HYPAT

H_2 Potential

Global Atlas of H_2 Potential

Sustainable locations in the world for the green hydrogen economy of tomorrow:
technical, economic and social analyses of the development of a global sustainable hydrogen atlas

HYPAT Working Paper 13/2024

Towards a Green H_2 Economy: Kenya Country Report

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Towards a Green H_2 Economy: Kenya Country Report

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Key Messages

- The development of a green hydrogen economy as part of Kenya's climate and energy vision to move to 100% clean energy by 2030 is currently still in its incipient stage. In September 2023, Kenya published the executive summary of its first Green Hydrogen Strategy and Roadmap, identifying three areas of application for green H_2 within the country's economy:
  - Green hydrogen as feedstock in the chemical industry, specifically to produce ammonia (used in nitrogen fertilizers) and methanol,
  - Green hydrogen for the decarbonisation of the transport sector with an emphasis on the decarbonisation of shipping (via ammonia or methanol) and aviation (via sustainable aviation fuels, SAF),
  - Green hydrogen as a means of energy storage to provide baseload power in the electricity sector.

While all of these areas are envisaged to play a role in Kenya's green hydrogen economy in the future, the agricultural sector, and with it the establishment of a domestic fertilizer production industry, is defined as the 'low hanging fruit' for the country and has been given high priority, as the current domestic market consists of 100% imported fertilizer. In addition to the benefits to the agricultural sector and hence food security from a focus on fertilizer production, Kenya's Green Hydrogen Strategy and Roadmap identifies benefits in two other dimensions for the successful establishment of a domestic green hydrogen economy, namely improved balance of payments and green industrialization and decarbonisation. The country's green hydrogen development is currently driven by the government and public institutions but enjoys strong support from the EU and some private sector associations representing national and international business interests.

While the Republic of Kenya has several competitive advantages for producing green hydrogen derivatives, mainly due to its renewable energy potential, and seeks to integrate its hydrogen economy into its overall socio-economic development plan with the objective to significantly reduce greenhouse gas emissions, we remain sceptical that the country's current trajectory will result in significant socio-economic benefits for the majority of the population as several factors pose challenges in ramping up the nascent green hydrogen market in Kenya.

Existing barriers in the energy sector may inhibit the development of a hydrogen economy in the country: Kenya aims to leverage its high geothermal potential to produce green hydrogen, but high renewable energy prices may increase the production cost of green hydrogen. Due to high upfront investment requirements in geothermal power plants, the global weighted average levelized cost of electricity from geothermal energy is quite high (USD 0.056/kWh), compared to both onshore wind (USD 0.035/kWh) and utility-scale solar PV (USD 0.049/kWh) (IRENA, 2023, p. 19). The efforts of the Kenyan government to increase the installed capacity of geothermal power do not seem to help bringing the energy prices down. This challenge currently results in limited incentives for domestic and regional heavy industries (e.g. cement and iron and steel) to use and produce green hydrogen. Therefore, the potential growth of the off-take market for Kenyan green hydrogen remains – both domestically and internationally-limited.

In addition, it remains unclear whether new renewable energy capacity will be installed for green hydrogen production, or whether existing green energy sources will be used for its production. If the latter becomes the norm, energy prices in the country could rise sharply, potentially leading to public resistance to the further development of a green hydrogen economy. The challenge is to balance increased renewable energy production for green hydrogen with domestic demand for affordable and decentralised renewable electricity.

Finally, it is unknown how the market price for green commodities will develop in Kenya in the near future. The risk of higher final prices is particularly relevant for the domestic fertilizer produced from green hydrogen, as food security in the country is highly dependent on access to fertilizer.

The success of Kenya's incipient green hydrogen economy in the coming years will depend to a large extent on the implementation and successful operation of a number of commercial pilot projects, currently being launched or underway, to demonstrate feasibility and attract interest and financial investment from the (international) private sector (Kenya Ministry of Energy and Petroleum, 2023). Several factors may pose challenges to the development of the nascent green hydrogen market in Kenya. We recommend that the following be addressed in the short to medium term:

- Prioritise an increase deployment of solar and wind power to tackle the high energy prices and to ensure competitive levelized cost of hydrogen (LCOH).
- Create local demand and develop debt-free financing models.
- Coordinate efforts, set ambitious political objectives, provide a regulatory framework, and actively involve the private sector to fully tap into the potential of green hydrogen in the country. This is not only seen as important for the market ramp-up, but also for ensuring social and environmental feasibility and acceptability of developing green hydrogen projects.
- Inform and engage local and regional stakeholders (particular civil society) early in the planning process of new hydrogen projects and related infrastructure.
- Channel international cooperation into contributing debt-free financing models like contingency financing through reallocated Specialized Drawing Rights (SDRs) to support the green fertilizer market in Kenya and to avoid possible social and economic damages.
- Use regional cooperation platforms such as the African Green Hydrogen Alliance to prioritise mechanisms such as benefit-sharing and good contracting in member countries' agendas.
- Promote international cooperation to support the green hydrogen market in Kenya by facilitating regional cooperation among African countries, not only in agreeing on common regulatory frameworks such as benefit-sharing mechanisms or good contracting, but also in common cross-border infrastructure projects such as pipelines and terminals.

1 Introduction and Methodology

1.1 Introduction

This country report was developed in the context of the HYPAT project, financed by the German Ministry of Education and Research *(Bundesministerium für Bildung und Forschung, BMBF*). The main objective of HYPAT is to map out the potential of different world regions and countries to (a) produce green hydrogen (GH2) and (b) potentially export GH2 or derivatives to Germany and Europe. HYPAT works under the assumption that the export potential of partner countries cannot be calculated solely from the potential of the exporting countries for renewable energies. Rather, mapping out the potential of different world regions and countries requires a complex understanding of specific national and regional socio-economic, technical, and socio-political contexts.

The global energy landscape is shifting as nations work to reduce greenhouse gas emissions and tackle climate change, with green hydrogen emerging as a key clean energy carrier. Produced through electrolysis using renewable energy sources like solar and wind, green hydrogen offers a carbon-neutral alternative to fossil fuels across various sectors. Developing countries, especially those in the Global South with abundant renewable resources, have the potential to become major players in the green hydrogen market, supplying the growing demand from the Global North, which is driven by ambitious climate goals and the need for sustainable energy solutions. This report aims to provide a comprehensive analysis of the green hydrogen market ramp-up in Kenya. Through an in-depth examination of policy frameworks (Chapter 2), stakeholders (Chapter 3), and opportunities and challenges (Chapter 4), this report seeks to shed light on the evolving landscape of green hydrogen production and export dynamics in Kenya. Lastly, the report makes some recommendations and identifies strategies to unlock Kenya's full potential in the global hydrogen economy, with a focus on international cooperation (Chapter 5). Overall, we argue in this report that the Republic of Kenya offers several competitive advantages for producing green hydrogen and its derivatives, mainly due to its renewable energy potential, and seeks to integrate its hydrogen economy into its overall socio-economic development plan with the objective to improve its balance of payment, increase food security and develop the country's green industrialization. Nevertheless, we remain sceptical that the country's current trajectory will result in significant socio-economic benefits for the majority of the population, as several factors pose challenges in ramping up the nascent green hydrogen market in Kenya in the short- to medium-term. High renewable energy prices may increase the production cost of green hydrogen and high upfront investment currently offer limited incentives for national and international companies to invest in green hydrogen production infrastructure. The success of Kenya's hydrogen roadmap in the upcoming years will - to a large extent - depend on the implementation and successful operation of some commercial pilot projects to demonstrate feasibility and to incite not only interest but also financial investment from the (international) private business sector.

Moreover, while the country is committed to establishing an effective regulatory system to facilitate the development of green hydrogen, particularly as nitrogen fertilizer for domestic use to promote food security, the development is still ongoing. Finally, concrete programs and policies need to be in place in order to ensure that economic benefits of the green hydrogen economy spill over into larger socio-economic benefits for the Kenyan population, including

finding fair and effective solutions for the tension arising between the need to protect communal land rights and land acquisitions for new renewable energy and green hydrogen projects.

1.2 Methodology

The HYPAT country reports are based on an extensive review of published peer-reviewed and 'grey' literature, as well as interviews with stakeholders and experts in potential production and export countries as well as in Germany in the development of a GH2 economy. The objective is to contribute to a better understanding of the starting conditions for the emerging global GH2 economy in several mainly developing countries. Based on the analyses, policy recommendations are derived.

Seven countries were selected for in-depth studies based on a combination of an extensive analysis of available indicators and a focus group discussion involving experts from various research groups at German institutes. These seven countries share an above-average potential to produce large quantities of hydrogen with electrolysis based on renewable energies and a reasonably good position to export hydrogen or derivatives to Europe. Developing countries with no significant potential for wind-, solar- or geothermal energy but good access to international maritime transport were not considered, e.g. Belize. The same applies to land-locked countries with excellent solar radiation (e.g. Chad). Beyond these two common denominators (RE potential, access to international maritime transport), the countries selected for the qualitative in-depth studies cover a range of different criteria, e.g. from large countries with complex industries (Brazil) to small countries with a mainly rural economy. An extensive literature research was conducted for the Kenya case study, followed by several rounds of online interviews with relevant policy, industry and civil society stakeholders in March and April 2023. Finally, a country visit in June 2023 also included semi-structured interviews with various stakeholders from politics, public institutions, universities, research centres, private sector, industry and renewable energy producers.

1.3 Hydrogen strategies and roadmaps

In September 2023, Kenya published its first Green Hydrogen Strategy and Roadmap identifying green hydrogen and its derivatives as a key driver of the country's energy transition (Kenya Ministry of Energy and Petroleum, 2023). However, Kenya's green hydrogen economy is still in its incipient stage. Already in 2021 at the COP26 in Glasgow, former president Uhuru Kenyatta mentioned green hydrogen as a source of green energy that Kenya would like to pursue while also announcing the country's goal to make its electricity use 100% renewable - currently it is at 90% (Statista, 2022a).

For this purpose, Kenyatta formed a national Green Hydrogen Working Group with diverse actors from the public and private sector to accelerate the process towards a green hydrogen economy (Wambua & Wagacha, 2022). Kenyatta's successor, President William Ruto, is also very ambitious in terms of green hydrogen adoption in Kenya. At the COP27 in Sharm El-Sheikh, he announced that the Kenyan Government signed a framework agreement with an investor to produce 30 GW of green hydrogen in Kenya (Ruto, 2022).

