the export market potential.

Figure 2: Overview of Kenya's hydrogen strategy.

2023 — 2027
Domestic market development



- Develop policy & regulatory instruments
- First commercial-scale green hydrogen project(s) operational
- Establish cooperation with international RTD centers
- **150 MW** new **renewable** capacity installed
- **100 MW electrolyser** capacity installed
- **100,000 t/a** green **fertilizer** production (=20% of imported fertilizers)
- **> 5,000 t/a** green **methanol** production (=100% of imported methanol)

2028 — 2032
Domestic market growth

- Pilot projects in other sectors, incl. baseload power & transport
- Production of green shipping fuels
- Explore regional export opportunities for green fertilizers
- **350—450 MW** new **renewable** capacity installed
- **150—250 MW electrolyser** capacity installed
- **300,00—400,000 t/a green fertilizer** production (= 50% of imported fertilizers)
- At least **1 billion USD direct investment**
- At least **25,000 direct jobs created**
- At least **250,000 t CO_2 avoided per year**

2032 and beyond
Domestic & export market growth

- Roll out further green hydrogen applications, like transport or green steel
- Expand existing and explore new export opportunities for green hydrogen products "Made in Kenya"

Fertilizers and their role in Kenya

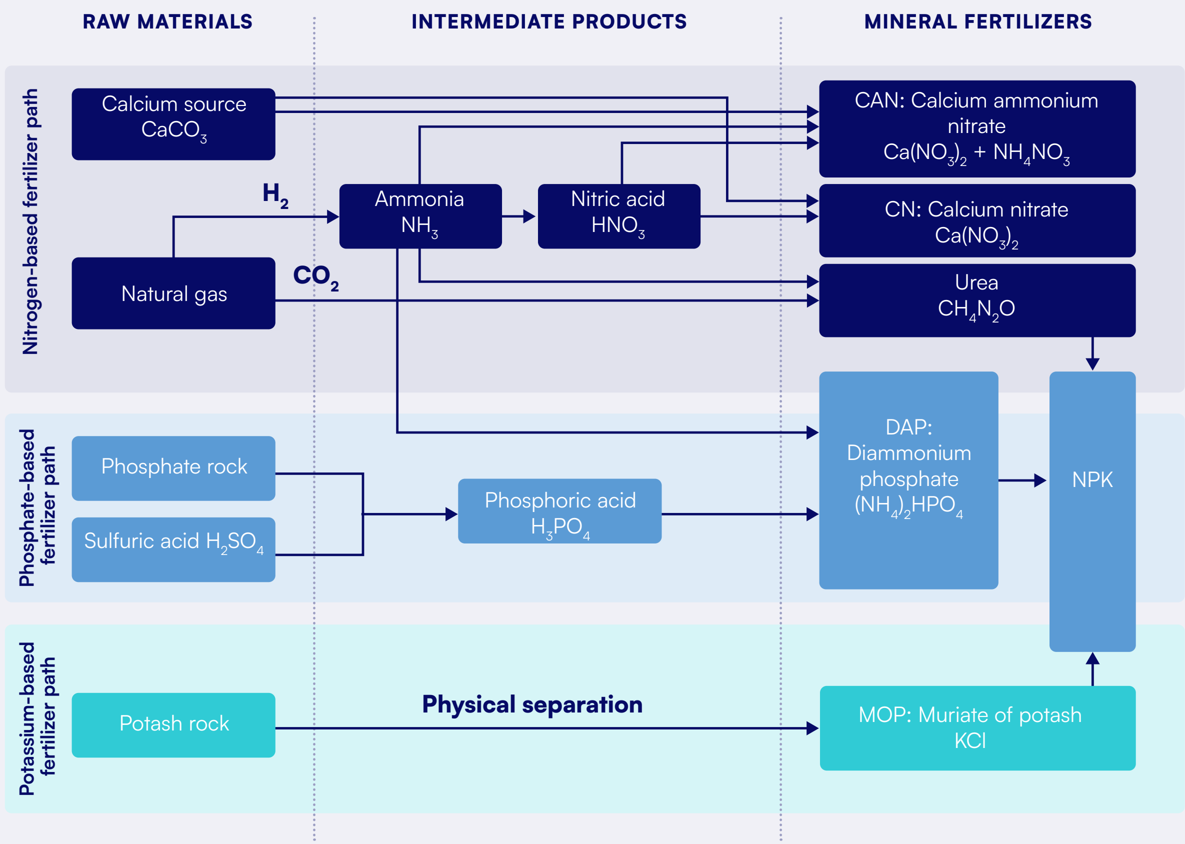
Fertilizers supply essential nutrients to crops.

They are categorized as organic—derived from plant and animal waste—or mineral—produced from natural deposits and atmospheric nitrogen fixation.[14] Mineral fertilizers, which support 50% of global food production, primarily provide macronutrients—nitrogen (N), phosphorus (P), and potassium (K)—and smaller quantities of secondary and micronutrients.[15]

Conventional nitrogen-based fertilizer production uses natural gas and nitrogen from the air to produce ammonia under high temperature and pressure. Ammonia is either converted to nitric acid for blending or reacted with carbon dioxide to make urea. Phosphorus and potassium fertilizers are derived from phosphate and potash rock. These materials are blended and reacted with other chemicals to create fertilizers with varied NPK ratios.[16] Phosphate rock is mainly mined in China, Jordan, Morocco, Russia, Saudi Arabia, and the USA, while potash is sourced from Belarus, Canada, China, Germany, Israel and Russia.[17]

Agriculture contributes 20% to Kenya's GDP and employs 40% of its active workforce. Annual fertilizer consumption in Kenya ranges from 590 to 820 metric kilotons (kt), including products like calcium ammonium nitrate (CAN), calcium nitrate (CN), urea, diammonium phosphate (DAP), muriate of potash (MOP), and NPK blends. Kenya relies entirely on imports for its fertilizers, since it lacks reserves of phosphate, potash and natural gas. About 50% of its fertilizers come from Saudi Arabia and Russia, with smaller shares coming from Turkey, Morocco and China.[18]

Figure 3: Fertilizer production pathways.



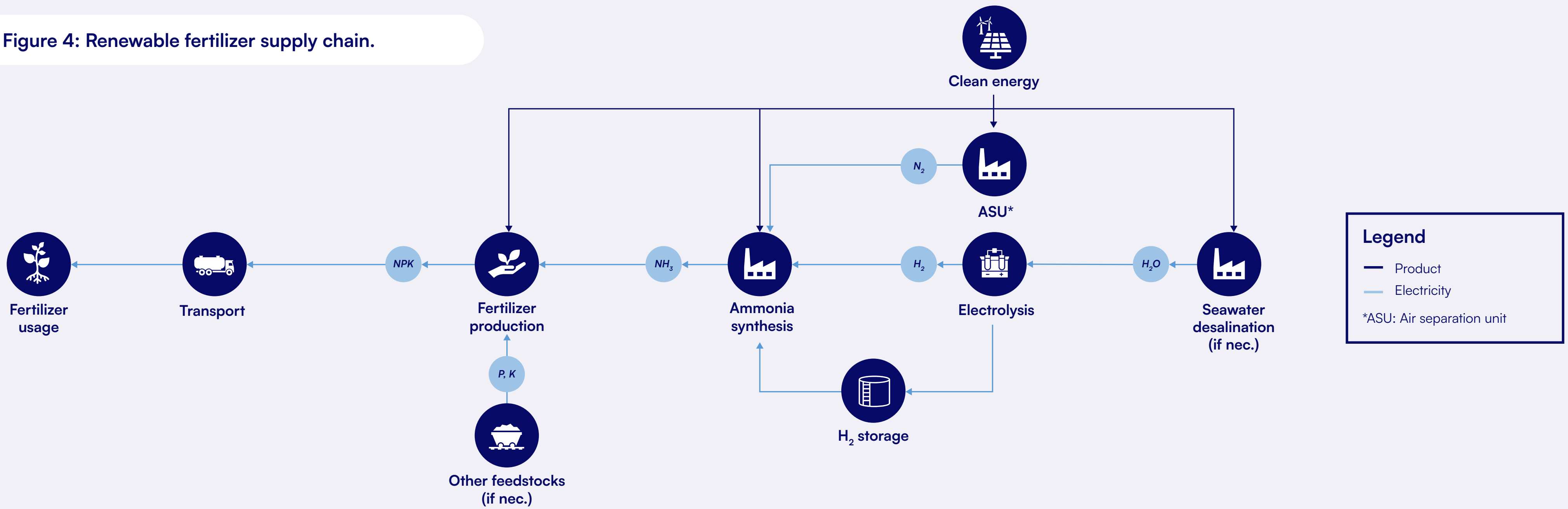
The renewable hydrogen-to-fertilizer opportunity

Phase 1 of Kenya's Green Hydrogen Strategy aims to replace 20% of the country's ammonia imports with domestically produced ammonia.

Ammonia is a key input stream in fertilizer production, accounting for 35—52% of production costs for DAP and NPK, and 77—84% of production costs for urea and CAN, respectively, according to our calculations. Fertilizer prices have fluctuated sharply, with CAN costing 45.02 USD per 50 kg bag in 2022, up from 19.63 USD in 2020.[19] Domestic renewable ammonia production would significantly increase Kenya's independence from global markets and offer an opportunity to mitigate price fluctuations for fertilizers. Additionally, it would enhance fertilizer accessibility and agricultural productivity, provide significant benefits to smallholder farmers, and contribute to broader food security goals.

Renewable fertilizers are produced using ammonia derived from hydrogen generated through electrolysis powered by renewable energy sources, such as solar, wind, hydro and geothermal power. This ammonia is then combined with nitrogen obtained from an air separation unit (ASU). Urea production additionally requires renewable CO2 from biogenic or waste sources. However, Kenya will still need imported phosphorus and potassium-based fertilizers. Kenya could source phosphate from Tanzania, which produces 25,000 tons annually and has reserves of five million tons.[20] While Africa lacks potash production, Ethiopia holds significant resources.[21] Regional collaboration could help Kenya and its neighbors achieve fertilizer self-sufficiency, reducing dependency on global markets.

Figure 4: Renewable fertilizer supply chain.

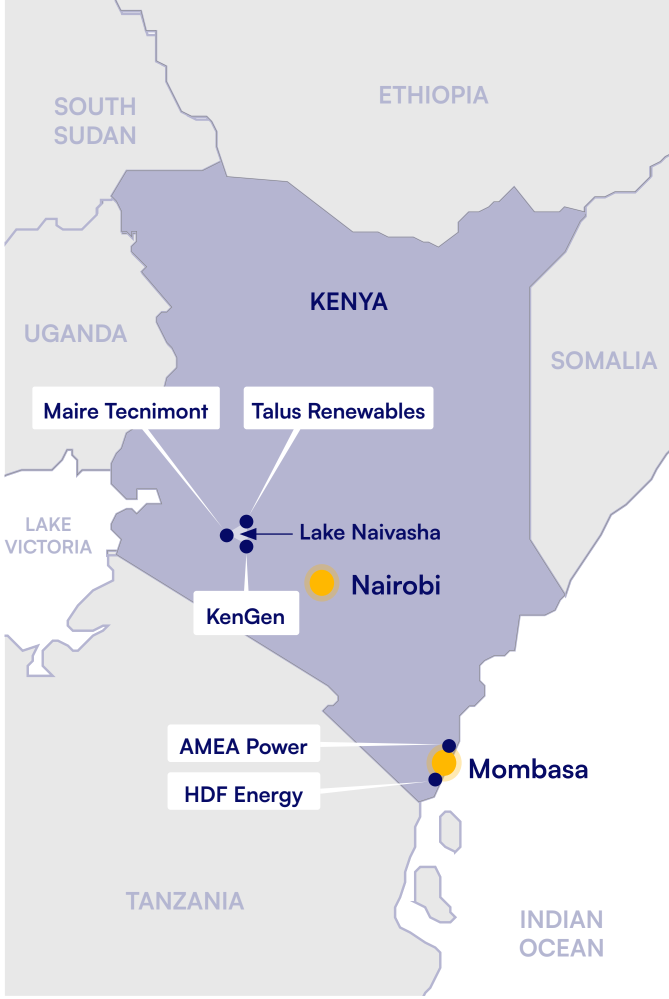


Kenya's announced hydrogen projects

Developer	Status	Product	Announced Size	Last press release
KenGen	Feasibility	Fertilizer	100 MW electrolyzer	July 2022
AMEA Power	Feasibility	TBD	1 GW electrolyzer capacity	September 2023
HDF Energy	Feasibility	Electricity and hydrogen	1 GW solar capacity	November 2024
Talus Renewables	Operational	Fertilizer	1 ton per day	December 2023
Maire Tecnimont	Feasibility	Fertilizer	550 tons per day	May 2021

The current pipeline of announced hydrogen projects in Kenya includes three projects located near Lake Naivasha in the Greater Nairobi area, and two close to the port of Mombasa. Most of these projects align with Kenya's hydrogen strategy, focusing on domestic fertilizer production.

However, a notable gap exists between the scale of the announced projects still in the feasibility stage—each requiring a minimum installed renewable energy capacity of over 100 MW—and the only operational project, Talus Renewables, with an installed solar capacity of approximately 2 MW. This disparity highlights the difficulty, up to now, in reaching final investment decisions for large-scale renewable hydrogen projects in Kenya.



Talus

In October 2023, Talus Renewables announced the deployment of its modular, renewable ammonia system, TalusOne, at the Kenya Nut Company's Morendat Farm in Naivasha. This innovative system, powered by a 2.1 MW solar PV installation, is designed to produce one ton of ammonia per day. Under a 15-year offtake agreement with TalusAg, the Kenya Nut Company—a leading Kenyan multinational agricultural enterprise—will receive carbon-free ammonia at a fixed price. Each ton of renewable ammonia produced by TalusOne is estimated to prevent up to 8 tons of carbon emissions compared to conventional ammonia production methods. Looking ahead, Talus Renewables plans to scale up operations with a 10-ton-per-day facility powered by an 11.5 MW solar PV installation. The Kenya Nut Company has also outlined plans for plant expansion, which is expected to significantly benefit local farmers, particularly subsistence farmers who play a critical role in Kenya's agricultural sector.

Methodology

This report explores viable locations and business cases for renewable hydrogen production in Kenya, with a focus on the renewable hydrogen-to-ammonia pathway.

It also examines the economic potential of processing renewable ammonia into greenhouse gas-neutral fertilizer in Kenya.

A GIS-based analysis of Kenya at a fine spatial resolution of 50 x 50 meters was conducted to identify suitable locations for renewable energy production. It integrated renewable energy potential with constraints arising from the natural and built environment, including factors such as proximity to existing infrastructure, availability of water resources, and protection of natural areas. Seven suitable locations for renewable energy production were identified prior to being reviewed and discussed during a stakeholder engagement workshop attended by approximately 30 Kenyan stakeholders from the public, private and academic sectors. This collaborative process led to the identification of four promising regions for further investigation.

Following this, a site optimization study was conducted to determine the cost-optimal sizes of renewable ammonia production facilities under three scenarios, with electrolyzer capacities of 10 MW, 100 MW, and 500 MW. The economic feasibility of producing renewable ammonia at these locations was assessed through a discounted cash flow analysis. This evaluation highlighted key determining factors and break-even scenarios, outlining the conditions required to establish economically viable business cases. Through this comprehensive analysis, the report sheds light on both the challenges and opportunities associated with establishing renewable ammonia production facilities in different regions of Kenya, offering valuable insights to stakeholders and decision makers.

Renewable energy potential in Kenya: A GIS-enabled map of high potential regions

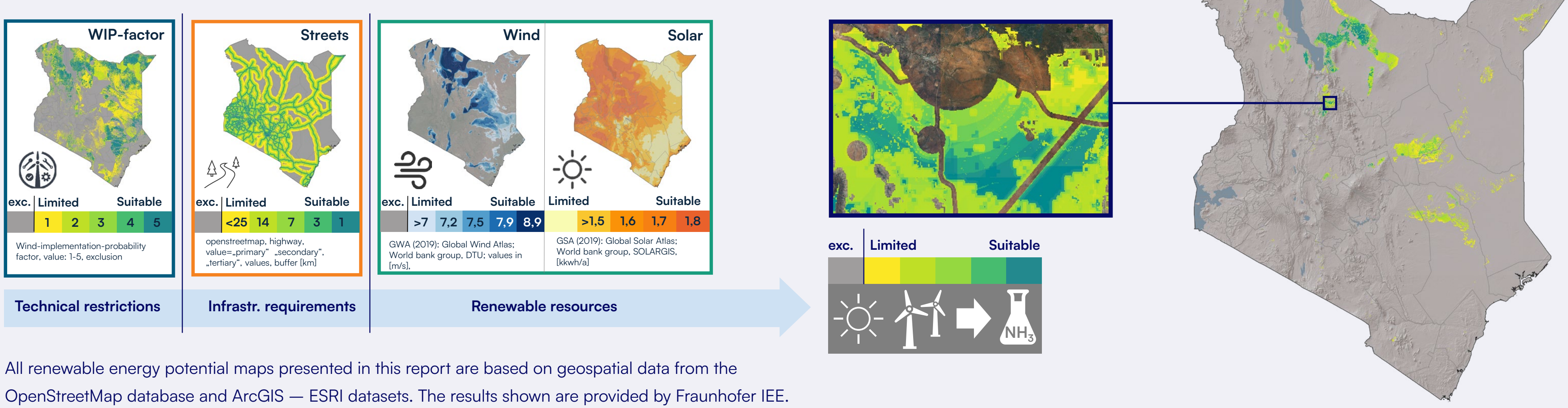
The study evaluated the technical feasibility and implementation potential of wind and solar energy in Kenya using GIS to identify areas with high wind speeds and solar irradiation levels.

These areas were assessed against more than 30 land exclusion criteria, considering constraints from both the natural and built environments, as well as potential land-use conflicts. Based on this analysis, the suitability of eligible locations for renewable energy projects was rated on a scale from 1 (low) to 5 (high).

A subsequent analysis refined the selection of regions by applying distance criteria. Key infrastructure and resources, including open water sources, roads and urban centers, were required to be within a maximum distance of 50 kilometers. Proximity to urban centers and roads ensures accessibility to workers during the construction and operation phases of the projects. Additionally, proximity to open water resources, such as large freshwater lakes and coastal areas, is essential for renewable hydrogen production, to ensure that projects are not dependent on scarce groundwater resources.

The analysis was further refined using the Analytical Hierarchy Process (AHP), which systematically weighs key criteria by integrating expert surveys, ensuring a robust multi-criteria assessment. This approach offers a comprehensive evaluation of Kenya's renewable energy potential, highlighting seven potential sites for renewable energy and ammonia production.

Figure 6: Exemplified GIS selection criteria.



All renewable energy potential maps presented in this report are based on geospatial data from the OpenStreetMap database and ArcGIS — ESRI datasets. The results shown are provided by Fraunhofer IEE.

Stakeholder engagement process

A two-hour online stakeholder engagement workshop was conducted on July 25, 2024, to refine the selection of potential renewable ammonia production sites before conducting further techno-economic analysis.

The workshop was attended by 31 participants representing various sectors in Kenya, including project development companies, government institutions and academia. During the session, detailed factsheets for each of the seven pre-selected sites were presented and thoroughly discussed. Following the discussions, participants were asked to evaluate the suitability of each location.

The results of the stakeholder survey indicate a clear preference for the following four locations: **Kisumu, Mombasa, Turkana Central and Turkana South**. All these locations offer significant potential for renewable energy production from wind and solar. Furthermore, projects in the Turkana South region could leverage the geothermal energy potential of the nearby Rift Valley.

Discussions during the workshop raised concerns about potential land rights conflicts in the Mt. Kenya and Garissa regions. Additionally, access to water for renewable hydrogen production was identified as a key challenge in Kajiado County and Garissa. Garissa faces further limitations due to its lack of road infrastructure, electricity grid connectivity, and potential offtakers.

Figure 7: Overview of analyzed locations for hydrogen-based ammonia production in Kenya.

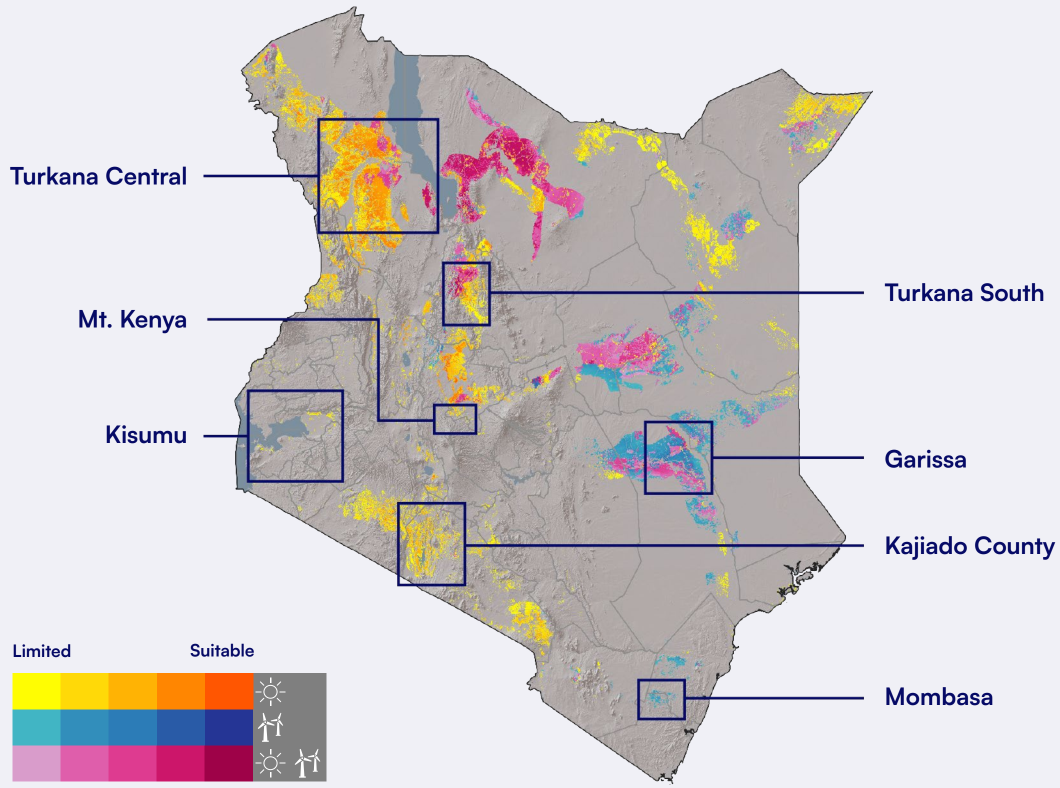
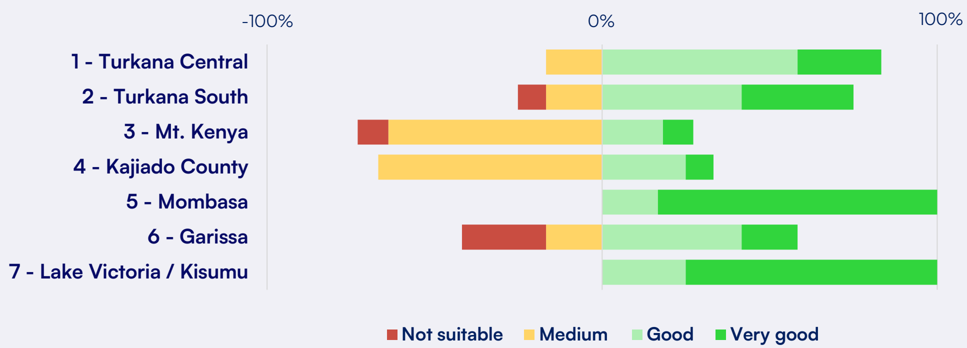


Figure 8: Survey results from stakeholder workshop on the suitability of locations for hydrogen-based ammonia production.



Turkana Central

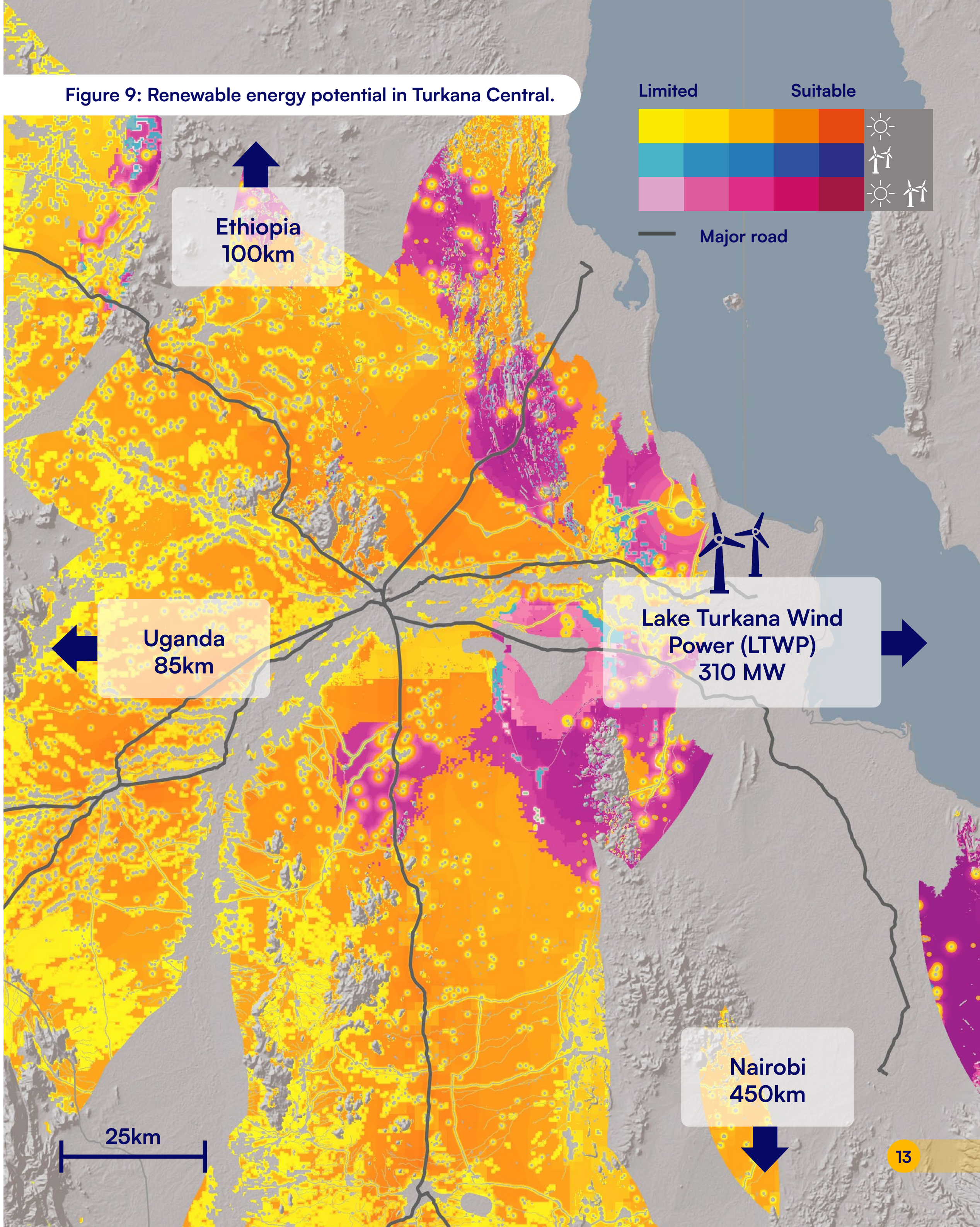
Turkana Central is in Turkana County, in the northwest of Kenya. It is the country's second-largest county by land area, covering approximately 78,000 km², or over 13% of Kenya's surface.

Bordered by Uganda to the west and South Sudan and Ethiopia to the northwest and north, respectively, Turkana County is an expansive region, with its capital at Lodwar, which serves as the main hub.

Advantages and challenges:

- **Water access:** Lake Turkana and the Turkwel River are potential freshwater sources for hydrogen-based ammonia production. However, due to limited local demand for ammonia, production is assumed to be centered near Nairobi, a demand center, where water access is more critical.
- **Infrastructure and accessibility:** Turkana Central, located in a remote area of Kenya approximately 450 km from Nairobi, is connected to the rest of the country via the A1 highway. The town of Lodwar, centrally located within the identified renewable energy production zone, offers essential infrastructure for day-to-day operations. Although a power line is present south of Lake Turkana, significant investment is needed to develop a stable and reliable connection to the national electricity grid.
- **Fertilizer offtake potential:** The Turkana region itself lacks significant local demand for hydrogen, ammonia or fertilizers. Consequently, it is assumed that the renewable electricity generated in the region would be transmitted to Nairobi, the country's economic hub, or to Mombasa for export purposes. As a result, hydrogen-based products, such as ammonia and fertilizers, would be produced closer to these key offtake markets.

Figure 9: Renewable energy potential in Turkana Central.



Site optimization: Turkana Central

The renewable ammonia supply chain consists of several key components: renewable energy generation, hydrogen production via electrolysis, associated water treatment facilities, electrical and hydrogen gas buffer storage, and the Haber-Bosch process for producing hydrogen-based ammonia. In the case of Turkana Central, the electrolyzer and ammonia production facilities—referred to as power-to-X facilities—are situated in the Nairobi region. These power-to-X facilities are connected by a 570 km power line to the renewable energy system in Turkana Central, which will require partial construction under various scenarios.

Solar resources in the region enable solar power plants to operate at rated capacity for 1,848 hours annually, corresponding to a capacity factor of 21%. Similarly, onshore wind farms can operate at a rated capacity for 3,653 hours annually, achieving a capacity factor of 42%.

Figure 10: Investment costs for hydrogen-based renewable ammonia production for three different scenarios of installed electrolyzer capacity in the Turkana Central region: 10 MWel, 100 MWel, and 500 MWel. Grid expansion costs include substation costs. Electrolysis costs include costs for water treatment. Ammonia production costs include costs for air separation unit.