In January 2022, Kenya's Ministry of Energy published a comprehensive baseline study on the potential of power-to-x (PtX) and green hydrogen in the country. The study was supported by the GIZ (Kenya Ministry of Energy and Petroleum, 2022). The report extensively analyses Kenya's green hydrogen potential, country specific challenges as well as facilitating factors, PtX opportunities and investment perspectives, and highlights the potential use of green hydrogen in Kenya in various areas:

1) As a commodity to produce the nitrogen content of fertilizers.
2) As a commodity for existing and new regional industrial processes (through hydrogen and its derivatives such as ammonia or methanol).
3) As an energy carrier for selected transport (mobility) options.
4) As a commodity and energy carrier for larger scale uses in new technologies with an industrial shift, e.g. for green domestic steel production.
5) As an energy carrier for off-grid supply of isolated grids.

Kenya's Green Hydrogen Strategy and Roadmap published in 2023 builds on the 2022 baseline study by outlining how a green hydrogen economy will contribute to the country's sustainable economic transformation and green growth. It identifies three areas of application for green hydrogen:

1) As feedstock in the chemical industry, specifically to produce ammonia (used in nitrogen fertilizers) and methanol,
2) for the decarbonisation of the transport sector with an emphasis on the decarbonisation of shipping (via ammonia or methanol) and aviation (via sustainable aviation fuels, SAF),
3) and as a means of energy storage to provide baseload power in the electricity sector.

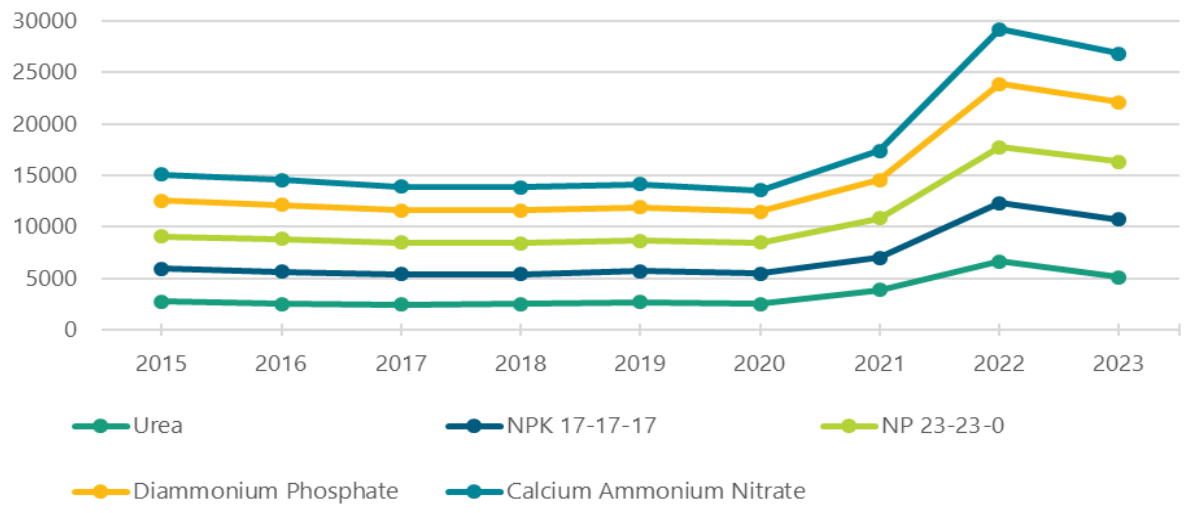
While all these areas are foreseen to play a role in Kenya's green hydrogen economy in the future, the agricultural sector and the establishment of a domestic fertilizer production industry is defined as high-priority sector in the short term.

The agricultural sector plays a pivotal role in Kenya's economy by sustaining the livelihoods of a significant portion of the population and contributing 33% of the country's GDP and another 27% of GDP indirectly through linkages with other sectors (FAO, 2023). The agricultural sector

employs more than 40% of Kenya's total and more than 70% of its rural population (ibid.). However, there is currently no domestic fertilizer production, and the market consists of 100% imported fertilizers. Increased climate variability resulting in recurrent severe drought in the country and an increase of fertilizer prices due to the Russian invasion of Ukraine in 2022 are putting the issue of food security at the top of Kenya's political agenda.

Despite a recent decreasing trend of global fertilizer prices, as can be seen below in Figure 1, compared to historical data, fertilizer prices remain high in Africa in general, which is also the case in Kenya. Moreover, the World Bank estimates that 28% of the country's population faced severe food insecurity in 2021 (World Bank, 2024). It is important to further note that the average applied fertilizer amount per hectare in Sub-Saharan Africa is already only 1/6 of the global amount (World Bank, 2023c). Green hydrogen is projected to play an important role in stimulating domestic fertilizer production. Vice versa, fertilizer production also has the potential to ease the market ramp-up of green hydrogen in Kenya. It is seen, according to the majority of the stakeholders interviewed for this report, as the "low-hanging fruit", compared to other potential application sectors like heavy industry and mobility, that are projected to play a more significant role in Kenya's green hydrogen economy in the medium and long term (Interviewee 21, 2023; Interviewee 22, 2023; Kenya Ministry of Energy and Petroleum, 2023).

Figure 1: Evolution of fertilizer retail price in Kenya (2015-2023) in Kenyan Shilling



Source: (AfricaFertilizer, 2023)

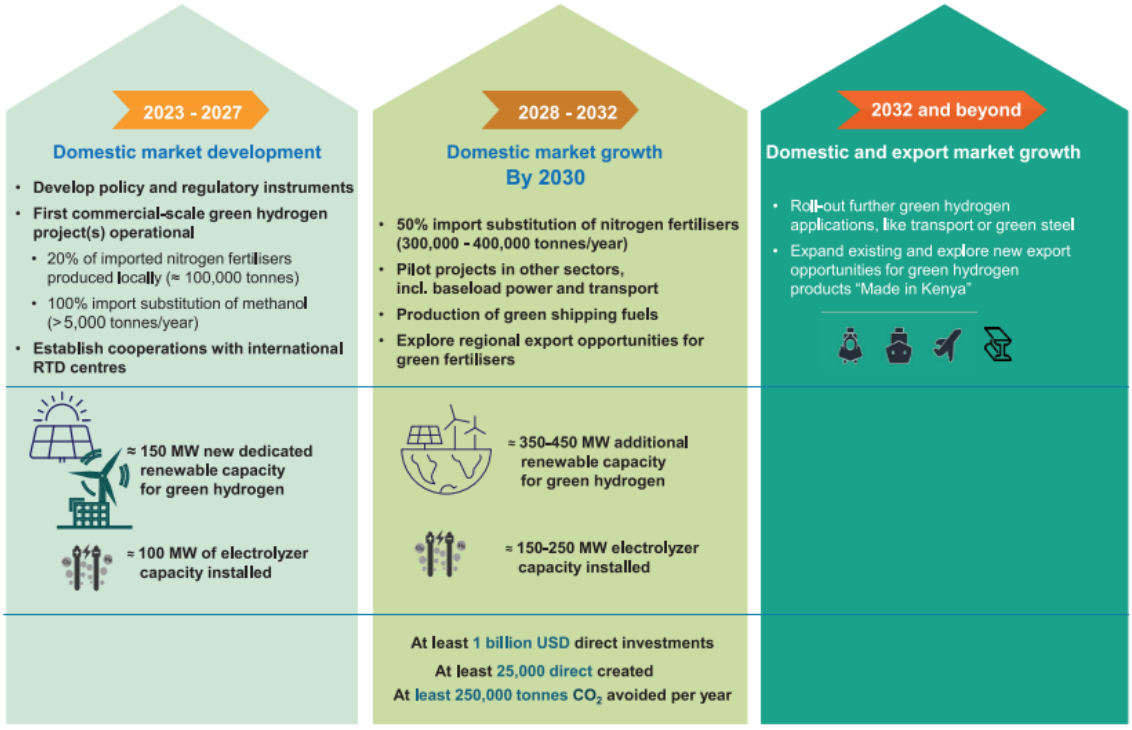
Kenya's Green Hydrogen Strategy and Roadmap identifies benefits across three key dimensions for the successful establishment of a domestic green hydrogen economy:

1) ***Improved balance of payment***: By generating green hydrogen as a feedstock for industrial processing facilities, Kenya can reduce its reliance on imported hydrogen-based products, such as nitrogen fertilizer and methanol. As a domestic market for green hydrogen derivatives takes shape, it will create avenues for export, leveraging Kenya's advantageous geographic location as a regional trading hub.
2) ***Food security and resilience***: As mentioned above, green hydrogen holds the promise of bolstering food security and strengthening resilience through its capacity to facilitate local nitrogen fertilizer production. Fertilizers play a pivotal role in augmenting agricultural productivity.

3) ***Green industrialization and decarbonization***: Green hydrogen can act as a catalyst for investment in the country by facilitating the creation of manufacturing value chains focused on the production of green hydrogen and its related products. This, in turn, promotes the growth of various downstream industries and generates employment opportunities along the entire green hydrogen value chain. Furthermore, the green hydrogen sector can serve as a dependable demand source, driving the expansion of the power grid, accelerating the development of the renewable energy sector, and ultimately enhancing access to electricity services for the people of Kenya.

To achieve these benefits, Kenya's Green Hydrogen Strategy and Roadmap identifies several new domestic institutions to be established in 2024 - such as the creation of a "green hydrogen programme coordination committee", a "green hydrogen secretariat", and a "national green hydrogen roundtable of finance and green fertilizer" - and foresees two distinct phases of implementation. As shown in Figure 2 below, Phase 1 (2023-2027) focuses on domestic market development and includes the development of appropriate policy and regulatory instruments as well as the implementation of some commercial-scale green hydrogen projects focusing on substituting imported nitrogen fertilizers and methanol. Phase 2 (2028-2032) emphasizes domestic market growth with a strong focus on the agriculture sector and initial application in transport and industry. Export market growth is foreseen to follow the first two phases in the year 2032 and beyond.

Figure 2: Kenya's green hydrogen targets



Source: (Kenya Ministry of Energy and Petroleum, 2023)

The success of Kenya's hydrogen roadmap in the upcoming years will - to a large extent - depend on the implementation and successful operation of some commercial pilot projects to demonstrate feasibility and incite not only interest but also financial investment from the (international) private business sector (Kenya Ministry of Energy and Petroleum, 2023). Given the nascent stage of the green hydrogen market, it is regarded as crucial for Kenya to coordinate

efforts, set ambitious political objectives, provide a regulatory framework, and actively involve the private sector to fully tap into the potential of green hydrogen.