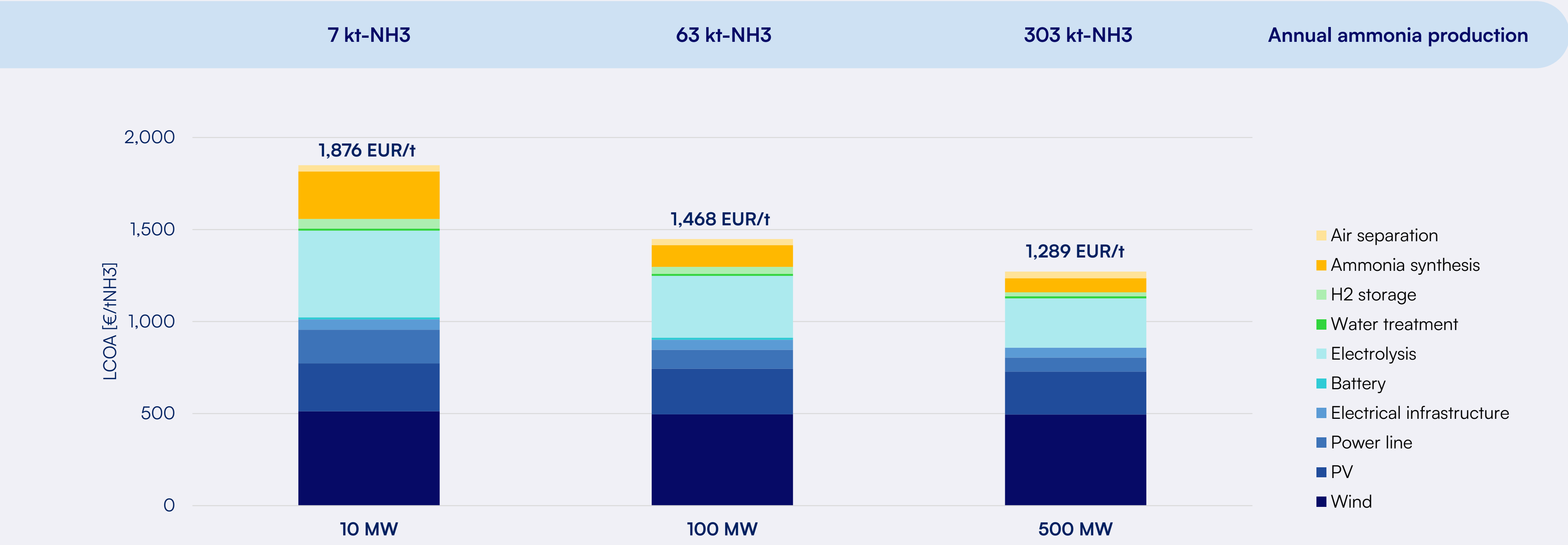
Solar	18 MW | EUR 10 Mio.	165 MW | EUR 93 Mio.	750 MW | EUR 421 Mio.
Wind	15 MW | EUR 18 Mio.	135 MW | EUR 167 Mio.	650 MW | EUR 805 Mio.
Grid expansion	170 km | EUR 9 Mio.	170 km | EUR 52 Mio.	570 km | EUR 250 Mio.
Electrolysis	**10 MW | EUR 15 Mio.**	**100 MW | EUR 103 Mio.**	**500 MW | EUR 392 Mio.**
Battery	1 MWh | EUR 0.4 Mio.	10 MWh | EUR 4 Mio.	0 MWh | EUR 0 Mio.
Hydrogen storage	1.5 t | EUR 2 Mio.	20 t | EUR 15 Mio.	80 t | EUR 42 Mio.
Ammonia production	1.1 t-NH3/h | EUR 11 Mio.	10 t-NH3/h | EUR 55 Mio.	54 t-NH3/h | EUR 198 Mio.
	Total: EUR 66 Mio.	**Total: EUR 489 Mio.**	**Total: EUR 2,107 Mio.**

Levelized costs: Turkana Central

The levelized cost of ammonia in Turkana Central ranges from 1,289 EUR/t for a large-scale project utilizing a 500 MW electrolyzer to 1,876 EUR/t for a small-scale project with a 10 MW electrolyzer. This assessment highlights the significant impact of economies of scale, with a cost-reduction potential of up to 31%. The primary drivers of these reductions are improvements in the costs associated with electrolysis and ammonia synthesis.

The levelized cost of ammonia in Turkana Central ranges from 1,289—1,876 EUR/t.

Figure 11: Levelized cost of renewable, hydrogen-based ammonia.



Turkana South

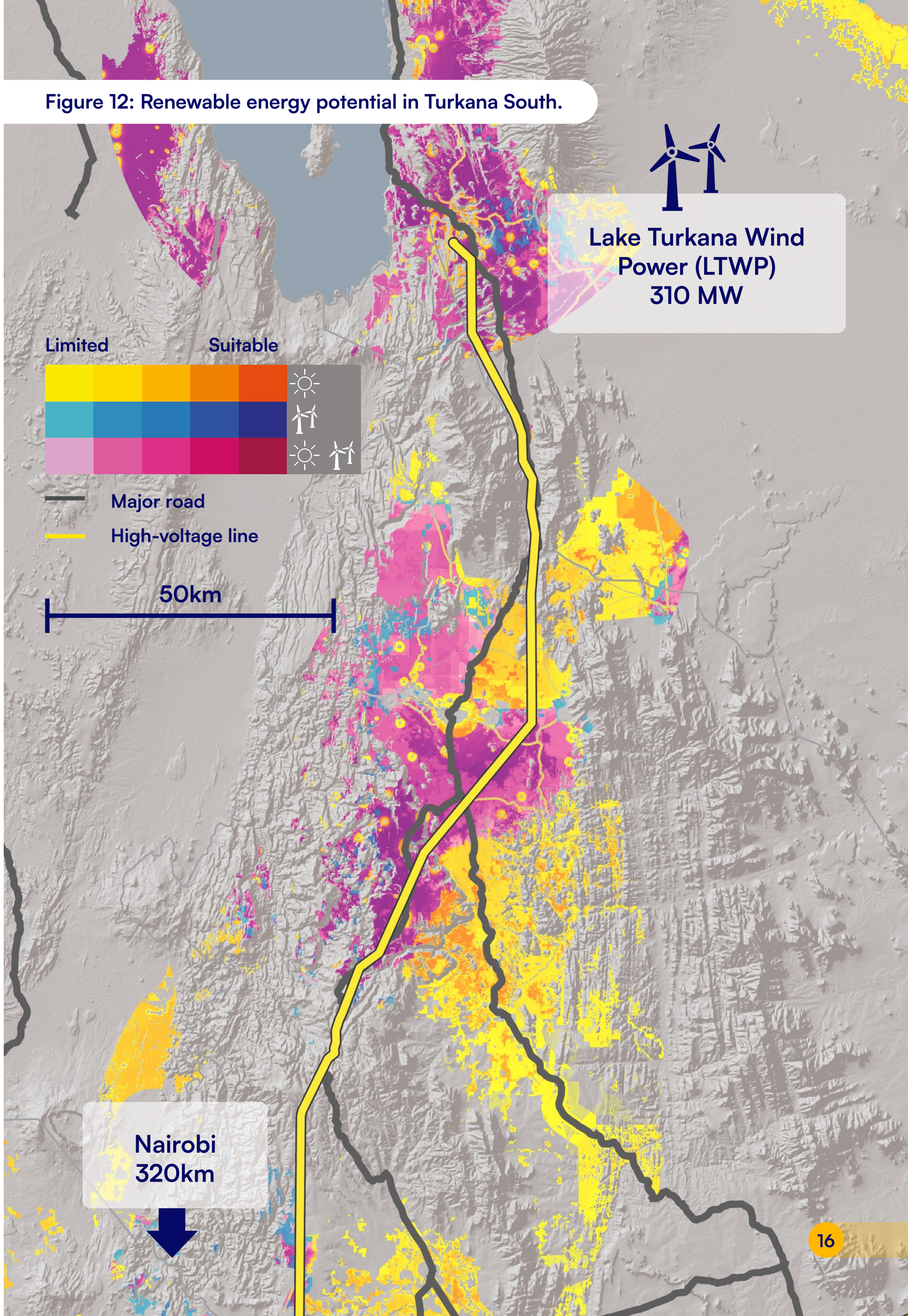
Turkana South is in Turkana County in Northern Kenya.

It lies to the south of Lake Turkana, within the Great Rift Valley, an area rich in geothermal energy resources.

Advantages and challenges:

- **Geothermal energy:** The analyzed region lies within the Great Rift Valley, offering substantial geothermal energy potential. However, precise evaluation of the potential requires ground drilling to obtain direct measurements.
- **Water access:** Lake Turkana is a potential freshwater source for hydrogen-based ammonia production. However, due to limited local demand for hydrogen/ammonia in the area, production is assumed to be centered near Nairobi, a demand center, where water access is more critical.
- **Infrastructure and accessibility:** Like Turkana Central, Turkana South is a remote area of Kenya, located approximately 320 km from Nairobi. The operation of a 310 MW wind farm to the north of the region has facilitated the development of a high-voltage power line nearby. This infrastructure can support small- to medium-scale renewable hydrogen projects. However, large-scale projects (>100 MW) would require additional investment in grid infrastructure to meet their energy demands. Moreover, the role of community conservancies in Kenya—particularly in Turkana South—is a critical factor and should be carefully assessed on a case-by-case basis during project planning and implementation.
- **Ammonia offtake potential:** The Turkana region has minimal local demand for hydrogen, ammonia or fertilizers. As a result, renewable electricity generated in the area is expected to be transmitted to Nairobi, Kenya's economic hub, or to Mombasa, for export. Hydrogen-based products would likely be produced closer to these key offtake markets to optimize logistics and market access.

Figure 12: Renewable energy potential in Turkana South.



Site optimization: Turkana South

The installed capacities and costs of all elements within the ammonia supply chain, linked to renewable energy production in the Turkana South region, are detailed below. This region boasts superior wind resources, with a capacity factor of 58%, which is significantly higher than the wind capacity factors observed in other regions, ranging between 12% and 42%. In contrast, the solar capacity factor is 20%, aligning with the percentages seen in other regions. As a result, the installed wind power capacity is proportionally higher in Turkana South, accounting for 89% of the total installed renewable energy capacity. One scenario considers the region's significant potential for geothermal energy production, assuming a power purchase agreement where geothermal energy is supplied to the power-to-X facilities at a cost of 6.5 EUR-ct./kWh, as estimated by domestic energy experts. This scenario is analyzed in the sensitivity analysis below. The power-to-X facilities, like those in the Turkana Central scenario, are in the Nairobi region. The renewable energy system is connected to the power-to-X facilities via a 440 km power line, which will require either partial or full construction, depending on the specific scenario being considered.

Figure 13: Investment costs for hydrogen-based renewable ammonia production for three different scenarios of installed electrolyzer capacity in the Turkana South region: 10 MWel, 100 MWel, and 500 MWel. Grid expansion costs include substation costs. Electrolysis costs include costs for water treatment. Ammonia production costs include costs for air separation unit.

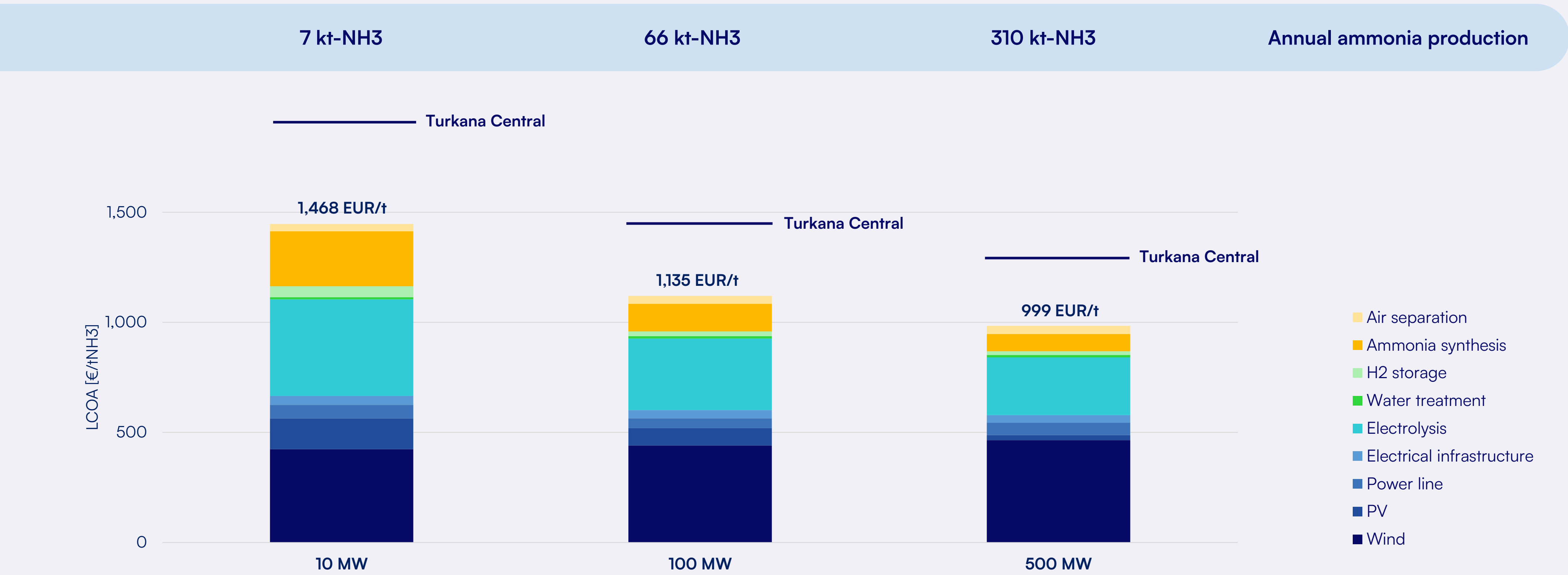
Solar	11 MW | EUR 6 Mio.	55 MW | EUR 31 Mio.	75 MW | EUR 42 Mio.
Wind	13 MW | EUR 16 Mio.	125 MW | EUR 155 Mio.	625 MW | EUR 774 Mio.
Grid expansion	40 km | EUR 15 Mio.	40 km | EUR 22 Mio.	440 km | EUR 180 Mio.
Electrolysis	**10 MW | EUR 15 Mio.**	**100 MW | EUR 103 Mio.**	**500 MW | EUR 392 Mio.**
Battery	0 MWh | EUR 0 Mio.	0 MWh | EUR 0 Mio.	0 MWh | EUR 0 Mio.
Hydrogen storage	1.5 t | EUR 2 Mio.	10 t | EUR 9 Mio.	60 t | EUR 34 Mio.
Ammonia production	1.1 t-NH3/h | EUR 12 Mio.	11 t-NH3/h | EUR 61 Mio.	57 t-NH3/h | EUR 208 Mio.
	Total: EUR 54 Mio.	**Total: EUR 381 Mio.**	**Total: EUR 1,630 Mio.**

Levelized costs: Turkana South

The levelized cost of ammonia (LCOA) in Turkana South ranges from 999 EUR/t for a large-scale project utilizing a 500 MW electrolyzer to 1,468 EUR/t for a small-scale project with a 10 MW electrolyzer. The LCOA for this region is on average 22% lower compared to renewable ammonia production in Turkana Central, due to more beneficial renewable energy resources. At the same time, the observed LCOA of 999 EUR/t is the lowest across all regions analyzed, but is 23% higher than the ex-factory costs of a brownfield project in Egypt, which produces at 811 EUR/t, as recently revealed through auctions conducted by H2Global.[22]

The levelized cost of ammonia in Turkana South ranges from 999—1,468 EUR/t.