1.4 Other relevant sector policies

Kenya's long-term development blueprint is outlined in its Vision 2030, which was launched in 2008 and aims to transform the country into a newly industrializing, middle-income country providing high quality of life to all its citizens by 2030. The Vision is being implemented through successive five-year medium-term plans. In 2023, the Fourth Medium Term Plan (MTP IV) was launched. It aims at revitalizing performance in all economic sectors in order to foster growth, employment creation, and poverty reduction (The National Treasury and Planning, 2022). The objectives outlined in the Green Hydrogen Strategy align with the government's overall developmental planning process in the current MTP IV, which is emphasizing the embedded role green hydrogen plays for the country's overall development and sustainable growth objectives. To complement and accelerate the objectives of Vision 2030, former President Kenyatta introduced his Big Four Agenda in 2018 focusing on food security, affordable housing, manufacturing and affordable healthcare (Ministry of Energy and Petroleum, 2018, p. 13), an agenda that appears to be continued under the new government. The Kenya Vision 2030 identifies energy as a key foundation for national transformation as well as an enabler in the realization of the Big Four Agenda (Ministry of Energy and Petroleum, 2018).

1.4.1 National Energy Policy 2018 and Energy Act 2019

The National Energy Policy was published by the Ministry of Energy in October 2018, replacing the former 2004 Sessional Paper Nr. 04, which had guided the energy sector for over 15 years. The main aim of both policies, however, seems to remain unchanged: cost-effective and affordable energy supply (Ministry of Energy and Petroleum).

In order to reach affordable energy, the main focus lies on the utilization of diverse energy sources including renewables but also domestic coal mines. Affordability, competitiveness, reliability and easy access are listed as the reasons for further coal adoption and new coal projects in the country (Ministry of Energy and Petroleum). The policy also initiated the transformation process of Rural Electrification Authority into Rural Electrification and Renewable Energy Corporation (REREC) to be the lead agency for development of renewable energy sources other than geothermal and large hydro (Ministry of Energy and Petroleum). Another point the document emphasizes is the facilitator role the government shall take in land acquisitions for private sector's energy projects. The aim of this initiative is that the investment risks related to land are taken upon by the government, to de-risk the investment environment especially for foreign investors.

In 2019, a new Energy Act was adopted to implement the 2018 Policy. This Act aims to consolidate the laws relating to energy, to properly delineate the functions of the national and devolved levels of government in relation to energy by requiring the Cabinet Secretary in the Ministry of Energy - in consultation with stakeholders - to publish and regularly review an Integrated National Energy Plan (based on the 47 County Energy Plans). The Energy Act also aims to provide for the exploitation of renewable and geothermal energy sources, which are now vested in the national government, clarifying that it is the right and responsibility of the national government to develop so far unexploited renewable resources *for* the Kenyan people. Finally, the Energy Act 2019 established several new energy sector entities, such as the Energy

and Petroleum Regulatory Authority (EPRA) as successor to the Energy Regulatory Commission (ERC) (The Republic of Kenya, 2019).

1.4.2 Kenya Energy Sector Roadmap 2040

The Ministry of Energy published the draft version of Kenya's Energy Sector Roadmap 2040 in July 2022. The document also serves as a White Paper. It targets four outcomes for the Kenyan energy sector and depicts the pathways to reach them. Below, Table 1 summarizes the outcomes that the roadmap aims to achieve, where green hydrogen plays a prominent and strategic role.

Table 1: Pathways to achieve outcomes specified in Kenya Energy Sector Roadmap (Ministry of Energy and Petroleum, 2022)

Outcomes	Pathways
Outcome 1 100% electricity access	600K connections per annum and de-risking mini-grid projects
	Increase per capita electricity consumption up to 3,000 kWh
	Reduce household electricity bills by 50% by 2040
	100% access for micro and small enterprises by 2040
Outcome 2 Decarbonized economic growth	Prioritize the exploitation of renewable energy (RE) sources but also leverage other options like natural gas, nuclear and green hydrogen
	Develop an interconnected smart grid and the introduction of meter system
	Reduce reliance on back-up generators
	Reduce biomass consumption by 5% per annum by 2040
	Decarbonize of high emission sectors e.g. agriculture and transport
	Benefit from competitive advantage through green hydrogen and ammonia
Outcome 3 A quantum leap to 100 GW by 2040	20% increase in the installed capacity per annum and exploring the role hydrogen can play
	Attract a total of $300bn in green energy investment
	Explore traditional but also non-traditional investment sources and de-risking local projects through domestic funds
Outcome 4 Decarbonized industry destination	Attract green heavy industries by offering competitive RE prices
	Stimulate industrial parks and mapping potential counties
	Utilize off-peak power at a reduced cost
	Develop an interconnected regional system in eastern Africa

1.4.3 Climate Change (Amendment) Act 2023

A new Climate Change Act - as an amendment to the previous Climate Change Act 2016 - entered into force shortly after the Africa Climate Summit was held in September 2023 in Nairobi. The Act is considered to be showing legal dedication in fulfilling Kenya's international obligations under Africa Agenda 2063, UN Agenda 2030 and the Paris Agreement (Republic of Kenya, 2023b, p. 227).

The Act established several different authorities to pave the way for a committed legal system towards a low carbon economy in Kenya. Maybe the most prominent among those is the establishment of the National Carbon Registry as the main operation system of the coming carbon market and NEMA (National Environment Management Authority) as the Designated National Authority, i.e. its regulatory body (Republic of Kenya, 2023b, p. 237).

The Climate Change Act prioritizes not only the environmental assessment of carbon projects but considers also the community as an indispensable part of the carbon market. To materialize this emphasis, the Act introduces the obligation for carbon projects to undertake a community development agreement, of which each proponent, such as the community, county government, national government and the project partners, are a party to (Republic of Kenya, 2023b, p. 235). Moreover, according to the Act, land-based carbon projects are obliged to provide at least 40% of their annual profits to local communities, whereas non-land based carbon projects are required to share at least 25% of profits (Republic of Kenya, 2023b, p. 235).

1.4.4 Kenya Energy Transition and Investment Plan 2023 – 2050

Launched at COP28 and published in February 2024, the Kenya Energy Transition and Investment Plan assesses the investment requirements of the Kenyan energy sector to reach its net zero target in 2050. *Sustainable Energy for All*, an international organization, and the UN Country Team supported the Ministry of Energy and Petroleum in developing the plan.

To abate the majority of CO_2 emissions and to support Kenya's rapid economic growth trajectory, the plan prioritizes the adaptation of renewable energy, low-carbon hydrogen, battery electric vehicles and clean cooking stoves. To achieve an energy transition based on these technologies, the plan foresees a total investment of USD 600 billion, the majority of which should be channelled into the power and transport sectors. The main strategy of the Kenyan government for the accumulation of this amount is to rely on capital markets, while repeating de-risking mechanisms as their share of allocated responsibility (Ministry of Energy and Petroleum, 2024, p. 5).

The Energy Transition and Investment Plan plays an important role in providing a comprehensive roadmap for the energy transition in the country, while signalling the dependence of the Kenyan government to international finance. It also emphasizes the role of the energy transition in having an impact on environmental sustainability, affordable energy, economic growth, energy security, and employment (Ministry of Energy and Petroleum, 2024, p. 7).

In the plan, low carbon hydrogen is expected to contribute 15% of the emission reductions by 2050, compared to business as usual, whereas carbon capture and storage technologies are expected to contribute a 9% reduction. The bigger shares of emission reductions are attributed to technologies addressing main emission sources in Kenya, namely clean cooking technologies with 28%, electrification, energy efficiency and renewable energies with 24% and battery

electric technologies with 22%. The remaining 2% is aimed to be achieved through negative emission solutions like bioenergy with CCS (Ministry of Energy and Petroleum, 2024, p. 10).

1.4.5 Africa Green Hydrogen Alliance

Kenya is one of the co-founder countries and a member of the *Africa Green Hydrogen Alliance*, launched at the COP26, which seeks to connect existing initiatives and leadership efforts in green hydrogen with the potential to generate new industry awareness, opportunities, and action (UNFCCC, n.d.). The Alliance focuses on public and regulatory policy, capacity building, financing and certification needs to mobilize green hydrogen production for domestic use and export (GH2, n.d.).

1.4.6 Kigali Communique

Kenya - together with nine other African countries (the Democratic Republic of Congo, Ghana, Malawi, Morocco, Nigeria, Rwanda, Senegal, Uganda and Zimbabwe) - is a signatory of the *Kigali Communique*, discussed and agreed upon in Kigali in May 2022, to outline the requirements for a just and equitable energy transition in Africa. Among the principles advocated in the communique is the need to pursue a modern energy consumption minimum of 1,000 kWh per capita– middle income economies are consuming 2,500 kWh per capita and high-income economies 6,000 kWh per capita – in Africa, which also prioritizes a revolution in clean cooking. Moreover, the communique highlights the development of a natural gas transition fuel and the long-term displacement of gas by renewable energy and green hydrogen for industrial development, if financially and technically sustainable.

1.5 Quality of policy formulation

The national government in Kenya, led by President Ruto, is one of the driving forces behind the development of a national green hydrogen economy (Interviewee 17, 2023; Interviewee 18, 2023; Interviewee 20, 2023). Similar to its predecessor government, led by ex-President Kenyatta, the current government regards the development of a green hydrogen economy as an opportunity for green growth, national development and increased domestic employment. However, while the further development of renewable energy capacity—along with a push for national green hydrogen production—can be regarded a priority on the country's political agenda, there are also discussions related to the possible development of the country's natural gas capacities as a transition fuel.

Since President Ruto and his cabinet assumed power in 2022, no major shift in the political agenda for the energy and industry sectors can be observed compared to the previous government under Kenyatta. For example, for power generation, the emphasis on utilizing the country’s geothermal resources has been kept and strengthened. Kenya wants to diversify its energy sources by increasing geothermal power capacity, since the historically largest energy source hydropower is being threatened in recent years by severe droughts in the region.

Challenges identified and targeted in some of the previous government’s policies still appear as priorities in need to be addressed in more recent policy documents. On the one hand, it can be argued that the policies are kept coherent among different governments. However, it also signals that the country's governments have been slow to address those challenges so far. One very relevant example of such a challenge are Kenya's high energy prices. Launched in 2008, Kenya's Vision 2030 (Government of the Republic of Kenya, 2007) targets high energy costs

and aims to solve this challenge by gradually increasing the energy supply in the country. But although power generation has more than tripled between 2000 and 2021 (IEA, 2023a), energy prices remained high. In the Energy Sector Roadmap 2040, which is the latest policy document published for the sector, there is no mention of how green hydrogen might improve or worsen this specific issue and what additional measures will be employed to ameliorate the two potentially conflicting goals of increased energy demand in a green hydrogen economy and lower energy prices for Kenya's consumers.

Despite an overall continuity in politics, maintaining the coherence between new policies and the already existing frameworks might prove to be challenging in the future, and some changes will need to be implemented in the short- to medium-term. For example, even though the domestic fertilizer production from green hydrogen is a priority for Kenya and repeatedly referred to as the "low hanging fruit", implementation might be difficult if the domestic market is not set up for it. To ensure food security with a 100% imported fertilizer supply, the government currently subsidizes fertilizers, which drives the price reduction as low as 50% in some cases. In order to make domestic green fertilizer a competitive product in the market, subsidy schemes on imported fertilizer should be removed and potentially shifted to the domestic product. Moreover, some structural challenges in the Kenyan political system impact the quality of policy formulation.

First, Kenyan politics operates on a framework where political parties coalesce around influential political leaders, who mobilize their ethnic communities to gain prominence in national leadership. This dynamic frequently results in political parties exhibiting strongholds in specific regions of the country. For instance, the Orange Democratic Movement (ODM) party is predominantly led by the Luo ethnic group, the United Democratic Alliance (UDA) has a significant following among the Kalenjin community, the African National Congress (ANC) is primarily influenced by the Luhya community, the Wiper party garners support from the Kamba community, and Ford Kenya is led by the Luhya, among others (Hamasi 2022). The core strength of these political parties lies in their ability to articulate the interests of the regions from which their supporters originate. These parties often enjoy backing from influential figures such as opinion leaders, elders, affluent business figures, religious leaders, and various stakeholders from these regions. Consequently, these parties serve as conduits for expressing local interests on the national stage.

Second, and relatedly, with 47 county governments, Kenya's decentralized governance structure is one of the most rapid and ambitious devolution processes in the world, posing challenges to political, fiscal, and administrative services in the country. The adoption of a devolved system of government in Kenya was a desire of its citizens, who wanted access to public services closer to them. However, the landscape for executing devolution has encountered significant hurdles in the past years. Challenges have emerged, including disputes between the National Government and County governments regarding funding for County functions, inadequate or absent consultations on issues impacting County Governments, limited technical assistance for function implementation, delayed disbursements of funds to Counties by the National Treasury, a deficit in capacity and expertise for service delivery, instances of corruption, insufficient public participation, and gender inequality (Ngigi, Samuel, and Doreen Nekesa Busolo, 2019). According to the 2019 Energy Act, the Cabinet Secretary in the Ministry of Energy must publish and regularly review an Integrated National Energy Plan, which is supposed to be based on 47 County Energy Plans.

Third, next to a lack of coordination between levels of governance due to processes of devolution, a lack of regular exchange among different ministries as well as between the government and some ministries on the national level - particularly in the development of a green hydrogen vision - can be observed (Interviewee 17, 2023; Interviewee 18, 2023). This may partly be attributed to different priorities: While the Presidency, together with some public and private stakeholders, is pushing for implementation of the country's green hydrogen vision, some ministries require time to align policies across various sectors and develop new regulations and policy frameworks.

Despite the challenges depicted above, it should be noted that President Ruto has been pushing the climate change agenda in two relevant ways. Firstly, Ruto's Presidency rapidly develops comprehensive regulations covering all relevant sectors. In addition to the regulations and policies mentioned above, Kenya has also recently updated its National Climate Change Action Plan (NCCAP) 2023-2027 and announced the Long-Term Low Emission Development Strategy (LT-LEDS) 2022-2050. Both documents are key in the implementation of Kenya's Nationally Determined Contribution (NDC). The last update of NDC in 2020 sets the 32% greenhouse gas emission reduction target by 2030 as well as pledges domestically to cover 13% of the required budget for the full implementation of the NDC. Such targets are then also successfully taken up by respective ministries or national public authorities to lead sectoral transition. Several ministries published their respective strategic plans for 2023-2027 following the national government's announcements. Yet, in most cases, it is not clear how green hydrogen targets will be aligned with those ministerial strategic plans. Also, as mentioned above, the degree of involvement and the role of county governments in pursuing those national targets remain unclear.

Secondly, President Ruto is being vocal about Kenya's targets on related international platforms. The Africa Climate Summit hosted and initiated by Kenya is a recent example of this. Ruto has used this opportunity to launch and publish many climate-related policies during the event, including the green hydrogen strategy. In addition to this, just like Kenyatta at COP26, Ruto has also used the opportunity of having an international high-level audience at both COP27 and COP28 to not just voice Kenya's commitment towards climate action, but also to take the lead in organizing intergovernmental initiatives within and for the African continent. The launch of the Africa Green Industrialization Initiative at COP28 is a good example of this. However, it should be noted that the Initiative builds on the existing Africa Green Investment Initiative launched by the United Arab Emirates with a volume of USD4.5 billion. Hence, Ruto's qcountries, as they will likely be key in establishing international infrastructure partnerships and in channelling international green finance.

2 Stakeholders Impacting the GH2 Economy

Kenya's green hydrogen development is currently driven by its government and public institutions but enjoys strong support from the EU as well as from some private sector associations representing both national and international business stakeholders. The government of President Ruto is one of the driving forces behind the development of a national green hydrogen economy aiming to promote green hydrogen development by fostering an enabling regulatory environment that will allow private investors to not only implement small-scale pilots but also establish large-scale green hydrogen plants. While Kenya has a history of societal stakeholder engagement (for example, in the renewable energy sector), representatives of civil society have thus far not played a major role in the incipient stage of the country's green hydrogen sector.

Government, ministries and public sector institutions

Kenya is a signatory of the Kigali Communique, and in October 2022, Kenya and Tanzania agreed to fast-track the construction of a natural gas pipeline to increase trade and lower energy costs for both countries (The Construction Index, 2022; African Energy Council, 2023). Moreover, a planned extension of the Kenya-Uganda oil pipeline aims to replace road tankers for oil transportation by connecting Eldoret in Kenya to Kampala in Uganda (The East African, 2024). While natural gas can be regarded as a bridge technology, especially when pipelines are designed in a way that allows easy repurposing for green hydrogen, this development can be interpreted as part of a broader debate in Kenya about what kind of energy sources are conceptualized and regulated as green or renewable, as also reflected in discussions around potential clean-coal technologies and the highly contested Lamu Coal Power Station project, a 1,050 MW power plant that was planned to be built on the shoreline of Manda Bay. After years of campaigning and widespread opposition from local communities and civil society, Kenyan courts canceled the project's environmental license in 2019, and in 2020, the Industrial and Commercial Bank of China announced its withdrawal of plans to finance it (Business & Human Rights Resource Centre, 2022).

Nevertheless, with approximately 90% of its electricity generated from renewable sources, Kenya is a leader when it comes to the use of renewable energy in Africa. The country's recently published executive summary of its green hydrogen strategy is a product of Kenya's Green Hydrogen Working Group, consisting of some of the most important public stakeholders as well as some private sector entities. This strategy was developed under the leadership of the Office of the President and the Ministry for Energy and Petroleum (MoEP). It also involved several other ministries, such as the Ministry of Agriculture and Livestock Development and the Ministry of Roads and Transport, reflecting three of the possible fields of application for green hydrogen in the country. Additionally, the National Treasury of Economic Planning's participation indicates the integration of the country's green hydrogen strategy into its overall green growth and development vision.

In addition to the involvement of several ministries, the Green Hydrogen Working Group included various other public stakeholders, such as the Kenya Bureau of Standards (KEBS), responsible for developing domestic or implementing international technical and performance standards across sectors, and the Energy and Petroleum Regulatory Authority (EPRA). Through the Energy Act of 2019, EPRA has explicit authority over the full regulation of the entire elec-

tricity supply chain in the country, including planning and licensing. The Geothermal Development Company (GDC) constitutes another crucial public stakeholder, being a fully government-owned company mandated to execute surface geothermal development in coordination with the Ministry for Energy's geo-exploration directorate.

Kenya's public electricity sector is an important player in the development of green hydrogen infrastructure. The Kenya Electricity Generating Company (KenGen) is a government enterprise charged with the production of electricity as well as the management and operation of power plants in the country (The National Treasury and Economic Planning, 2021). It is the largest electric power producer in Kenya, holding strong market power by generating more than 60% of electricity consumed in the country. It shares responsibilities in the country's electricity sectors with KETRACO as the country's main electricity transmission company and Kenya Power and Lighting Company (KPLC), which handles distribution. While KETRACO is 100% state-owned (KETRACO, n.d.), the Kenyan government is also the majority shareholder of KPLC (with 50.1% stake) and KenGen (with 70% stake) (KPLC, 2023b; The National Treasury and Economic Planning, 2021). In June 2023, KenGen announced plans to significantly scale up the development of renewable energy, driven largely by the increase in geothermal and hydroelectric sources within the Rift Valley region and the Tana River Basin, respectively (Ingram, 2023).

Finally, while not actively involved in the current stage of developing a green hydrogen roadmap and overall strategy for the country, several public stakeholders will play key roles in project planning and implementation. At the national level, this particularly involves the National Environment Management Authority (NEMA), responsible for project environmental impact assessment. Moreover, Kenya's devolved system of governance places its 47 counties in a central role for hydrogen project planning and implementation. Official energy project licensing is done at the national level through EPRA; however, county governments have a say in what can be called a 'social license to operate' in their jurisdiction (Interviewee 19, 2023).

Private sector stakeholders

Kenya's green hydrogen development is currently driven by its government and public institutions but enjoys strong support from some private sector alliances. The Kenyan Private Sector Alliance (KEPSA) is a key player in championing the interests of the Kenyan business community in trade, investment, and industrial relations. Its participation in the development of the country's green hydrogen strategy indicates a significant role for multinational companies in the country's hydrogen sector, as its mission is to bring together local and foreign business associations. KEPSA supports the MoU between the Australian company Fortescue Future Industries (FFI) and the Kenyan government to launch a 300 MW green ammonia and fertilizer facility harnessing the geothermal resources of the Olkaria field in Naivasha (Fortescue, 2023).

Other important private sector players include the Electricity Sector Association of Kenya (ESAK), composed of stakeholders in the electricity sector ranging from Independent Power Producers (IPPs) and project developers to finance organizations, as well as the Kenya Association of Manufacturers (KAM), which aims to increase local value for national manufacturing industries in the medium to long term.

International (development) actors

As mentioned above, the European Union, in the form of the Delegation of the European Union to Kenya, co-authored Kenya's Green Hydrogen strategy, offering financial assistance and technical expertise during its development. This support was provided through the EU Global Technical Assistance Facility (GTAS) and was built upon an H_2 baseline study supported by the German GIZ. The European Union also announced the establishment of the Hydrogen Bank facility and supports the development of projects through the Global Gateway strategy to boost sustainable investments, including in green hydrogen. Additional relevant development and funding agencies currently active in the Kenyan green hydrogen sector include the World Bank, the European Investment Bank (EIB), Agence Française de Développement (AfD), the German Kreditanstalt für Wiederaufbau (KfW), the Japan International Cooperation Agency (JICA) and the British Foreign, Commonwealth & Development Office (FCDO).