Figure 14: Levelized cost of renewable, hydrogen-based ammonia.



Lake Victoria: Kisumu and Homa Bay

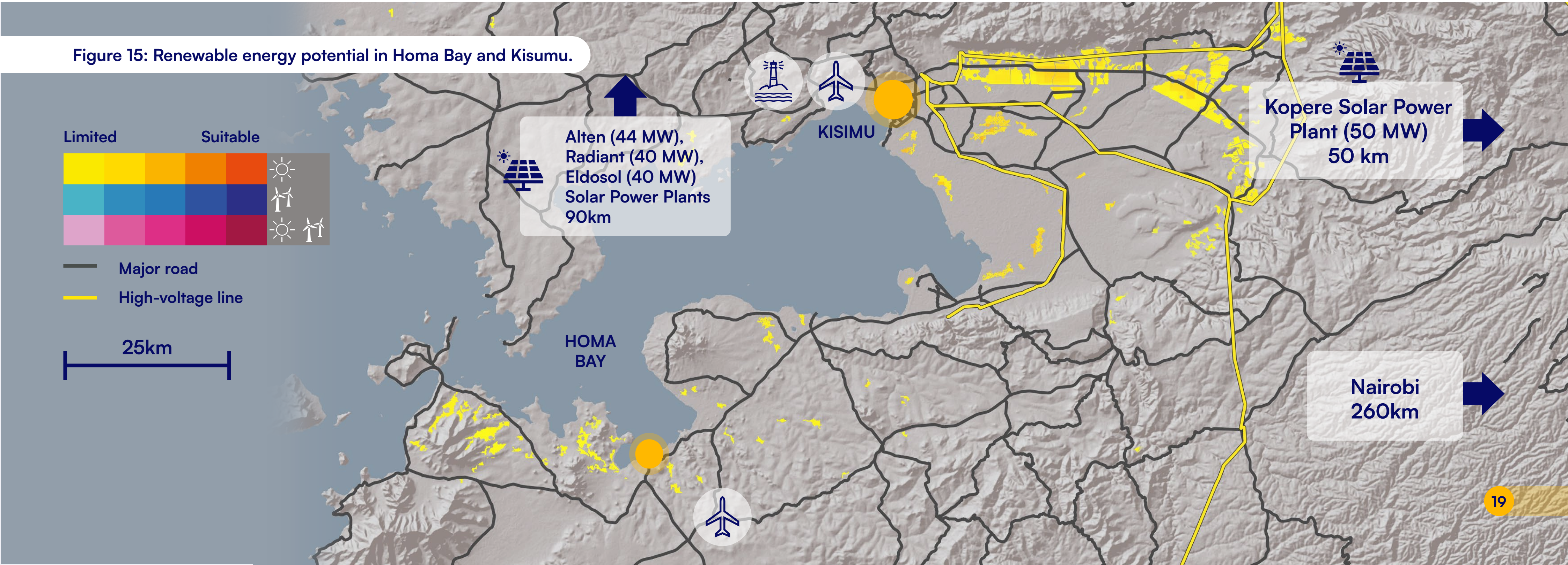
Kisumu and Homa Bay are located on the northeastern shores of Lake Victoria.

Covering approximately 3,200 km², Homa Bay County is home to around 1.1 million people, the same as Kisumu County. The city of Kisumu is also Kenya's third-largest city, with approximately 400,000 inhabitants.

Advantages and challenges:

- **Water access:** The region benefits from proximity to Lake Victoria, a major freshwater source. However, as Lake Victoria is shared by Kenya, Uganda, and Tanzania, any water abstraction must adhere to the regulatory requirements agreed by these nations to ensure sustainable and equitable use.
- **Infrastructure and accessibility:** The region is well connected by road networks, with major routes such as the A104 linking Kisumu to Nairobi and the B3 connecting Homa Bay to Nairobi, supporting efficient transport and distribution logistics. Kisumu, Kenya's third-largest city, offers robust infrastructure and a readily available labor force for the construction and operation of hydrogen projects. Additionally, the port of Kisumu serves as a regional export hub via Lake Victoria. While existing high-voltage power lines can support smaller hydrogen projects, grid expansion will be necessary to accommodate larger-scale developments. Given the region's high population density and extensive agricultural land use, suitable project sites are more dispersed than in other locations and require detailed, site-specific assessments.
- **Ammonia offtake potential:** The site's proximity to key agricultural regions in western Kenya and the Rift Valley, as well as neighboring Uganda, provides a strong potential market for renewable fertilizers.

Figure 15: Renewable energy potential in Homa Bay and Kisumu.



Site optimization: Kisumu

The region's renewable energy potential is limited to solar resources, with a capacity factor of 20%. While this results in the lowest investment costs among all regions, it also leads to the highest volatility in renewable electricity production. To address this challenge, production project(s) have a higher share of installed battery and hydrogen storage systems compared to other regions. In this scenario, the power-to-X facilities are located within the city of Kisumu, leveraging its proximity to the Kisumu port and the local agricultural industry as potential offtake opportunities. The solar power production site is in the Homa Bay region. To connect both sites, a 150 km power line is required in all scenarios.

Figure 16: Investment costs for hydrogen-based renewable ammonia production for three different scenarios of installed electrolyzer capacity in the Kisumu region: 10 MWel, 100 MWel, and 500 MWel. Grid expansion costs include substation costs. Electrolysis costs include costs for water treatment. Ammonia production costs include costs for air separation unit.

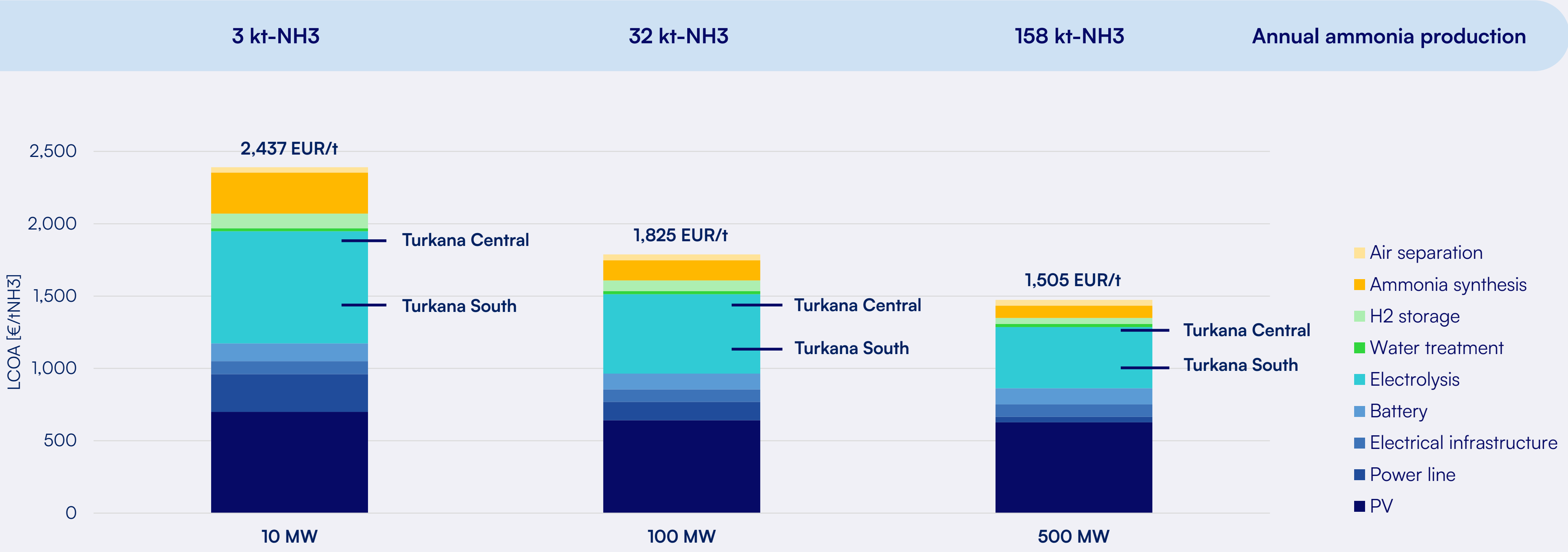
Solar	26 MW | EUR 14 Mio.	220 MW | EUR 123 Mio.	1050 MW | EUR 589 Mio.
Wind	0 MW | EUR 0 Mio.	0 MW | EUR 0 Mio.	0 MW | EUR 0 Mio.
Grid expansion	150 km | EUR 8 Mio.	150 km | EUR 44 Mio.	150 km | EUR 119 Mio.
Electrolysis	**10 MW | EUR 15 Mio.**	**100 MW | EUR 103 Mio.**	**500 MW | EUR 392 Mio.**
Battery	6 MWh | EUR 2 Mio.	50 MWh | EUR 20 Mio.	250 MWh | EUR 100 Mio.
Hydrogen storage	1.5 t | EUR 2 Mio.	20 t | EUR 15 Mio.	80 t | EUR 42 Mio.
Ammonia production	1.5 t-NH3/h | EUR 2 Mio.	20 t-NH3/h | EUR 15 Mio.	80 t-NH3/h | EUR 42 Mio.
	Total: EUR 47 Mio.	**Total: EUR 340 Mio.**	**Total: EUR 1,357 Mio.**

Levelized costs: Kisumu

The levelized cost of ammonia (LCOA) in Kisumu ranges from 1,505 EUR/t for a large-scale project utilizing a 500 MW electrolyzer to 2,437 EUR/t for a small-scale project with a 10 MW electrolyzer. Renewable ammonia production in Kisumu has the highest LCOA among all regions analyzed. This is primarily due to the region's reliance purely on solar power, as it lacks wind resources that could otherwise be leveraged to reduce costs.

The levelized cost of ammonia in Kisumu ranges from 1,505—2,437 EUR/t.

Figure 17: Levelized cost of renewable, hydrogen-based ammonia.



Mombasa

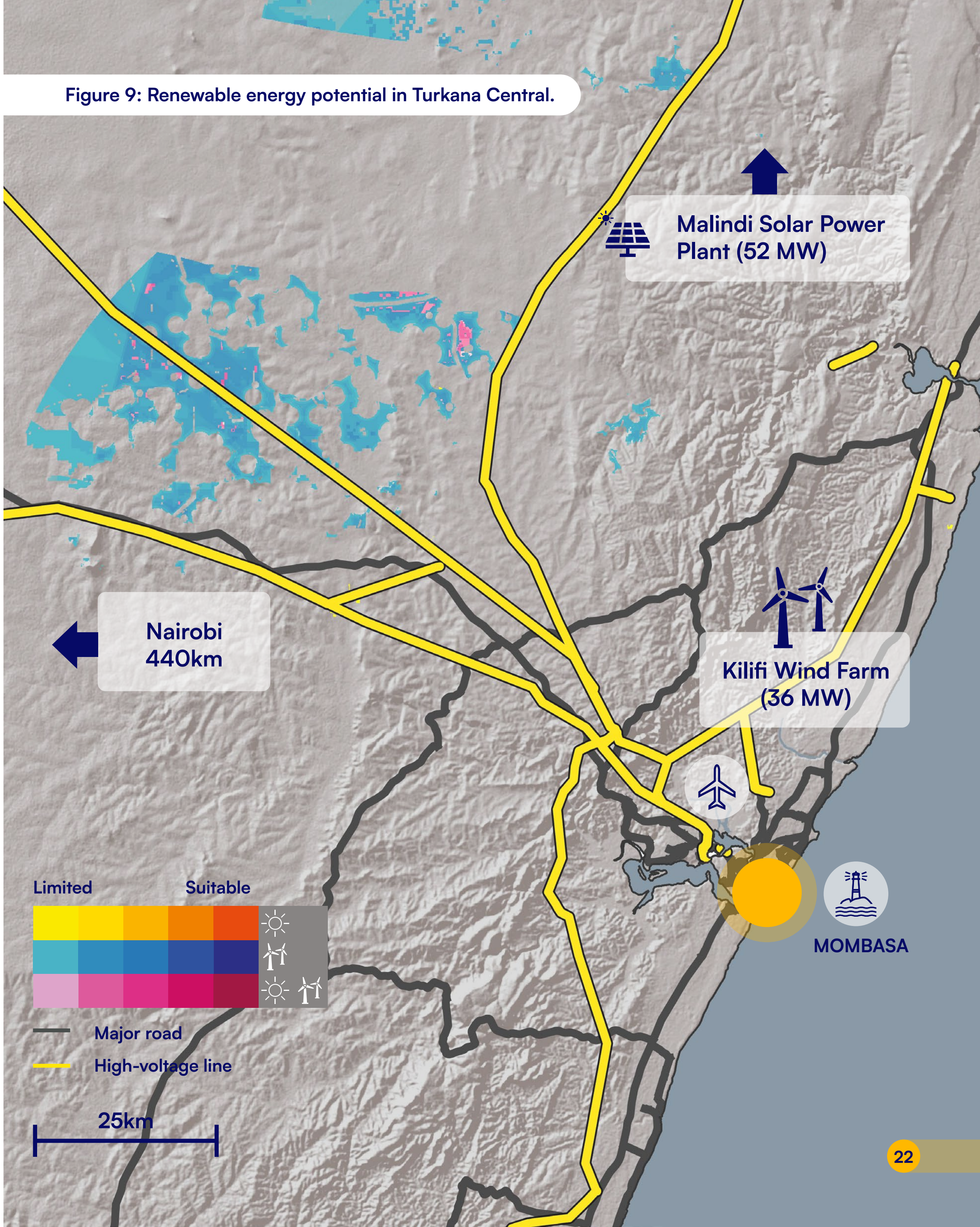
Mombasa, the second-largest city and principal port of Kenya, is located on a coral island within a bay of the Indian Ocean.

The island covers an area of 14 km^2 and is home to 1.2 million inhabitants. It is connected to the mainland (259 km^2) by a causeway, a bridge and a ferry. The area identified as suitable for wind power production lies approximately 45 km northwest of Mombasa.

Advantages and challenges:

- **Water access:** Mombasa and the nearby region identified for wind power production can access the Indian Ocean as a plentiful water source. However, investments in desalination infrastructure and water pipelines will be required to ensure a reliable supply.
- **Infrastructure and accessibility:** The Mombasa region benefits from a well-developed transport infrastructure and a major port, enabling efficient trade with neighboring countries and the global market. Several high-voltage power lines run through the identified wind power region and extend towards Nairobi. While these may meet the needs of small- to medium-scale projects, significant upgrades and investments will be necessary to support large-scale projects.
- **Ammonia offtake potential:** Potential domestic offtakers for renewable fertilizers are located near Kenya's agricultural hub, close to the capital, Nairobi. Mombasa's port provides strategic access to global markets and offers an additional offtake opportunity through ammonia bunkering for the decarbonization of international shipping routes.

Figure 9: Renewable energy potential in Turkana Central.



Site optimization: Mombasa

Mombasa is characterized by its well-developed infrastructure, including a robust electric grid, efficient transport networks, proximity to populated areas, and significant export potential through its port. In this scenario, the power-to-X facilities are in Mombasa and connected to renewable energy production via a 90 km power line, which would need to be extended by a new 40 km power line.

The region offers potential for both wind and solar power generation, with capacity factors of 42% and 16%, respectively, making it a viable location for renewable energy development.