Additionally, Power Shift Africa, an umbrella organization for several international development and climate NGOs, seems to be at least part of the conversation, sharing some civil society perspectives on the green hydrogen economy. Finally, Kenya is one of the co-founding countries and a member of the Africa Green Hydrogen Alliance, a government-led platform of six governments (namely Egypt, Kenya, Mauritania, Morocco, Namibia, and South Africa).

Table 2: Main Stakeholders Impacting the GH2 Economy in Kenya

Government, ministries and public sector institutions	Private sector stakeholders	International (development) actors
- President William Ruto / Office of the President - Ministry for Energy and Petroleum - Ministry of Agriculture and Livestock Development - Ministry of Roads and Transport - National Treasury of Economic Planning	- Kenyan Private Sector Alliance (KEPSA) - Fortescue Future Industries (FFI) - Electricity Sector Association of Kenya (ESAK) - Kenya Association of Manufacturers (KAM)	- Africa Green Hydrogen Alliance - European Union - EU Global Technical Assistance Facility (GTAS) - German GIZ - World Bank - European Investment Bank (EIB) - Agence Française de Développement (AfD) - German Kreditanstalt für Wiederaufbau (KfW) - Japan International Cooperation Agency (JICA)

Government, ministries and public sector institutions	**Private sector stakeholders**	**International (development) actors**
		- British Foreign, Commonwealth & Development Office (FCDO)
- Kenya Bureau of Standards (KEBS) - Energy and Petroleum Regulatory Authority (EPRA) - National Environment Management Authority (NEMA) - Geothermal Development Company (GDC) - Kenya Electricity Generating Company (KenGen) - Kenya Electricity Transmission Company (KETRACO) - Kenya Power and Lighting Company (KPLC)		- Power Shift Africa

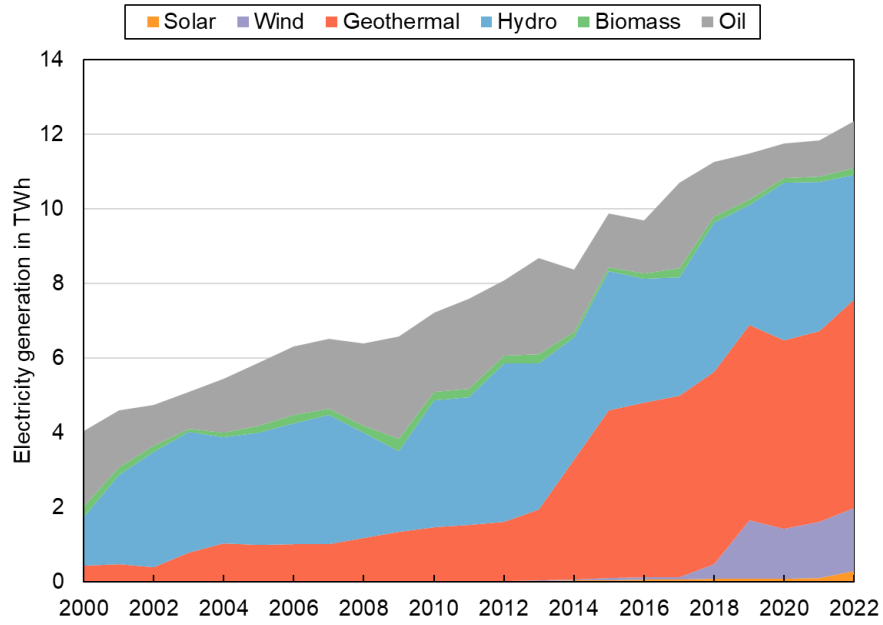
3 Opportunities and Challenges

3.1 Natural and energy resources

According to the 2022 Baseline Study and the Kenyan Ministry of Energy, there are ample renewable energy (RE) resources within the country to support large-scale green hydrogen production without negatively impacting the availability and pricing of electricity for existing consumers. Under the precondition that green hydrogen is solely produced from additional RE capacity or surplus energy, the costs of RE-based electricity are projected to range from USD 2 to 5 per kWh. This cost range is contingent on the expectation of technological advancements leading to increased efficiency and the extent to which excess energy is compensated. Consequently, this cost structure could enable green hydrogen production at a cost ranging from USD/kg 2 - 4, in comparison to the international range of USD/kg 1.5 – 4. Similarly, ammonia production costs are estimated to fall within the range of USD/t 500 - 900, compared to the global range of USD/t 400 – 600. It is important to note that, depending on the production site, these costs are in need of adjustment upward by approximately 5% to 9% to account for electricity transmission expenses (Kenya Ministry of Energy and Petroleum, 2022). However, on-site consultations with various experts and additional literature challenge these optimistic estimates about both surplus energy and low energy prices in Kenya. A more detailed discussion can be found in chapter 3.10.

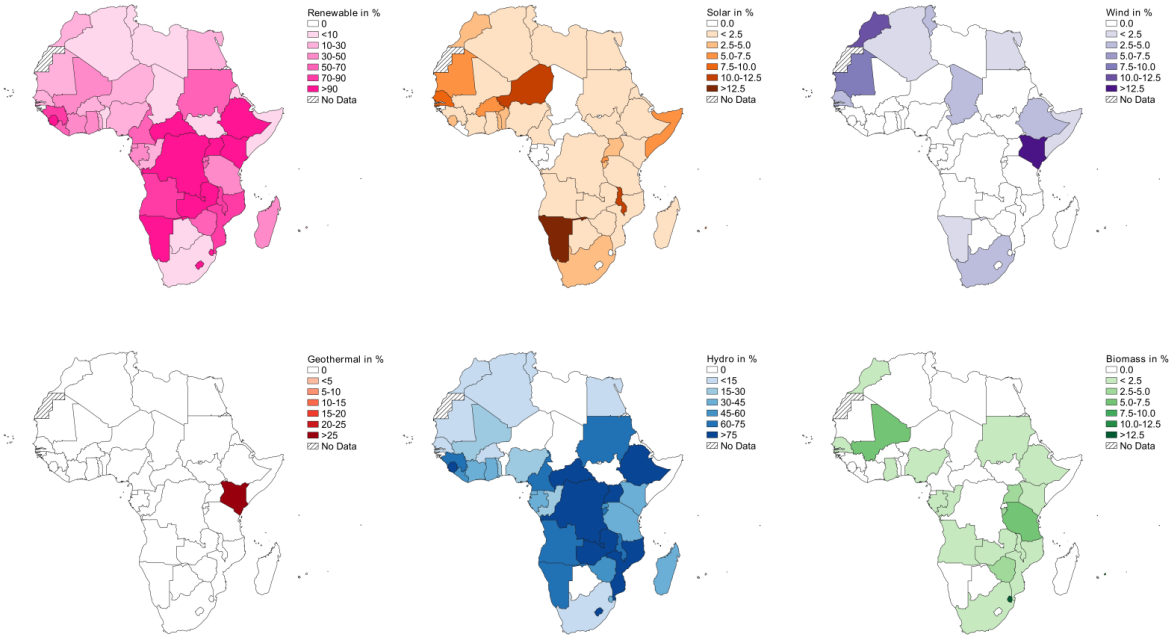
Figure 3 shows that Kenya's electricity generation in the year 2000 relied on a mix of oil, hydro and geothermal sources. Fast forward to 2022, there is a notable shift: reduced dependence on oil, expanded utilization of geothermal energy and a diversified energy mix incorporating solar and wind power. In 2022, electricity generation was around 13 TWh (from 4 TWh in 2000). While solar and wind energy made their debut in 2014, their contribution was initially marginal. However, a noteworthy trend emerged in 2017, with a substantial increase in wind energy, reaching its peak in 2019. This evolution signifies a significant stride towards a more sustainable and diversified energy landscape for Kenya.

Figure 3: Development of electricity generation in Kenya by source between 2000 and 2022



Source: own depiction based on Global Change Data Lab (2023)

Figure 4: Share of different renewable energy sources in electricity generation in each African country in 2021



Source: own depiction based on Global Change Data Lab (2023)

Kenya is one of the top producers of geothermal energy in Africa (see Figure 4). Geothermal energy is a base-load renewable energy source, which provides the country with a competitive advantage compared to other regional but also continental actors, who either highly depend on non-dispatchable sources, like wind and solar, or on hydropower, which has become vul-

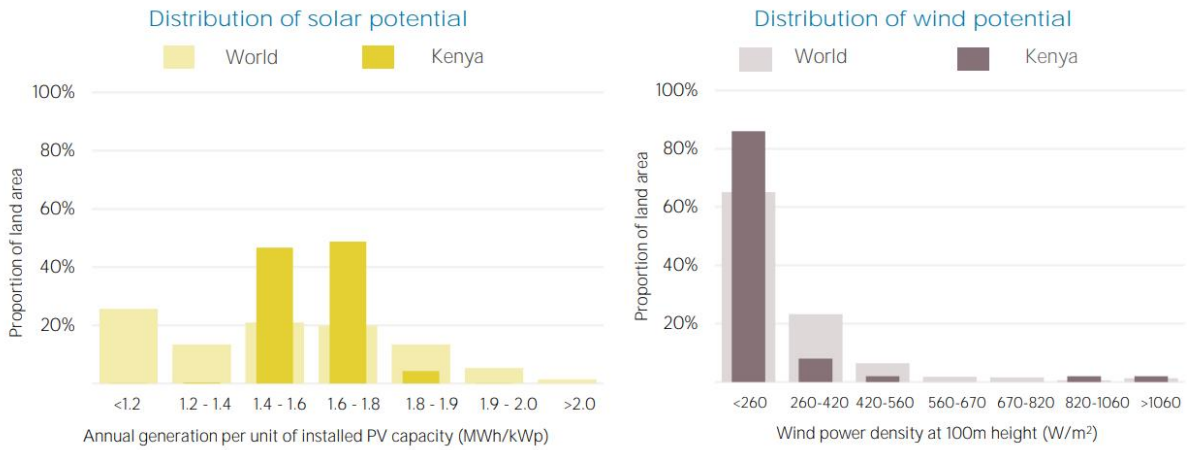
nerable due to severe droughts in recent years. During the Africa Climate Summit, at the Kenyatta International Convention Centre (KICC), Nairobi, President Ruto pledged to move to 100% clean energy by 2030 (Republic of Kenya, 2023a). Kenya's vast geothermal sources will play a key role in realising this goal. The government estimates 10 GW of untapped geothermal energy on top of Kenya's existing power capacity of 2.4 GW (Begisheva, 2018; The Republic of Kenya, June 20th). With this, geothermal energy stands as the predominant source of clean energy in the country, constituting 47% of the total. In 2015, the rift valley region witnessed the construction of two additional geothermal power plants, boasting a combined capacity of 280 MW (George et al., 2019).

Moreover, Kenya already extensively uses its potential for hydropower. Dating back to the early 1920s, hydropower emerged as one of Kenya's earliest recognized national resources. Initial systems consisted of small-scale schemes, including micro-hydros and mini-hydros. The shift towards large-scale hydropower schemes gained momentum with the commissioning of the Kindaruma hydropower station in 1968. Currently, Kenya's installed hydropower capacity exceeds 800 MW, with a nationwide potential estimated at 3 GW for small, mini, and micro-hydro systems (State department of Energy of Kenya, 2023 https://www.energy.go.ke/small-hydro-power-development-kenya - :~:text=Kenya's%20installed%20hydropower%20capacity%20is,estimated%20at%203%2C000MW%20nationwide). The considerable potential of hydropower has been extensively harnessed; however, prolonged periods of drought have undermined its reliability. Consequently, Kenya is escalating its utilization of geothermal, wind, and solar energy sources.

The country does have a high potential of solar energy. Kenya's annual average solar radiation stands at 5 kWh/m^2/day, equivalent to 250 million tonnes per day of oil. Solar energy availability ranges from 700 kWh/year in mountainous regions to 2,650 kWh/year in arid and semi-arid areas, with most of the country falling within the range of 1,750–1,900 kWh/year. However, despite this abundant resource, the current utilization remains negligible (George et al., 2019; Kiplagat et al., 2011. https://doi.org/10.1016/j.ref.2019.03.007). Kenya also boasts a high potential for wind generation (0.346 kWh/m^2), yet the current contribution of wind energy to the overall energy mix of the country is minimal. Various regions, primarily located in the Northwest encompassing Marsabit and Turkana districts, as well as those along the edges of the Rift Valley and the coastal area, experience favourable wind speeds with the potential for successful exploitation (Kazimierczuk, 2019. https://doi.org/10.1016/j.rser.2018.12.061)

Figure 5 compares annual generation per unit of installed PV capacity and wind power density at 100 m height in Kenya and worldwide, considering the proportion of needed land area. It implies that Kenya possesses a high potential for renewable solar energy production that could be used in the electrolysis process. However, it has limited potential for wind energy generation compared to global averages. Finally, the biomass potential in Kenya defined by the net primary production is approximately equal to the global average value (IRENA, 2022).

Figure 5: Distribution of solar and wind potential for Kenia



Source: (IRENA, 2022)

The 2022 baseline study on green hydrogen published by Kenya's Ministry for Energy outlines three suitable geographical areas to produce hydrogen: The coastal region around Mombasa, due to its vicinity to existing infrastructure and the availability of water through desalination as well as the wider Olkaria area (Rift Valley), and the wider Nairobi area, due to their vicinity to power generation sources and power network nodes. Other sites such as in Western or Northern Kenya do also offer some advantages (i.e. wind energy potential) but show disadvantages in terms of existing infrastructure and require special attention regarding water management (rights and sustainable supply) and plants for storage (Kenya Ministry of Energy and Petroleum, 2022).

3.2 Water

In Kenya, water resources encompass a diverse range, including inland saline, freshwater lakes, the Indian Ocean, rivers, wetlands, and ponds. The inland water and wetlands cover an area of 11,200 km^2, and the annual underground abstraction throughout the country amounts to 3,115 million m^3. Notably, the five permanent water basins (Lake Victoria, Rift Valley, Athi, Tana, and Ewaso Ng'iro North) collectively contribute over 14.9 billion m^3 of water flow. However, the distribution of water resources is uneven, with Tana and Lake Victoria Basins reported to have surplus water, while the remaining three basins grapple with deficits (The African Development Bank Group, 2016).

A 2011 projection indicates that by the year 2025, Kenya's per capita water availability is anticipated to decrease to 235 m^3 per year, representing approximately a two-thirds reduction from the 2010 level of 650 m^3. Despite its availability of water resources, Kenya is thus considered a water-scarce country (Marshall, 2011). The water challenges faced by Kenya encompass a spectrum of issues, each contributing to the complex landscape of water resource management. First and foremost, water scarcity, particularly in the arid and semi-arid regions of the country, presents a significant hurdle. Additionally, the underdevelopment of available water infrastructure and the limited utilization of accessible water sources impede the effective management of water resources. Climate variability introduces uncertainties in water availability and demand, exacerbated by severe droughts linked to global warming and deforestation. Catchment degradation further compounds the challenges, impacting both water quality and availability.

The deficiency in water resources assessment and monitoring systems is a major challenge to water management in the country, while pollution and the degradation of water resources from various sources, such as agricultural activities, contribute to water pollution. Trans-boundary water resource conflicts arise from shared water bodies, presenting complexities in effective management. Moreover, the attitudes of communities towards water resources, including perceptions of ownership and management, play a pivotal role in shaping sustainable water resource practices (Ministry Of Water, Sanitation and Irrigation, 2021; Shisanya et al., 2008).

Persistent challenges in water management and service provision in Kenya, arising from the previously centralized governance, inadequate investments and weak enforcement of water laws prompted the establishment of the Water Resources Management Authority (WRMA) in 2003. This agency, designated as the lead authority for national water resources management, oversees lakes, aquifers, rivers, and related functions. The National Water Policy (1999) led to the Water Act in 2002, aligned with the National Water Master Plan 2030 (2013). Constitutional reforms in 2010 introduced decentralization, effective from 2013. Kenya's robust policy and legislative framework address climate change challenges, with adaptation and resilience strategies outlined in the National Adaptation Program (NAP) and operationalized through the National Climate Change Action Plan (NCCAP) and others (Asokan et al., 2021; Obando et al., 2018).

Situated in the North Mainland area of Mombasa County, the Mombasa desalination plant represents the inaugural large-capacity facility of its kind in Kenya. With a daily capacity of 100,000 m^3, the plant is poised to provide drinking water to a population exceeding one million people. It is one of four plants planned by Almar water solutions in Mombasa (Almar Water Solutions, 2018).

3.3 Built infrastructure

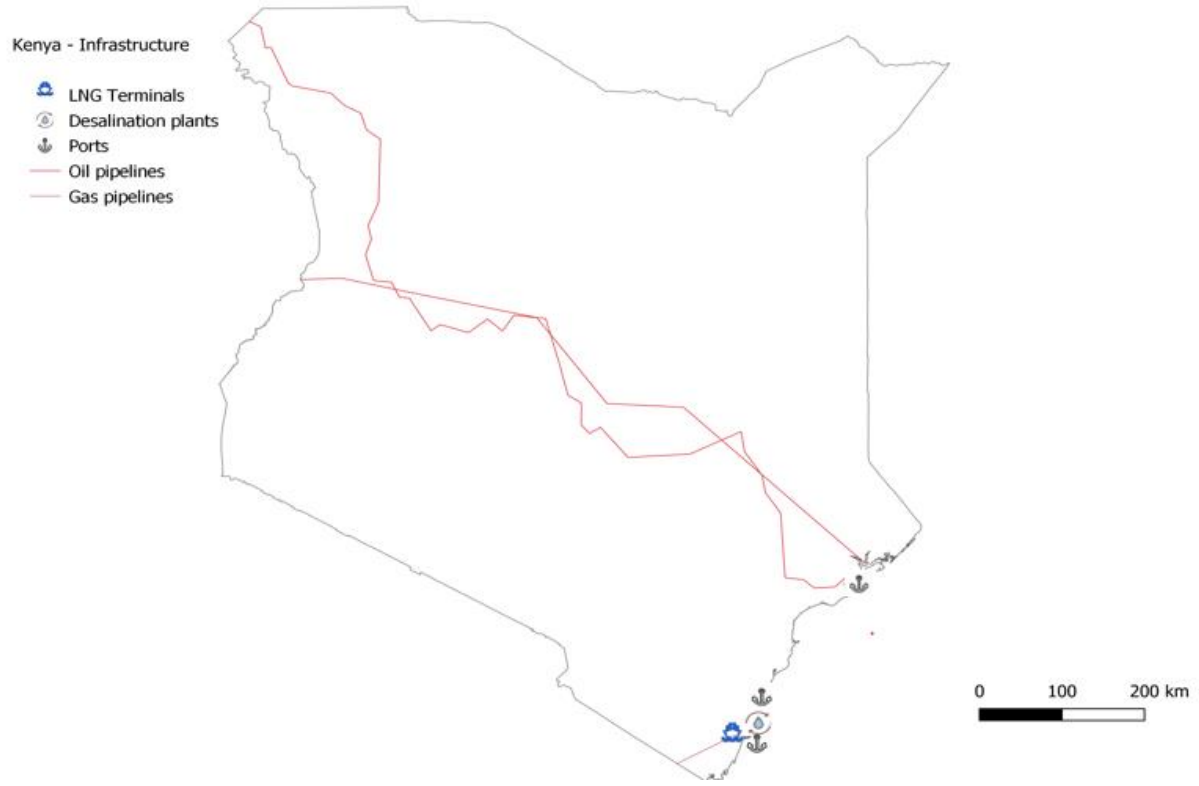
Along its coastline, Kenya boasts multiple essential ports that play a vital role in maritime trade and transportation. Among these, the Port of Mombasa stands out as their largest and most consequential seaport, functioning as a pivotal gateway for both imports and exports. This port holds significant importance as a cornerstone of East Africa's trade infrastructure (Mohit, 2021).

Kenya also has a major pipeline plan: the Kenya-Uganda oil pipeline. It is a joint venture between the Kenyan and Ugandan governments, aims to replace road tankers for oil transportation. Connecting Eldoret to Kampala via Malaba, the pipeline facilitates the exchange of white petroleum products (The East African 2024). The governments collectively hold 49% (24.5% each), and private investors, yet to be confirmed, will have a 51% stake (Hydrocrbons Technology, 2017). Similarly, Kenya is collaborating with Tanzania to build a gas pipeline. In April 2021, Kenya and Tanzania signed an agreement to potentially export gas from Dar es Salaam to Mombasa through a new pipeline, aiming to enhance gas infrastructure ties between the two countries. However, as of September 2023, construction had not commenced, and no specific start date was confirmed. The acquisition of petroleum refineries by the Government of Kenya in Mombasa is expected to facilitate the project, which has completed feasibility studies (Global Energy Monitor, 2023).

The described built infrastructure is depicted in Figure 6. The map also shows an LNG terminal, which has been planned since 2011. In October 2021, K&M, a US advisory firm, conducted a

feasibility study for natural gas power generation in Kenya, which includes the potential development of an LNG import terminal in Mombasa (Dakhling 2023 and K&M Advisors 2022).