Figure 19: Investment costs for hydrogen-based renewable ammonia production for three different scenarios of installed electrolyzer capacity in the Mombasa region: 10 MWel, 100 MWel, and 500 MWel. Grid expansion costs include substation costs. Electrolysis costs include costs for water treatment. Ammonia production costs include costs for air separation unit.

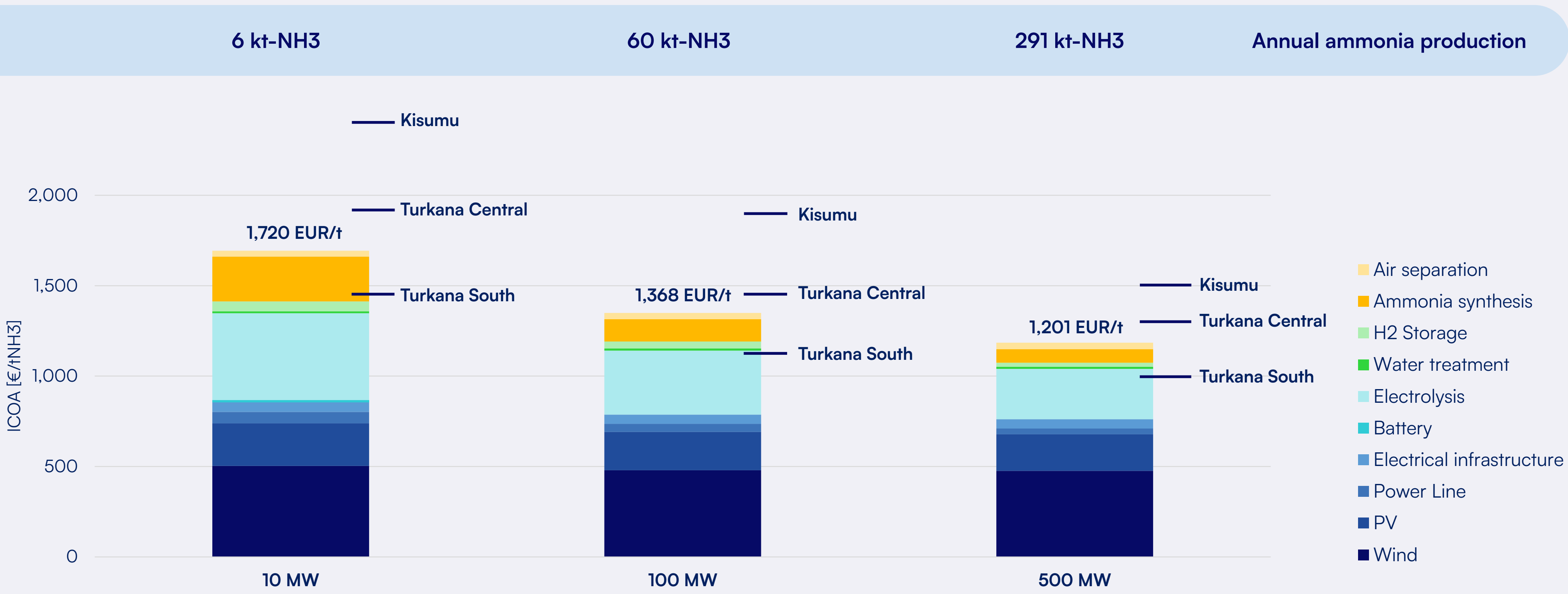
Solar	16 MW	EUR 9 Mio.	135 MW	EUR 76 Mio.	625 MW	EUR 351 Mio.
Wind	14 MW	EUR 17 Mio.	125 MW	EUR 155 Mio.	600 MW	EUR 743 Mio.
Grid expansion	40 km	EUR 4 Mio.	40 km	EUR 40 Mio.	40 km	EUR 98 Mio.
Electrolysis	**10 MW	EUR 15 Mio.**	**100 MW	EUR 103 Mio.**	**500 MW	EUR 392 Mio.**
Battery	1 MWh	EUR 0.4 Mio.	0 MWh	EUR 0 Mio.	0 MWh	EUR 0 Mio.
Hydrogen storage	1.5 t	EUR 2 Mio.	20 t	EUR 15 Mio.	80 t	EUR 42 Mio.
Ammonia production	1.0 t-NH3/h	EUR 10 Mio.	10 t-NH3/h	EUR 55 Mio.	51 t-NH3/h	EUR 187 Mio.
	Total: EUR 58 Mio.	**Total: EUR 430 Mio.**	**Total: EUR 1,813 Mio.**

Levelized costs and annual ammonia production: Mombasa

The levelized cost of ammonia (LCOA) in Mombasa ranges from 1,201 EUR/t for a large-scale project utilizing a 500 MW electrolyzer to 1,720 EUR/t for a small-scale project with a 10 MW electrolyzer. This positions Mombasa as the second most cost-competitive region among those analyzed. Coupled with its favorable infrastructure, these conditions make Mombasa particularly well suited for renewable ammonia production.

The levelized cost of ammonia in Mombasa ranges from 1,201—1,720 EUR/t.

Figure 20: Levelized cost of renewable, hydrogen-based ammonia.

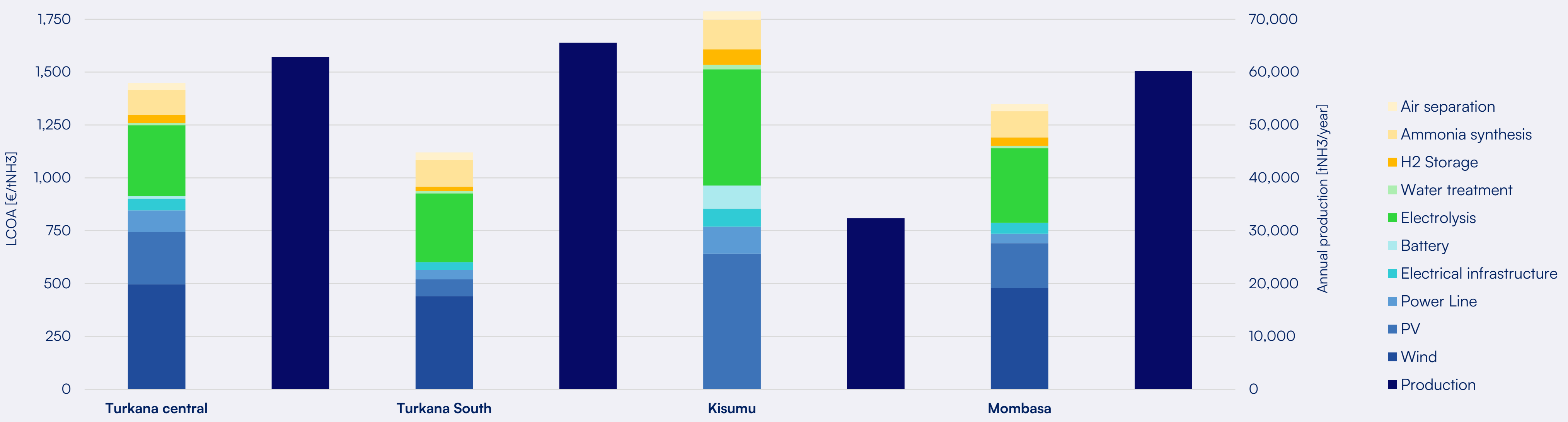


Identifying the most suitable location for renewable ammonia-based fertilizer production in Kenya

The chart illustrates the levelized costs of producing renewable ammonia (LCOA) and the annual production quantities for each region, based on an installed electrolyzer capacity of 100 MW. The lowest LCOA is observed in Turkana South, at 1,135 EUR/ton, which also achieves the highest annual production quantity of 66 kt. Mombasa follows with the second-lowest LCOA of 1,368 EUR/ton, approximately 21% higher than in Turkana South. Turkana Central records an LCOA of 1,468 EUR/ton, while the highest LCOA is calculated for Kisumu at 1,825 EUR/ton. The primary contributors to the LCOA are the investment costs for renewable energy systems and electrolyzers. In Turkana South, Turkana Central and Mombasa, wind and solar investment costs account for 49—54% of the total LCOA, compared to only 36% in Kisumu. The electrolyzer contributes 20—29% of the LCOA across all regions. In addition to investment costs, annual production quantities significantly influence the LCOA. Although Kisumu has the lowest investment costs, it has the highest LCOA, as its annual ammonia production of 32 kt represents only 49—54% of the production levels achieved in the other regions.

According to this analysis, Turkana South and Mombasa are identified as the most suitable regions for renewable ammonia production. Turkana South offers the lowest LCOA, while Mombasa combines the second-lowest LCOA with a well-developed infrastructure, making it ideal for production and offtake activities. However, observed LCOA for Turkana South and Mombasa still range above market prices for fossil-based ammonia[23] by a factor of ~2, exceeding the "green premium" for renewable ammonia which the market is willing to pay. To fill this cost gap, either suitable financial support instruments, such as H2Global's double auction mechanism, must be deployed, or alternative offtake markets, such as processing into value-added products like fertilizers, must be explored.

Figure 21: Overview of the levelized cost of renewable, hydrogen-based ammonia (LCOH), cost-breakdowns and annual production quantities across all four simulated regions in the 100 MWel electrolyzer scenario.



Key factors influencing the business model for renewable ammonia-based fertilizer

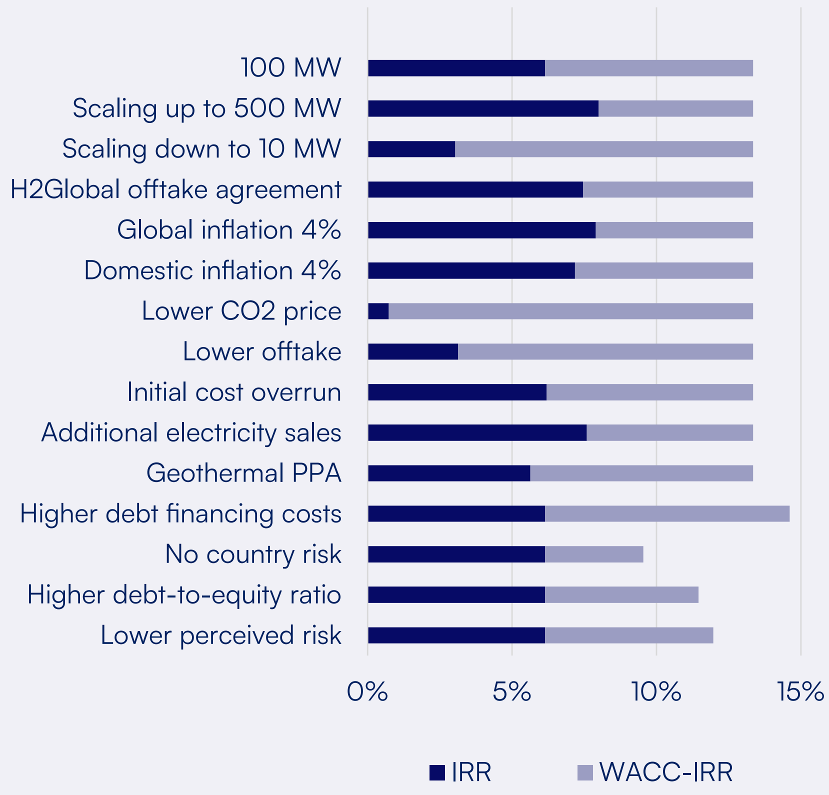
In the previous sections, the analysis highlighted technology costs and site-specific factors, such as wind and solar capacity factors, as key drivers of the levelized cost of ammonia (LCOA).

While critical, these factors are insufficient to assess the business model for renewable ammonia production, which also requires accounting for financial parameters.

The bar chart illustrates the gap between the internal rate of return (IRR) and the weighted average cost of capital (WACC), estimated at 13.34%, under varying financial assumptions for an installed electrolyzer capacity of 100 MW in Turkana South. This analysis assumes an ammonia sales price of 627 EUR/ton for 2030 (adjusted to 2024 EUR). Several factors positively influence the IRR. For example, a 10-year offtake agreement with an entity like Hintco[24], at a fixed ammonia price of 1,000 EUR/ton, significantly improves profitability. Likewise, lower domestic inflation reduces operational expenses, while higher global inflation increases future revenues, further enhancing profitability. Additionally, the option to sell surplus electricity to the public grid improves the internal rate of return (IRR). On the other hand, the IRR is highly sensitive to reductions in carbon pricing or lower offtake volumes, both of which negatively affect project viability. On the financing side, reducing the WACC plays a crucial role in improving project economics. Lower WACC can be achieved by increasing the debt-to-equity ratio or mitigating the risks associated with the project. Additionally, Kenya's perceived country risk significantly drives financing costs, and a reduction in this risk would generate important cost reductions.

Despite these considerations, none of the analyzed projects are economically viable in any of the observed regions if competing with fossil-based ammonia. To achieve bankability—defined as the IRR equaling the WACC—the sales price of renewable ammonia would need to rise to 1,135 EUR/ton for a 100 MW electrolyzer, 1,468 EUR/ton for a 10 MW electrolyzer, and 999 EUR/ton for a 500 MW electrolyzer. Alternatively, reducing the cost of capital to below 8% could render the projects viable.

Figure 22: Sensitivity analysis of the influence of key factors on the project's IRR and WACC in the 100 MWel electrolyzer scenario.



Unlocking the opportunity: renewable fertilizer becomes cost-competitive

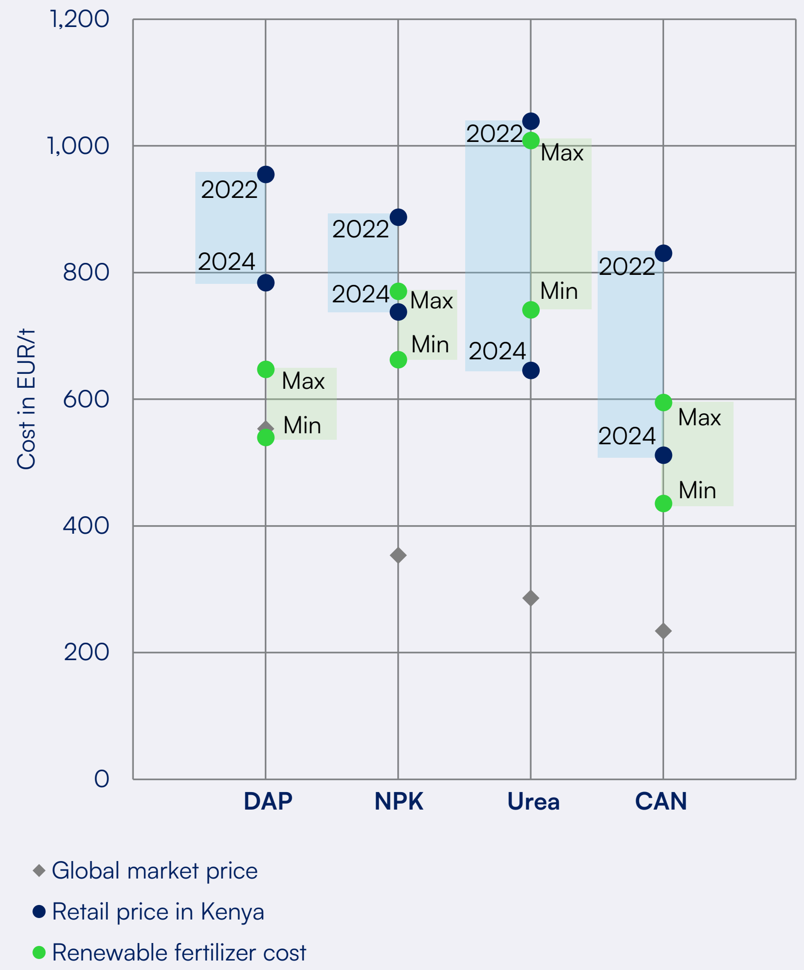
Renewable ammonia is undoubtedly more expensive than conventional ammonia at international market prices.