Figure 6: Kenya's built infrastructure: harbors, seawater desalination equipment, pipelines



Source: own depiction based on (European Commission, 2023; Global Energy Monitor, 2023))

3.4 Human and social capital

Countries' ability to adapt to changing global markets is highly influenced by the availability of human capital (Hjeij et al., 2022, p. 4998). Human capital is understood as the "the knowledge, skills, competencies and attributes embodied in individuals that facilitate the creation of personal, social and economic well-being" (OECD, 2001). According to the Human Capital Index (HCI), Kenya (0.55) scores above the Sub-Saharan Africa average (0.40) (World Bank, 2020b).

Indicators such as the HCI indirectly contribute to the analysis of a country's potential for adopting and advancing a green hydrogen market. Additional indicators, such as the number of researchers in R&D per million people and the percentage of total working-age population with advanced education, have also been used in the literature to more directly measure this potential (Hjeij et al., 2023). Table 3 shows numbers for both additional indicators in selected Sub-Saharan countries.

Table 3: Number of researchers in R&D per million people

Country	Number of researchers		*% of working-age population with advanced education*	
Kenya	227	(2010)	68	(2021)
Rwanda	59	(2019)	76	(2022)
Uganda	29	(2014)	87	(2021)
South Africa	473	(2020)	81	(2022)
Tanzania	19	(2013)	30	(2020)
Senegal	581	(2015)	51	(2019)
Namibia	153	(2014)	79	(2018)
Ghana	87	(2015)	67	(2017)
Ethiopia	90	(2017)	94	(2013)

Source: (World Bank, 2023b)

After South Africa and Senegal, whose latest available data are much more recent, Kenya ranks third in number of researchers per million people in Sub-Saharan Africa. On the other hand, 68% of the working-age population have advanced education in Kenya, a share that is generally higher in other Sub-Saharan countries like Namibia and South Africa, who are also very ambitious in establishing a green hydrogen economy.

A report of the Kenyan Commission for University Education (CUE) for the 2017-2018 period provides details on the academic fields that are most often offered in Kenyan universities. According to this report, 56% of the all programmes offered in public and private universities are in academic fields like social sciences, business and administration, health, education or agriculture (CUE, 2019, p. 17), whereas higher education programs in STEM fields like engineering, mathematics, natural sciences and information and communication technologies account in total for 29% (CUE, 2019, p. 17). However, this is not just a trend in Kenya. On average less than 25% of higher education students in Africa are enrolled in STEM fields (UNESCO, 2023, p. 33). In Kenya, the gender gap among STEM students is a critical one. In 2020, only 1/3 of the admitted students to STEM fields registered as female (UNESCO, 2023, p. 34).

Nevertheless, STEM education - both in secondary and higher education - has been given increased importance by the Kenyan public authorities since the late 1990s (CEMASTEA, n.d.). As of 2003, the Centre for Mathematics, Science and Technology Education in Africa (CEMATEA) has been the main public body to support the improvement of STEM education both in Kenya and in Africa (CEMASTEA, n.d.). One of their programs, the Kenya National Science Technology Engineering and Mathematics Learning Ecosystem (NSLE) was established in 2019 to improve STEM opportunities for the economy.

These efforts, however, do not seem to suffice. According to the World Bank, the smaller share of graduates in science and engineering is one of the reasons why Kenyan firms are less able to scale up, despite high levels of newly established firms (World Bank, 2021, v). Manufacturing is one of the sectors most affected by this trend. Higher shares of manufacturing firms in Kenya fail to achieve scale and remain small and informal than in other countries (World Bank, 2021, p. 20). In addition, 62% of workers in manufacturing did not complete a secondary education degree and, hence, are classified as low-skilled labour (World Bank, 2023a, p. 29). Moreover, in 2019, the rate of informal employment in STEM occupations was 43.5% (ILOSTAT, 2021). These data represent a mismatch between the job market and the labour force in Kenya. Although technical sectors like manufacturing would benefit highly from qualified and skilled labour,

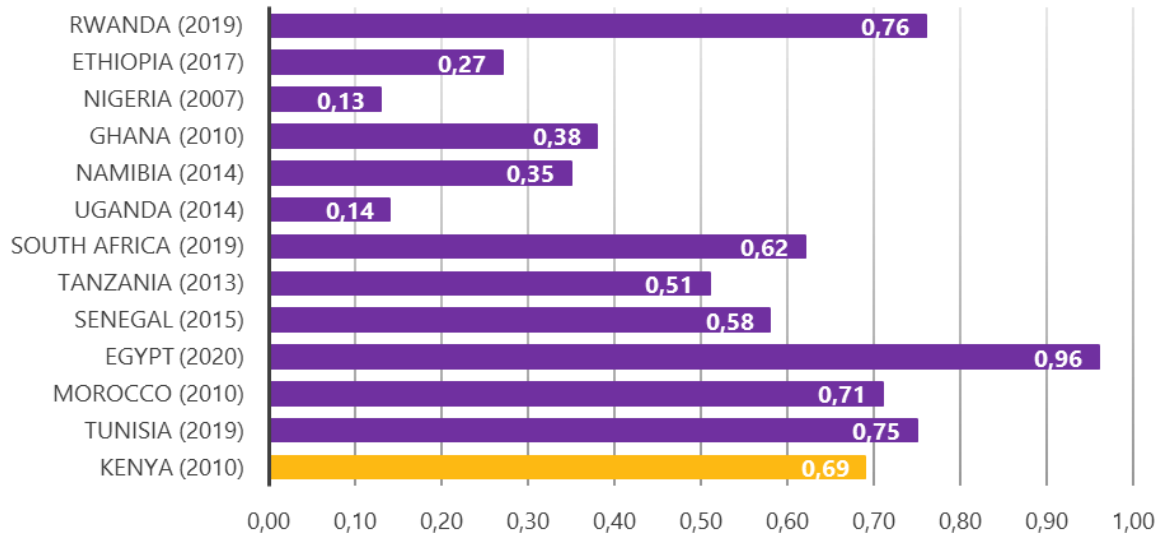
almost half of the STEM employees remain in the informal sector. This is either because businesses that employ STEM employees are too small and cannot afford to become formalized, or half of the STEM occupations are rather for low-skilled labour who cannot find a position in the formal sector. Either way, this shows a potential that Kenya can tap into to improve labour market and manufacturing sector simultaneously.

Not just in STEM fields, but overall, the Kenyan higher education and its capacity to shape a more qualified workforce in the country has been contested (Fosci et al., 2019; McCowan, 2018; OECD, 2013). The main reason for such a limited capacity was identified as the phenomenon of "quantity over quality", something that applies not only to Kenya, but is also common among many other lower income countries of Africa, Asia and Latin America (McCowan, 2018, p. 128). As the financial, physical and staffing (lecturers) resources are not increased proportionally with each additional higher education facility, the overall education quality decreases.

3.5 R&D institutions, incubators

The research and development (R&D) ecosystem – including research institutions and research support mechanisms - in Kenya are well-established, especially when compared to other Eastern African countries (Fosci et al., 2019). In fact, Kenya has the most tech hubs in Central and East Africa (UNESCO, 2023, p. 6). Figure 7 shows the gross domestic expenditure on research and development (GERD) as percentage of GDP for several countries. According to the World Bank database (2023b), in 2010, Kenya spent 0.69% of its GDP on R&D. The Kenyan Science, Technology and Innovation (STI) Act 2013 anticipated, however, the allocation of 2% of GDP on R&D through the then established National Research Fund (NRF) (The Republic of Kenya, 2013). Yet, a National Research and Development Survey conducted in 2019 revealed that the R&D expenditure remained at 0.77% (Ministry of Education, 2020). This means that in 2019, Kenya had the second highest gross domestic expenditure on research and development on the continent, coming in second to Egypt.

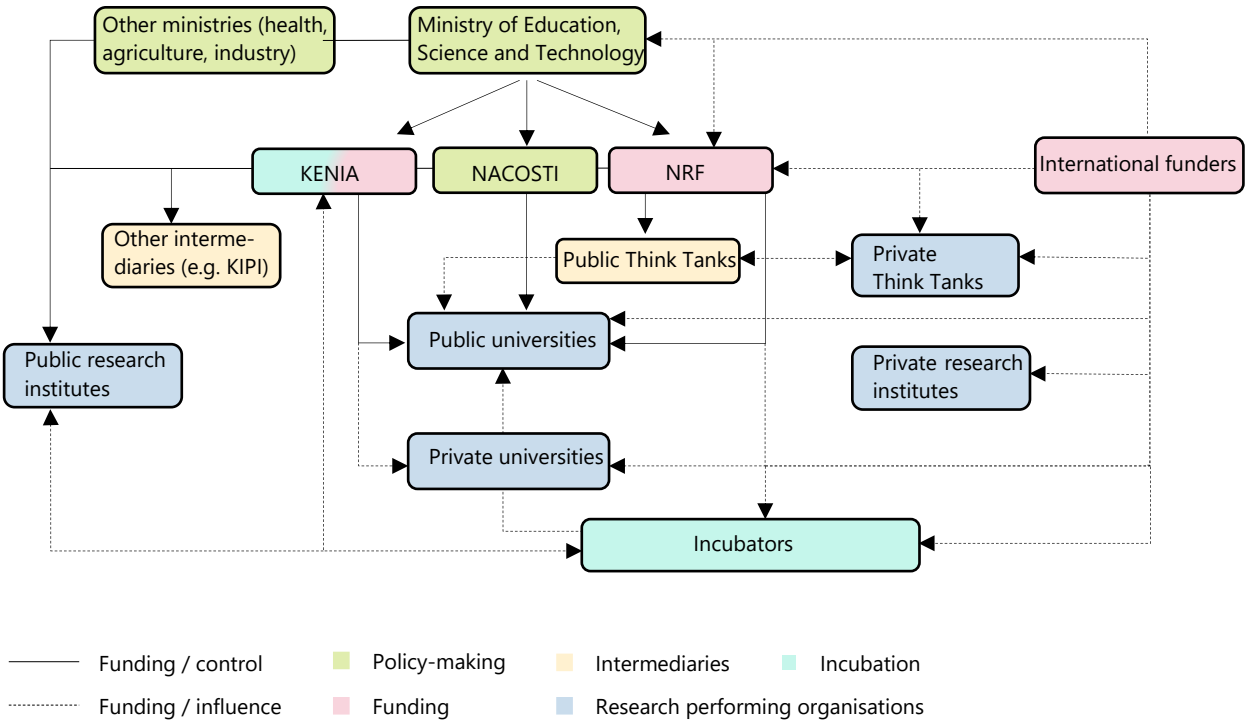
Figure 7: Gross domestic expenditure on research and development (% of GDP)



Source: own depiction based on (World Bank, 2023b)

Figure 8 represents the central institutional structure of R&D in Kenya. The Ministry of Education, Science and Technology shapes policymaking but, depending on the subject, other ministries are also involved. To regulate, coordinate and support STI in the country, the STI Act established three key institutions, namely the Kenya National Innovation Agency (KENIA), National Commission for Science, Technology and Innovation (NACOSTI) and the National Research Fund (NRF) (The Republic of Kenya, 2013). Through different programmes and support mechanisms, they shape the STI agenda in the country and provide funding and incubation possibilities.