However, a significant opportunity lies in further processing renewable ammonia to produce fertilizers. The large gap between international market prices and Kenya's retail fertilizer prices provides a potential advantage. The latter are already in a similar range to the production costs of renewable fertilizers. Our analysis demonstrates that for some fertilizer types, renewable production can already be cost-competitive with these retail prices, presenting a viable opportunity for local production.

Based on LCOA calculations, two scenarios were analyzed: a low-cost scenario of 999 EUR/t (for a 500 MW electrolyzer in Turkana South) and a high-cost scenario of 1,468 EUR/t (for a 10 MW electrolyzer in Turkana South). The results indicate that, under the low-cost scenario, renewable fertilizers (DAP, NPK and CAN) are cheaper than local retail prices. For urea, renewable fertilizers are slightly more expensive than retail prices in this scenario. However, in all cases renewable fertilizer prices remain below the record-high levels observed in 2022.

These findings demonstrate that renewable fertilizer production could be a competitive and viable business opportunity in Kenya.

Figure 23: Comparison of the production costs of renewable, hydrogen-based fertilizer versus domestic retail prices of different common fertilizer products in Kenya.



Recommendations and key takeaways

The report identifies four suitable locations for producing renewable hydrogen and ammonia: Turkana Central, Turkana South, Kisumu and Mombasa. All these locations have substantial renewable-energy potential, are in regions with low-potential land-use conflicts, and have access to required infrastructure and large open-water resources.

The levelized costs of producing renewable ammonia vary between 999 EUR/ton using a 500 MW electrolyzer in Turkana South and 2,437 EUR/ton with a 10 MW electrolyzer in Kisumu.

Location	Pro	Con	LCOA [EUR/ton]
Turkana Central	Medium LCOA	Remote region, poor infrastructure, difficult water access	1,289—1,876
Turkana South	Low LCOA, geothermal energy access	Remote region, poor infrastructure, difficult water access	999—1,468
Kisumu	Proximity to regional port, water access	Highest LCOA	1,505—2,437
Mombasa	Medium LCOA, proximity to international port, water access	-	1,201—1,720

Fertilizer opportunity

- Domestic **fertilizer prices in Kenya can absorb the premium cost of renewable ammonia**, a key feedstock for the production of nitrogen-based fertilizers (DAP, NPK and CAN).
- Domestic fertilizer production **decreases dependence on global fertilizer markets**, reduces market price risks, and improves the balance of payments.

Financial support instruments

- **Renewable ammonia projects** could benefit from financial support instruments that leverage **concessional finance** to bridge the green premium and provide long-term offtake certainty.
- **Renewable fertilizer projects** could benefit from financial support mechanisms that mitigate market price risks. With the domestic fertilizer market able to absorb the green premium, this presents an opportunity to **attract private capital**.

Enablers

- Macroeconomic factors, such as domestic inflation and country risk, drive the **cost of capital** and hinder investment.
- **Infrastructure development**, especially the extension of the electric grid, benefits the business case for renewable hydrogen production and associated products.
- New projects should showcase their **social contributions** and impact on **regional development**.

Annex 1: Methodology of GIS analysis

The methodology for the GIS-based land eligibility analysis consists of three main steps:

1. **Calculating the technical renewable energy potential** for wind and solar photovoltaic (PV).
2. **Applying infrastructural and resource constraints**, including distance criteria and a minimum wind speed of 7 m/s (for wind sites), to exclude areas that are too remote or have insufficient wind resources.
3. **Assessing potential areas using an Analytical Hierarchy Process (AHP) score**, which is calculated based on multiple evaluation criteria and weightings derived from expert surveys.

Technical potential analysis

The technical land eligibility assessment follows the methodology established by Zink and Häckner.[25] This approach quantifies the Implementation Probability for wind and solar PV, resulting in Wind and Solar Implementation Probability (WIP/SIP) scores.

To better capture the local conditions in Kenya, additional datasets were incorporated. These supplementary criteria were derived from expert surveys conducted during stakeholder workshops, as well as an extensive literature review. Tables 1 and 2 provide an overview of all criteria and their respective thresholds for calculating the implementation scores.

Table 1: Applied area categories and their distance values for the calculation of the WIP-score.

	Wind implementation value (buffer [m])					
Area category	**Exclusion**	**WIP 1**	**WIP 2**	**WIP 3**	**WIP 4**	**WIP 5**
Residential area	<800	800-1,000	1,000-1,200	1,200-1,400	1,400-1,600	>1,600
Population density [inhabitant/km^2]	>5					
Religious areas, cemeteries, parks	<500	500-600	600-700	700-800	800-900	>900
Industrial and commercial	<400	400-500	500-600	600-700	700-800	>800
Roads, highway, motorway	<150	150-200	200-250	250-300	300-350	>350
Railroads and accompanying areas	<200	200-250	250-300	300-350	350-400	>400
Airports, airfields	<3,000	3,000-4,000	4,000-5,000	5,000-6,000	6,000-7,000	>7,000
Harbors	<500	500-600	600-700	700-800	800-900	>900
Power grid	<100	100-150	150-200	200-250	250-300	>350
High voltage grid	<200	200-300	300-350	350-400	400-450	>450
Substations, transformers	<200	200-300	300-400	400-500	500-600	>600

	Wind implementation value (buffer [m])					
Area category	**Exclusion**	**WIP 1**	**WIP 2**	**WIP 3**	**WIP 4**	**WIP 5**
Pipelines (gas, oil)	<500					
Sealed surfaces	0					
Seismological stations	<3,000	3,000-4,000	4,000-5,000	5,000-6,000	6,000-7,000	>7,000
Radar and rotating beacon	<5,000	5,000-6,000	6,000-7,000	7,000-8,000	8,000-9,000	>9,000
Nature reserves, strictly protected land	0	0-100	100-200	200-300	300-400	>400
Hunting and biosphere reserves, critical habitats	-	-	-	0-100	100-200	>200
Reserves for indigenous peoples	-	-	0	0	0	0
Forests	-	-	-	200-400	200-400	>400
Mixed landcover (forest, cropland)	-	-	-	-	0	0
Mixed landcover (forest, grassland)	-	-	-	0-200	0-200	>200
Soil sand fraction and deserts	0	0	0	0	0	0
Snow and ice areas	<200					
Water surfaces	0	0	0	>50	>50	>50
Wetland, marshland	0					
Agricultural areas	-	-	-	0	0	0
Mining, earth moving areas	<1,000	1,000-1,200	1,200-1,400	1,400-1,600	1,600-1,800	>1,800
Military areas	<1,500	1,500-2,000	2,000-2,500	2,500-3,000	3,000-3,500	>3,500
Areas of historical value	<1,000	1,000-1,200	1,200-1,400	1,400-1,600	1,600-1,800	>1,800
Areas of tourist value	<1,000	1,000-1,500	1,500-2,000	2,000-2,500	2,500-3,000	>3,000
National borders	<1,000					
Slope [in degree]	>5	5-4	4-3	3-2	2-1	<1
Altitude	>3,000					
Calamity areas (volcanoes, avalanches)	<5,000					
Earthquake risk areas	-	-	-	-	0	0
Flood risk areas	0					
Cyclone risk areas	-	-	-	0	0	0
Landslide risk areas	<200					

Table 2: Applied area categories and their distance values for the calculation of the SIP-score.

		Wind implementation value (buffer [m])				
Area category	**Exclusion**	**WIP 1**	**WIP 2**	**WIP 3**	**WIP 4**	**WIP 5**
Residential area	<300	300-400	400-500	500-600	600-700	>700
Population density [inhabitant/km^2]	>5					
Religious areas, cemeteries, parks	<300	300-400	400-500	500-600	600-700	>700
Industrial and commercial areas	<100	100-200	200-300	300-400	400-500	>500
Roads, highways, motorways	<50	50-100	100-150	150-200	200-250	>250
Railroads and accompanying areas	<100	100-150	150-200	200-250	250-300	>300
Airports, airfields	<1,000	1,000-1,200	1,200-1,400	1,400-1,600	1,600-1,800	>1,800
Harbors	<100	100-200	200-300	300-400	400-500	>500
Power grid	<100	100	100	100	100	100
High voltage grid	<150	150-200	200-250	250-300	300-350	>350
Substations, transformers	<100					
Pipelines (gas, oil)	<100					
Sealed surfaces	0					
Seismological stations	<200					
Radar and rotating beacon	<200					
Nature reserves, strictly protected land	0	0	100-200	200-300	300-400	>400
Hunting and biosphere reserves, critical habitats	-	-	-	0	0-100	>100
Indigenous areas	0					
Forests	200					
Mixed landcover (forest, cropland)	200					
Mixed landcover (forest, grassland)	-	-	0	200	200	200
Soil sand fraction	0					
Snow and ice areas (permanent)	200					
Water surfaces	0	0	0	50	50	50
Wetland, marshland	0	0	100	100	100	100
Agricultural areas	-	-	0	0	0	0
Mining areas	<500	500-600	600-700	700-800	800-900	>900

	Wind implementation value (buffer [m])					
Area category	**Exclusion**	**WIP 1**	**WIP 2**	**WIP 3**	**WIP 4**	**WIP 5**
Military areas	<1,000	1,000-1,500	1,500-2,000	2,000-2,500	2,500-3,000	>3,000
Areas of historical value	<500	500	500	1,000	1,000	1,000
Areas of tourist value	<500	500	750	1,000	1,250	1,500
National borders	<1,000					
Maximum Slope	>5	5-4	4-3	<3	<3	<3
Maximum Altitude	>3,000					
Calamity areas (volcanoes, avalanches)	5,000					
Earthquake risk areas	-	-	-	-	0	0
Flood risk areas	0					
Cyclone risk areas	-	-	-	0	0	0
Landslide risk areas	<200					

A "-" indicates that the criterion does not apply to the respective WIP/SIP score. An empty cell signifies that the thresholds for WIP/SIP scores are identical to those used for exclusion criteria, but with the comparison operator reversed where applicable.

Infrastructure and wind resource limits

Several infrastructure-related criteria have been identified as relevant for the production of power-to-X (PtX) fuels using renewable electricity. These criteria account for both the availability of feedstock for hydrogen production and the construction, operation and maintenance of production facilities. Key considerations include the distance to the nearest freshwater sources (such as rivers or major lakes) and the proximity to the coastline for seawater desalination. To ensure economic viability and avoid locations with insufficient wind resources, a minimum wind speed threshold is applied. This threshold is based on the long-term average wind speed at a hub height of 150 meters. For photovoltaic (PV) energy, a minimum irradiation criterion is not applied, as the predicted PV output is estimated to exceed 1,200 kWh/kWp across the study area. The maximum distance values for infrastructure criteria were derived from a literature review of scientific studies employing similar methodologies.

Table 3: Infrastructure and windspeed limits applied during the GIS analysis.

Criteria	Limit
Distance to the next town/city	50 km
Distance to the next major road	25 km
Distance to the next water source	50 km
Minimum windspeed (on 150 m HH)	7 m/s

Evaluating potential areas

The evaluation of identified potential areas is conducted using the Analytical Hierarchy Process (AHP). A pairwise comparison matrix was created for all relevant evaluation criteria and distributed to internal and external experts for feedback. The responses were used to calculate weighting factors, which were rounded to the nearest whole number to ensure that the total did not exceed 100%. Separate weighting factors were assigned and calculated for PV, wind and hybrid sites.

To enable the aggregation and scaling of evaluation criteria, they were reclassified in advance, as seen in Table 4. Each criterion was categorized into suitability intervals, ranging from 1 (lowest suitability) to 5 (highest suitability). For example, the distance to the nearest water source was divided into several intervals, with 0—10 km representing the highest suitability category (Score: 5) and 40—50 km representing the lowest suitability category (Score: 1). All thresholds and corresponding scores are detailed in Table 4.

Values that fall outside the lowest suitability range are assigned an AHP category score of 0, meaning they do not contribute to the overall score for the corresponding pixel.

The criteria related to renewable resources, and implementation probability scores are applied only to their respective potential analyses (e.g., irradiation and SIP scores apply only to PV and hybrid sites).

The literature review on maximum distance criteria also provided reference values for the corresponding suitability intervals. For renewable resource availability, suitability categories were established based on the 20th, 40th, 60th and 80th percentiles, as well as the maximum value of the long-term average wind speed.[26] Only areas with wind speeds exceeding the minimum threshold of 7 m/s were considered in this classification. Water stress levels are represented using baseline water stress data.[27] To enhance accuracy, the population density dataset was further processed using internal models that incorporate values from neighboring pixels. This approach ensures that the population density of a given pixel also reflects the density of its surrounding areas, preventing abrupt transitions in population density values.

Table 4: Suitability class interval limits used for the area evaluation using the AHP.

Criterion	Best suitability (score 5)	High suitability (score 4)	Good suitability (score 3)	Moderate suitability (score 2)	Limited suitability (score 1)	Source of data
Windspeed [m/s]	8.95-20.6	7.88-8.95	7.48-7.88	7.2-7.48	7-7.2	[28]
Solar energy output [kWh/kWp]	1,765-1,941	1,685-1,765	1,610-1,685	1,562-1,610	1,200-1,562	[29]
Water stress	0-0.1	0.2-0.4	0.4-0.6	0.6-0.8	0.8-1	[30]
Distance to water source [km]	0-10	10-20	20-30	30-40	40-50	[31]
Population density [inhabitants/km²]	0-10	10-20	20-30	30-40	40-50	[32]
Distance to major roads [km]	0-1	1-3	3-7	7-14	14-25	[33]
Distance to HV electricity lines [km]	0-1	1-3	3-9	9-16	16-30	"
Distance to the next town/city [km]	0-3	3-7	7-15	15-30	30-50	"
WIP-score	5	4	3	2	1	[34]
SIP-score	5	4	3	2	1	"

Figure 24 presents the results of the reclassification process, illustrating how each criterion was categorized based on the defined rules.

Figure 24: Maps of the reclassified evaluation criteria.

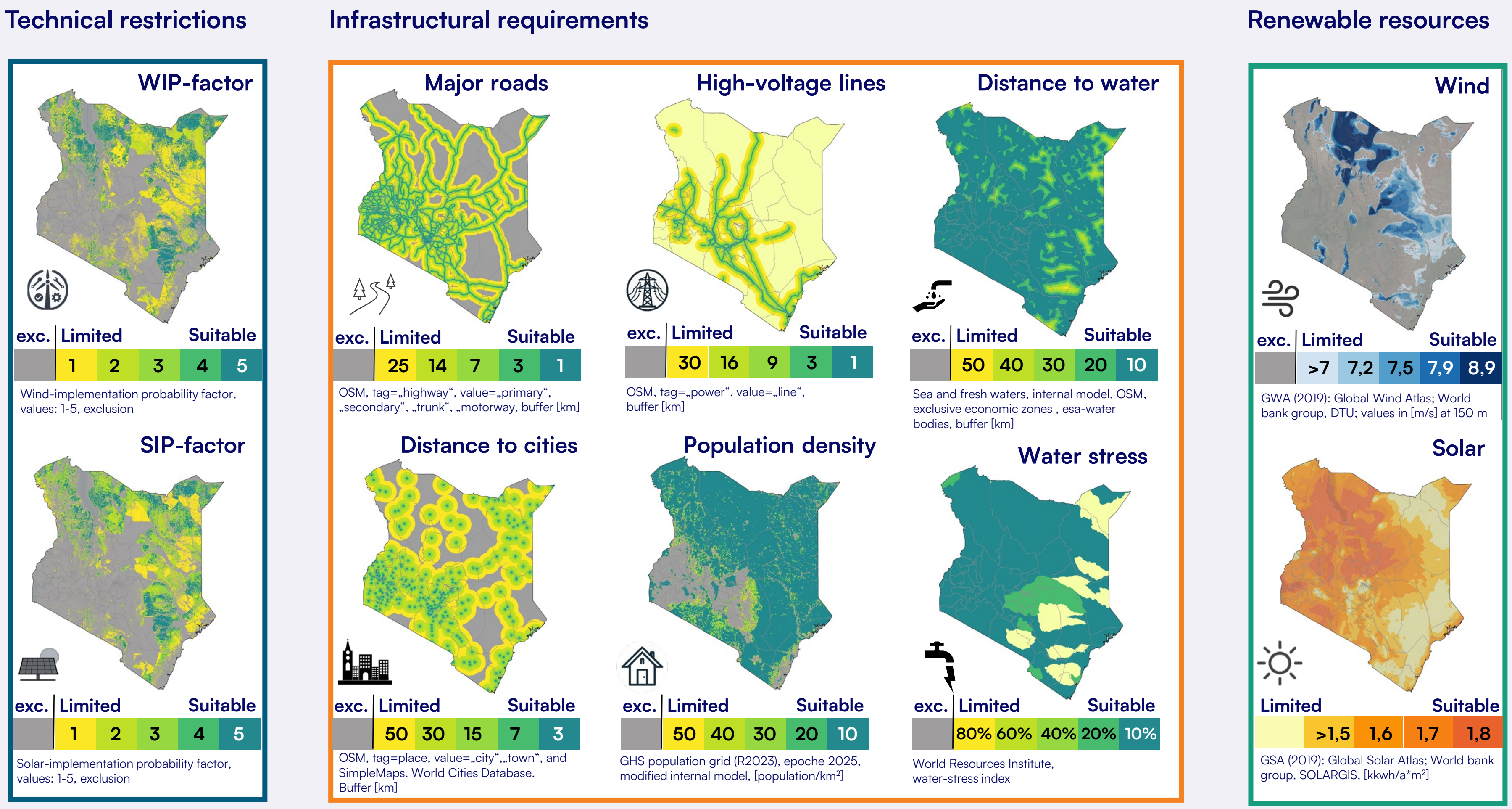


Table 5: Weighting factors for each criterion used for the AHP calculation.

Criteria	Hybrid	Wind	PV
Windspeed	19%	31%	Not used
Solar energy output	19%	Not used	34%
Water stress	6%	7%	8%
Distance to water source	5%	6%	6%
Population density	6%	8%	7%
Distance to major roads	4%	9%	7%
Distance to HV electricity lines	8%	11%	9%
Distance to the next town/city]	5%	6%	5%
WIP-score	14%	22%	Not used
SIP-Score	14%	Not used	24%

The overall AHP score for each pixel is calculated by multiplying the weighting factor of each criterion by its corresponding AHP score. The resulting values are then summed up to obtain the final AHP score for that pixel. This process is conducted separately for PV, wind and hybrid sites. The AHP scores were then used to identify the most suitable clusters, considering only the top 50% of evaluated locations. These high-scoring areas were presented to local stakeholders during the workshop for further discussion and validation.

Annex 2: Financial assumptions

Technology		CAPEX	OPEX [% of CAPEX]	Technical lifetime	Efficiency	Reference
PV		561,068 €/MW	1.7	25 years	-	[35]
Onshore wind		1,238,092 €/MW	2.8	25 years	-	
Electrolysis	10 MW*	1,500,000 €/MW	2	90,000 hours	67%	[36]
	100 MW*	1,000,000 €/MW				
	500 MW*	750,000 €/MW				
Battery		400,000 €/MWh	1.5	15 years	95%	[37]
Hydrogen storage		Variable	1	30 years	-	[38]
Haber-Bosch	10 MW*	9,095,944 €/(tNH3/h)	2	30 years	Electric energy demand: 0.44 MWh/tNH3	[39]
	100 MW*	4,234,968 €/(tNH3/h)				
	500 MW*	2,481,945 €/(tNH3/h)				
Air separation unit		1,450,000 €/(tN2/h)	2	30 years	Electric energy demand: 0.2 MWh/tNH3	[40]
Water treatment		9.5 €/(tH2O/a)	4	30 years	Electric energy demand: 4.5 kWh/m^{3}H2O	[41]
Power line	10 MW*	40,000 €/km	0.7	40 years	Losses: 1.1%/100 km	[42]
	100 MW*	185,000 €/km				
	500 MW*	270,000 €/km				
Grid substation		49,283 €/MW	-	40 years	99.5%	

*: Indicates the installed capacity of the electrolyzer in the three different scenarios being observed.

Annex 3: Net-present value and cost of capital

The calculation of a project's net-present value (NPV) is based on the concept of discounting all nominal future cashflows—positive and negative—that are forecasted over the depreciation period of the project to the year of the initial investment:

$$NPV = S_0 - I_0 + \sum_{t=0}^{T} \frac{R_t - I_t + S_t}{(1 + WACC)^t} \qquad \text{Eq. 1}$$

with:

T : Depreciation period

I_0 : Initial investment costs (CAPEX)

S_0 : CAPEX subsidy

R_t : Revenue in year t

S_t : Subsidy in year t

V_t : Residual value in the last year T

$WACC$: Weighted Average Cost of Capital

The WACC reflects the financing costs of a project. Its calculation is based on an estimation of the associated project risks.

$$WACC = C_e * \alpha_e + C_d * \alpha_d \qquad \text{Eq. 2}$$

with:

C_e, C_d : Cost of equity and cost of debt

α_e, α_d : Share of equity capital (assumed to 40%) and share of debt capital (assumed to 60%).

And:

$$C_e = R_{free} + \beta * ERP + CRP \qquad \text{Eq. 3}$$

with:

R_{free} : Risk-free rate of return. Assumed to 4.5%, based on the average return of 10y-US treasury bonds.

β : Beta-factor, indicating the risk premium of the sector compared to the overall market. Assumed to 1.058 according to Damodaran.[43]

ERP : Equity-risk premium, indicating the risk premium of the overall market. Assumed to 6.5%, based on the long-term average return of the US stock market.

CRP : Country-risk premium, indicating the risk-premium due to additional country-specific risk factors such as political stability, is assumed to 9.51% according to Damodaran.[44]

Finally, the cost of debt is calculated as follows:

$$C_d = R_{debt} * (1 - Tax) \qquad \text{Eq. 5}$$

with:

R_{debt} : Interest rate. Assumed to 5% (=3% long-term SWAP-rate + 2% credit margin)

Tax : Corporate tax rate. Assumed to 30% for Kenya according to Damodaran.[45]

Annex 4: Renewable fertilizer price calculation

This is the equation for the cost of the renewable fertilizer diammonium phosphate (DAP):

$$Cost_{DAP} = 0.23 * Cost_{Ammonia} + 0.47 * Cost_{Phosphoric\ acid} + Fixed\ Cost_{DAP} \quad \text{Eq. 6}$$

This is the equation for the cost of the renewable fertilizer NPK:

$$Cost_{NPK} = 0.23 * Cost_{Ammonia} + 0.6 * Cost_{Phosphoric\ acid} + 0.23 * Cost_{Potassium\ oxide} + Fixed\ Cost_{NPK} \quad \text{Eq. 7}$$

This is the equation for the cost of the renewable fertilizer urea:

$$Cost_{Urea} = 0.57 * Cost_{Ammonia} + 0.74 * Cost_{CO2} + Fixed\ Cost_{Urea} \quad \text{Eq. 8}$$

This is the equation for the cost of the renewable fertilizer calcium ammonium nitrate (CAN)

$$Cost_{CAN} = 0.34 * Cost_{Ammonia} + 0.2 * Cost_{CaCO3} + Fixed\ Cost_{CAN} \quad \text{Eq. 9}$$

Input data	Value	Comment	Source
Cost ammonia_low	1,000 €/t	Calculation results	H2Global/Fraunhofer IEE
Cost ammonia_high	1,500 €/t	Calculation results	H2Global/Fraunhofer IEE
Cost phosphoric acid	554 €/t	Average in 2024 for Africa	46
Cost potassium oxide	221 €/t	Average in Jan—Oct 2024 for "Potash Granular MOP bulk fob Baltic"	47
Cost CO2	20.8 €/t	Average of biogenic CO2: 15—30 USD/t	48
Cost calcium carbonate	231 €/t	Average in 2024 for Africa	49

Input data	Value	Comment	Source
Fixed cost DAP, NPK, CAN	50 €/t		50
Fixed cost urea	157 €/t		
Ammonia consumption per ton DAP	0.23		
Phosphoric acid consumption per ton DAP	0.47		
Ammonia consumption per ton NPK	0.23		
Phosphoric acid consumption per ton NPK	0.6		
Potassium oxide consumption per ton NPK	0.23		
Ammonia consumption per ton urea	0.57		
Carbon dioxide consumption per ton urea	0.74		
Ammonia consumption per ton CAN	0.34	Based on stoichiometric calculation	H2Global
Calcium carbonate consumption per ton CAN	0.2	Based on stoichiometric calculation	H2Global
DAP international price 2024	554 €/t		51
DAP retail price Kenya 2024	784 €/t		
DAP retail price Kenya 2022	955 €/t		
NPK international price 2024	354 €/t	Average price of MOP, urea & DAP)	
NPK retail price Kenya 2024	738 €/t		
NPK retail price Kenya 2022	888 €/t		
Urea international price 2024	286 €/t		
Urea retail price Kenya 2024	646 €/t		
Urea retail price Kenya 2022	1,039 €/t		
CAN international price 2024	234 €/t		52
CAN retail price Kenya 2024	512 €/t		53
CAN retail price Kenya 2022	831 €/t		
Exchange rate 2024 $/€	1.0838 $/€		54

Annex 5: Water consumption

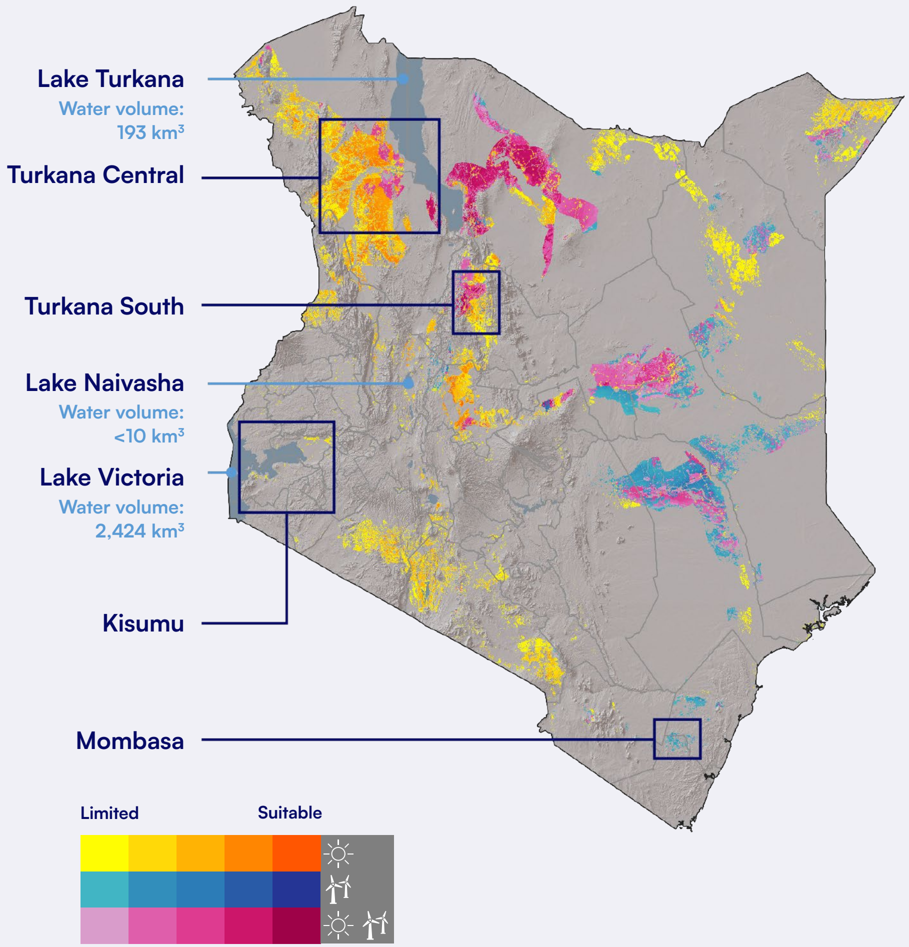
The production of renewable hydrogen via water electrolysis requires water in a stoichiometric ratio of approximately 9 liters per kilogram of hydrogen.

However, due to process losses and inefficiencies, the actual water demand can increase to 20—30 liters per kilogram of hydrogen.[55]

In this analysis, we assume that the electrolysis facilities are co-located with large open freshwater sources or near the coast, where desalinated seawater can be utilized. The primary freshwater sources considered within Kenya include Lake Turkana[56] in the north, Lake Victoria[57] in the west, and Lake Naivasha[58], located near the capital, Nairobi. The annual water demand of the modeled PtX (power-to-X) projects ranges from approximately 15 million liters for a 10 MWel electrolyzer in Kisumu to around 1,378 million liters for a 500 MWel electrolyzer in Turkana South.* When compared to the total volume of Lake Naivasha—the smallest of the freshwater sources analyzed—this corresponds to only 0.00015% to 0.01378% of the lake's total water volume. This suggests that the annual water demand of the modeled PtX projects is unlikely to have a significant impact on the availability of these freshwater resources.

Nevertheless, water consumption must be carefully assessed during project development. Lake Naivasha, for example, has experienced fluctuating water levels in recent decades and is already under pressure from nearby water-intensive industries relying on the lake as a key resource. In the case of Lake Victoria and Lake Turkana, the use of water for industrial purposes may also require cross-border coordination and permission processes, as these lakes extend beyond Kenya's national boundaries.

Figure 25: Location and size of freshwater lakes in Kenya.



Endnotes

1 Swetha Ravikumar Bhagwat and Maria Olczak, 'Green Hydrogen: Bridging the Energy Transition in Africa and Europe', 2020, doi:10.2870/126402.

2 'Baseline Study on the Potential for Power-to-X in Kenya' (Ministry of Energy and Petroleum Kenya, January 2022) <https://energy.go.ke/sites/default/files/KAWI/Other%20Downloads/Baseline%20Study%20on%20the%20Potential%20for%20Power-to-X%20(Green%20Hydrogen)%20in%20Kenya_Final%20Report.pdf>.

3 Sector Analysis - Kenya: Green Hydrogen for the C&I Sector (GIZ) <https://www.giz.de/de/downloads/giz2023-en-h2pep-sector-analysis-kenya.pdf> [accessed 21 February 2024].

4 Innovation Outlook: Renewable Ammonia (IRENA, AEA, 2022) <https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2022/May/IRENA_Innovation_Outlook_Ammonia_2022.pdf?rev=50e91f792d3442279fca0d4ee24757ea>.

5 The Africa Hydrogen Opportunity (Hydrogen Council, McKinsey & Company, March 2024).

6 Africa Energy Outlook (IEA, 2022) <https://www.iea.org/reports/africa-energy-outlook-2022>.

7 Africa's Extraordinary Green Hydrogen Potential (African Union, International Solar Alliance, European Investment Bank, 2024) <https://www.eib.org/attachments/press/africa-green-hydrogen-flyer.pdf>.

8 Laima Eicke and Nicola De Blasio, 'Green Hydrogen Value Chains in the Industrial Sector—Geopolitical and Market Implications', Energy Research & Social Science, 93 (2022), p. 102847, doi:10.1016/j.erss.2022.102847.

9 Sector Analysis - Kenya: Green Hydrogen for the C&I Sector.

10 Swetha RaviKumar Bhagwat and Maria Olczak, Green Hydrogen: Bridging the Energy Transition in Africa and Europe (Florence School of Regulation, 2020).

11 Just Transition in a Renewable Energy Rich Environment - Potential Role of Green Hydrogen (African Development Bank; Climate Investment Funds, 17 November 2022) <https://www.afdb.org/en/documents/just-transition-renewable-energy-riche-environment-potential-role-green-hydrogen>.

12 Ministry of Energy and Petroleum Kenya, 'Green Hydrogen and Strategy Roadmap for Kenya', September 2023.

13 Kenya Energy Transition and Investment Plan 2023-2050 (Ministry of Energy and Petroleum, Kenya) <https://energy.go.ke/sites/default/files/KAWI/Other%20Downloads/Kenya%20ETIP%202050%20-%20full%20doc_final%20231023.pdf>.

14 International Fertilizer Association, 'Organic and Mineral Fertilizers' <https://www.fertilizer.org/about-fertilizers/organic-and-mineral-fertilizers/> [accessed 10 December 2024].

15 The Fertilizer Institute, 'Intro to Fertilizer' <https://www.tfi.org/why-fertilizer/intro-to-fertilizer/> [accessed 10 December 2024].

16 Fertilizer Basics <https://www.fertilizerseurope.com/wp-content/uploads/2019/08/Fertilizer_Basics.pdf> [accessed 2 December 2024].

17 statista, 'Phosphate Rock Production Worldwide in 2023, by Country', 4 November 2024 <https://www.statista.com/statistics/681617/phosphate-rock-production-by-country/>; statista, 'Leading Potash Producing Countries Worldwide in 2023', 19 April 2024 <https://www.statista.com/statistics/1376220/worldwide-largest-potash-producing-nations/>.

18 Africa Fertilizer, 'Fertilizer Availability' <https://viz.africafertilizer.org/#/kenya/availability> [accessed 11 December 2024]; AfricaFertilizer, 'Kenya Country Overview' <https://viz.africafertilizer.org/#/kenya/wpContentPage/country-overview> [accessed 11 December 2024].

19 AfricaFertilizer, 'Fertilizer Price Data' <https://viz.africafertilizer.org/#/kenya/price> [accessed 11 December 2024].

20 Minjingu Mines & Fertilizer Limited, 'About Us' <https://www.minjingumines.com/about.html> [accessed 11 December 2024]; USGS, Minerals Yearbook 2023: Phosphate Rock, 5 September 2024 <https://view.officeapps.live.com/op/view.aspx?src=https%3A%2F%2Fd9-wret.s3.us-west-2.amazonaws.com%2Fassets%2Fpalladium%2Fproduction%2Fs3fs-public%2Fmedia%2Ffiles%2Fmyb1-2023-phosp-ert.xlsx&wdOrigin=BROWSELINK>.

21 Hongwei Sun and others, 'A Review of the Geological Characteristics and Resource Potential Analysis of Potash Deposits in Africa', Journal of African Earth Sciences, 213 (2024), p. 105226, doi:10.1016/j.jafrearsci.2024.105226; USGS, 'Potash Statistics and Information' <https://www.usgs.gov/centers/national-minerals-information-center/potash-statistics-and-information> [accessed 11 December 2024].

22 Riham Alkousaa, 'Germany Awards Tender to Fertiglobe for Green Ammonia from Egypt', Reuters, 11 June 2024 <https://www.reuters.com/sustainability/climate-energy/germany-awards-tender-fertiglobe-green-ammonia-egypt-2024-07-11/>.

23 The comparison assumes a reference price of 627 EUR/t in 2030 for fossil-based ammonia.

24 Hintco, the hydrogen intermediary company and a wholly owned subsidiary of the H2Global Foundation, creates markets by trading clean hydrogen, its derivatives, and other low-emission fuels. Hintco stimulates clean energy markets by securing production through long-term purchase agreements and selling via short-term contracts, accelerating the global energy transition. To bridge the gap between the purchase and sale prices of clean fuels and their derivatives, Hintco uses concessionary capital to cover the green premium.

25 Christoph Zink and others, 'Proposing a Methodology to Evaluate the Feasibility and Implementation Potential of Wind Energy in Africa Using GIS Data' (presented at the IEEE PES/IAS PowerAfrica, Johannesburg, 2024), pp. 1—7, doi:10.1109/PowerAfrica61624.2024.10759357; Benedikt Häckner and others, 'GIS-Based Evaluation of Suitability and Implementation Prospects for Solar PV Energy in Africa' (presented at the IEEE PES/IAS PowerAfrica, Johannesburg, 2024), pp. 1—7, doi:10.1109/PowerAfrica61624.2024.10759431.

26 ESMAP and others, 'Global Wind Atlas'.

27 'Aqueduct Water Risk Atlas'.

28 ESMAP and others, 'Global Wind Atlas', 2019 <https://globalwindatlas.info>.

29 ESMAP, World Bank Group, and SOLARGIS, 'Global Solar Atlas' <https://globalsolaratlas.info/map> [accessed 13 October 2024].

30 'Aqueduct Water Risk Atlas' (World Resources Institute) <https://www.wri.org/applications/aqueduct/water-risk-atlas/>.

31 'Marineregions' <https://www.marineregions.org/downloads.php> [accessed 16 October 2024]; ESA and CCI, 'Global Water Bodies', 2016 <http://maps.elie.ucl.ac.be/CCI/viewer/download.php>.

32 M Schiavina, S Freire, and K. MacManus, 'GHS-POP R2023A - GHS Population Grid Multitemporal (1975-2030)' (European Commission, Joint Research Centre (JRC), 2023), doi:10.2905/2FF68A52-5B5B-4A22-8F40-C41DA8332CFE.

33 'Planet Dump' (OpenStreetMap, 2015) <https://planet.openstreetmap.org>.

34 Christoph Zink and others, 'Proposing a Methodology to Evaluate the Feasibility and Implementation Potential of Wind Energy in Africa Using GIS Data'.

35 Oeko-Institut, PTX Business Opportunity Analyser (BOA): Data Documentation of Data Sources and Data Processing for Version 2.0 (Commissioned by Agora Energiewende and Agora Industry, 25 June 2024) <https://www.agora-industry.org/fileadmin/Projects/2022/2022-01_INT_PtX-Dialog/Oeko-Institut_2024_PTXBOA_Data_Documentation_v_2.1.pdf>; IEA, World Energy Outlook 2024, IEA (IEA, 16 October 2024) <https://www.iea.org/reports/global-hydrogen-review-2024>.

36 Alexander Buttler and Hartmut Spliethoff, 'Current Status of Water Electrolysis for Energy Storage, Grid Balancing and Sector Coupling via Power-to-Gas and Power-to-Liquids. A Review.', Renewable and Sustainable Energy Reviews, 82 (2018), pp. 2440—54, doi:10.1016/j.rser.2017.09.003; The Future of Hydrogen IEA G20 Hydrogen Report. (International Energy Agency, 2019) <https://www.iea.org/reports/the-future-of-hydrogen>; K.H.R. Rouwenhorst and others, 'Ammonia Production Technologies', in Techno-Economic Challenges of Green Ammonia as an Energy Vector, ed. by Agustin Valera-Medina and Rene Banares-Alcantara (Academic Press, 2020) <https://doi.org/10.1016/B978-0-12-820560-0.00004-7>.

37 Oeko-Institut, PTX Business Opportunity Analyser (BOA): Data Documentation of Data Sources and Data Processing for Version 2.0; Wesley Cole and Akash Karmakar, Cost Projections for Utility-Scale Battery Storage: 2023 Update. (National Renewable Energy Laboratory, 2023) <https://www.nrel.gov/docs/fy23osti/85332.pdf>; Christoph Hank and others, Power-to-X Country Analysis. Site-Specific, Comparative Analysis for Suitable Power-to-X Pathways and Products in Developing and Emerging Countries. (Fraunhofer-Institut für Solare Energiesysteme (ISE), 2023) <https://www.ise.fraunhofer.de/en/publications/studies/power-to-x-country-analyses.html>; Renewable Fuels. Technology Descriptions and Projections for Long-Term Energy System Planning. (Danish Energy Agency, 2024); Eero Vartiainen and others, 'Impact of Weighted Average Cost of Capital, Capital Expenditure, and Other Parameters on Future Utility scale PV Levelised Cost of Electricity', Progress in Photovoltaics: Research and Applications, 28.6 (2020), pp. 439—53, doi:10.1002/pip.3189.

38 Hydrogen Storage. State-of-the-Art and Future Perspective. (EU Commission, 2003) <http://bookshop.europa.eu/en/hydrogen-storage-pbLDNA20995/>; Jussi Ikäheimo and others, 'Power-to-Ammonia in Future North European 100 % Renewable Power and Heat System.', International Journal of Hydrogen Energy, 43.36 (2018), pp. 17295—308, doi:10.1016/j.ijhydene.2018.06.121; Hans Dambeck and others, Kosten Und Transformationspfade Für Strombasierte Energieträger. Projekt „Transformationspfade Und Regulatorischer Rahmen Für Synthetische Brennstoffe" (Prognos AG, BMWi, 2020) <https://www.prognos.com/de/projekt/kosten-und-transformationspfade-fuer-strombasierte-energietraeger>.

39 Renewable Fuels. Technology Descriptions and Projections for Long-Term Energy System Planning.; Jussi Ikäheimo and others, 'Power-to-Ammonia in Future North European 100 % Renewable Power and Heat System.'; Julien Armijo and Cédric Philibert, 'Flexible Production of Green Hydrogen and Ammonia from Variable Solar and Wind Energy: Case Study of Chile and Argentina', International Journal of Hydrogen Energy, 45.3 (2020), pp. 1541—58, doi:10.1016/j.ijhydene.2019.11.028.

40 Christoph Hank and others, Power-to-X Country Analysis. Site-Specific, Comparative Analysis for Suitable Power-to-X Pathways and Products in Developing and Emerging Countries.; Jussi Ikäheimo and others, 'Power-to-Ammonia in Future North European 100 % Renewable Power and Heat System.'

41 Hans Dambeck and others, Kosten Und Transformationspfade Für Strombasierte Energieträger. Projekt „Transformationspfade Und Regulatorischer Rahmen Für Synthetische Brennstoffe".

42 Christoph Hank and others, Power-to-X Country Analysis. Site-Specific, Comparative Analysis for Suitable Power-to-X Pathways and Products in Developing and Emerging Countries.; Electricity Infrastructure (Agency for the Cooperation of Energy Regulators, 2015) <https://acer.europa.eu/sites/default/files/documents/Publications/UIC%20Report%20%20-%20Electricity%20infrastructure.pdf>; Ana Đorđević and Željko Đurišić, 'Mathematical Model for the Optimal Determination of Voltage Level and PCC for Large Wind Farms Connection to Transmission Network.', IET Renewable Power Generation, 13.12 (2019), pp. 2240—50, doi:10.1049/iet-rpg.2018.5913.

43 Aswath Damodaran, 'Betas by Sector', January 2024 <https://pages.stern.nyu.edu/~adamodar/New_Home_Page/datafile/Betas.html>.

44 Aswath Damodaran, 'Country Default Spreads and Risk Premiums', 5 January 2024 <https://pages.stern.nyu.edu/~adamodar/New_Home_Page/datafile/ctryprem.html>.

45 Aswath Damodaran, 'Country Default Spreads and Risk Premiums'.

46 Business Analytiq, 'Phosphoric Acid Price Index'.

47 AfricaFertilizer, 'Fertilizer Price Data'.

48 IEA, 'Simplified Levelised Cost of Competing Low-Carbon Technologies in Long Distance Transport' <https://www.iea.org/data-and-statistics/charts/simplified-levelised-cost-of-competing-low-carbon-technologies-in-long-distance-transport> [accessed 16 December 2024].

49 Business Analytiq, 'Calcium Carbonate Price Index' <https://businessanalytiq.com/procurementanalytics/index/calcium-carbonate-price-index/> [accessed 16 December 2024].

50 GIZ, Report on Modelling Tool for Production Cost of Green Ammonia in India, June 2024 <https://energyforum.in/fileadmin/india/media_elements/publications/20240601_Cost_Modelling_Tool_Report/20240709_pb_Report_Final_Website.pdf>.

51 AfricaFertilizer, 'Fertilizer Price Data'.

52 Business Analytiq, 'Calcium Ammonium Nitrate (CAN) Price Index' <https://businessanalytiq.com/procurementanalytics/index/calcium-ammonium-nitrate-price/> [accessed 17 December 2024].

53 AfricaFertilizer, 'Fertilizer Price Data'.

54 European Central Bank, 'US Dollar (USD)', 2024 <https://www.ecb.europa.eu/stats/policy_and_exchange_rates/euro_reference_exchange_rates/html/eurofxref-graph-usd.en.html>.

55 Kaitlyn Ramirez and others, 'Hydrogen Reality Check: Distilling Green Hydrogen's Water Consumption', RMI, 2 August 2023 <https://rmi.org/hydrogen-reality-check-distilling-green-hydrogens-water-consumption/#:~:text=Per%20chemistry%20fundamentals%2C%209%20liters,20%20L%2Fkg%20is%20needed>.

56 'Lake Turkana', Wikipedia <https://en.wikipedia.org/wiki/Lake_Turkana> [accessed 20 March 2025].

57 Stuart Hamilton, 'Lake Victoria Statistics from This Dataverse' (Harvard Dataverse), doi:https://doi.org/10.7910/DVN/FVJJ4A.

58 D. Walker and others, 'Quantifying Water Storage within the North of Lake Naivasha Using Sonar Remote Sensing and Landsat Satellite Data', Ecohydrology & Hydrobiology, 22.1 (2022), pp. 12—20, doi:10.1016/j.ecohyd.2021.07.011; Arnim Kuhn and others, 'Simulating the Viability of Water Institutions under Volatile Rainfall Conditions — The Case of the Lake Naivasha Basin', Environmental Modelling & Software, 75 (2016), pp. 373—87, doi:10.1016/j.envsoft.2014.08.021.

H2Global Stiftung

T: +49 40 36197500
E: info@h2-global.org

www.h2-global.org