Figure 8: Actors in Kenya's research ecosystem



Source: own representation based on Fosci et al., 2019, p.6

Since, as of 2022, more than 20% of the added value in the Kenyan economy came from agriculture, forestry and fishing, and in 2021 33% of the total employment was in agriculture (World Bank, 2023b), most of the R&D and innovation projects focus on the optimisation and sustainability of these sectors. For example, NACOSTI's strategic plan for 2023/2024-2027/2028 prioritizes projects and programmes in leather, livestock, textile, crops and pharmaceuticals production sectors (NACOSTI, 2023). The selected projects for KENIA's incubation program R2C (Research to Commercialization) similarly focus on agrochemicals, crop technologies, agricultural value chains and wastewater treatment. A parallel pattern can also be seen among the projects supported by Kenya Climate Innovation Center (KCIC) who is one of the few incubation centres with a climate change targeted innovation focus. Even though the subject of renewable energy and energy efficiency is one of the thematic areas they support, it is the area with the fewest number of applications they receive. According to on-site consultations, the main reason for this is the small size of the market, or in the case of green hydrogen the nonexistence of it (Interviewee 11, 2023). That is why most renewable energy projects that KCIC supports focus on increasing the efficiency of clean cooking technologies, as there is already a market

and need for it and they don't require high technology solutions. The same pattern also applies to the Energy Resources and Energy Efficiency Research Center of Kenya Industrial Research and Development Institute (KIRDI). Their main R&D activities are on clean cooking technologies, energy efficiency of electrical appliances and waste-to-energy technologies.

It is nevertheless noteworthy that some initiatives support innovation and technology development on green hydrogen in Kenya. In 2023, Endeva, a Germany-based non-profit independent association, led the co-creation of the model "Hydrogen Center of Excellence" for Kenya through its Inclusive Innovation 2030 (ii2030) format. The model refers to a one-stop-shop for hydrogen innovation in Kenya, which can support the technology developers through various stages of their innovation process. These include trainings, mentoring, incubation and acceleration, green hydrogen research and innovation lab for product development, as well as an information centre for other relevant stakeholders, all focusing on the needs of technology start-ups in green hydrogen (Endeva, 2023). If implemented and sustained, the Center can boost the technology development in Kenya on green hydrogen, enabling more Kenyan start-ups be active in the market. This could also boost the research ecosystem in the country, showcasing its ability to develop high-technology products. The decisive factor in the success of this model seems to be whether the continuation of funds can be maintained or not.

3.6 Implementing capacities

As seen in Figure 8 above, Kenya's research ecosystem is composed of a diversified landscape of research institutions with different missions and responsibilities. The current and previous governments have published several policy, strategy and vision documents indicating their eagerness to improve STI in Kenya. Yet, certain factors seem to limit the effective functioning of the research ecosystem, hindering its ability not only to produce upstream hydrogen technologies like electrolyzers, but also to adapt and develop technologies required for downstream applications like PtX.

The first factor that challenges an effective research policy implementation is the limited funding. Even though Kenya is allocating a bigger share of its GDP to R&D than many other Sub-Saharan African countries, it only provides a limited budget for research, which is allocated to vital areas for the country, such as clean cooking and agrichemicals. Such an allocation results in the fact that other R&D activities, like monitoring and assessment studies, are cut off or less supported (Fosci et al., 2019). This leads, on the one hand, to less efficient public research, and, on the other hand, to limited public presence in critical STI areas and hence restricted possibility to build research capacity. Moreover, it should also be noted that funding also constitutes the main challenge to sufficient digital and technical infrastructure (Fosci et al., 2019). Although the number of universities in Kenya has almost tripled since 2012 (Fosci et al., 2019), the pace of the expansion has constrained available financial and human resources leading to limited access for research materials as well as diminished emphasis on research (McCowan, 2018; Ministry of Education, 2020).

The second factor that can be cited is corruption. In the literature, significant negative correlation between corruption and firms' R&D performance has been observed in Latin America (Viglioni et al., 2022) and in the Global North as well (Aldieri et al., 2023). While, in Kenya, such a relation has not been reported yet, it can be argued that corruption diverts public resources away from high impact R&D.

Kenya ranks 123th among 180 countries in the Corruption Perceptions Index (Transparency International, 2023) and improves its ranking steadily. Yet, according to the Global Corruption Barometer published in 2019, 67% of Kenyans think that corruption has increased in the last twelve months, and 45% of the respondents reported they had to pay a bribe, give a gift or do a favour to get a public service they needed (Pring & Vrushi, 2019). Apart from corruption cases in public services that citizens must face daily, different forms of corruption are also observed in public sector project procurement. According to a recent study conducted by Kenyan Ethics and Anti-Corruption Commission (EACC & UNODC, 2023), favouritism and manipulation of costs are the main forms of corruption in the pre-tendering phase for health care projects, whereas making payments for substandard works was reported to be the most prevalent form of corruption in the post-tendering phase. Even assuming that the situation is not that dramatic in public research institutes, it still hinders the efficient use of scarce public resources.

The final identified major factor is the lack of coherence in STI policy formulation. As explained in chapter 1.5, not just in STI Policy but in general, coherence in policy formulation is sometimes difficult to reach across different government entities and levels within Kenya's regulatory framework. The STI Act 2013 constitutes the backbone of Kenya's research structure. The Act has established three key public research institutions (see Figure 8) with clearly formulated functions for each (The Republic of Kenya, 2013). However, apart from establishing these and several other additional advisory commissions, the Act does not seem to bring much clarity in terms of how and by whom particular targets will be achieved. The 2020 STI Policy Draft acknowledges the challenge of governance in coordination, compliance, and enforcement due to multiple legislations with overlapping mandates between county and national government (Ministry of Education, 2020). To overcome these governance challenges, the Policy Draft requires the development of an Implementation Framework and Plan, which should outline the specific programmes, activities as well as the respective timelines and key performance indicators for each responsible actor (Ministry of Education, 2020). If implemented, the Draft might provide a well-established basis for a common national research strategy, as it identifies the challenges clearly and matches those with some concrete steps delegated to national authorities and ministries. However, the vertical agenda setting and the involvement of important parties across the whole research system in the country seem to still be lacking in the Draft. In other words, county governments, local research institutions and other intermediaries are not currently considered in the process, making the national government the only authority to set the research agenda of diverse STI fields and providing less chance to other intermediary and local research centres to build up capacities.

Even though these challenges might be or stem from some long-standing structural problems, the UK Department for International Development suggests in a report on Kenya's research needs (Fosci et al., 2019), that supporting the implementation capacities of national institutions, promoting research quality and strengthening the role of national intermediaries would contribute to strengthening the research capacity in Kenya. Moreover, making clear and systematic STI policies an indispensable part of national development strategies would help to address some of the challenges mentioned above. It is expected that the government prepares a policy reflecting its particular political interests. Yet, it is similarly crucial that the public research institutions, universities and think tanks at both national and local levels are involved also at the agenda-shaping stages of STI policies in a participatory way. Active involvement of actors from different levels of the research ecosystem in the country can ensure effective implementation

of the policies as well as a research agenda accurately reflecting the economic and development needs of the society.

3.7 Availability of funds for RDI

As mentioned above, limited funding in RDI demonstrates a bottleneck for the entire research structure in the country. According to the 2014 African Innovation Outlook Report, external funding accounted for 47% of the total funding sources in 2010 in Kenya, whereas government expenditure remained at 26%, business at 4.3%, higher education at 19% and private non-profit at 3.5% (NPCA, 2014). This means that almost one of every two research projects were externally funded. For example, Kenyan Treasury represents only one seventh of funding sources for the annual budget of the Kenya Medical Research Institute, while the rest is covered by foreign donors (Muchangi, 2023). The 2019 African Innovation Outlook points out that the average share of public R&D expenditure in GDP is at similar levels around the world (AUDA-NEPAD, 2019, p. 15). Business expenditure in R&D, however, varies significantly. While, among the OECD countries, research expenditures from business as a share of GDP is the highest compared to other funding sources, in Africa (except South Africa), it is international funds that provide the biggest source (AUDA-NEPAD, 2019, p. 18). This means, also in Kenya, that R&D does not constitute a priority for the business sector, nor does its share cover the government's inadequacy in providing research funds. Therefore, this gap is covered by international funds, which remain unpredictable (OECD, 2013). However, evidence suggests that exceeding 1% of GERD to GDP target can be achieved when business actively engages in R&D (AUDA-NEPAD, 2019, p. 18).

3.7.1 National level

The National Research Fund (NRF) is the main state authority to manage and allocate the national research funds in Kenya. It was established under the STI Act 2013. NRF has three main funding mechanisms: (i) Competitive funding to individuals, institutions or firms through grant calls for proposals that are in line with national research priorities identified by NACOSTI, (ii) matching grants funding for joint research projects in collaboration with local and international development partners, and (iii) institutional-support grants funding to specialized and national strategic research facilities.

For the financial year 2023-2024, the total budget for the State Department for Higher Education and Research, whose mandate also covers semi-autonomous government agencies like NRF and NACOSTI, was approved to be KES 79 billion in total, and the NRF's budget within that total was KES 323 million (National Treasury of Kenya, 2023).

3.7.2 International level

As explained above, international funding constitutes a big portion of the available funding to the actors of the Kenyan research system. Major donors and cooperation partners of this funding pool are from the Global North, with substantial focus on green energy and climate change mitigation. On the other hand, apart from investments on infrastructure and energy projects, China has also been supporting research in Kenya within the framework of South-South Cooperation. While the know-how and technology transfer in Chinese energy projects seem to be rather limited, their research cooperation mainly focuses on agriculture and crop technologies.

3.7.3 The European Union

Together with the Delegation of the European Union (EU) to Kenya and the GIZ, the European Union Global Technical Assistance Facility (GTAF) for Sustainable Energy has been assisting the development of the Green Hydrogen Strategy and Roadmap for Kenya. Following the launch of the strategy at the Africa Climate Summit, which was held in September 2023 in Nairobi, as part of the Global Gateway initiative of the EU, European Commission and Kenya signed an agreement for the provision of EUR12 million grants to support both public and private investments in Kenya's green hydrogen industry (European Commission, 2023).

Also, the European Investment Bank (EIB) entertains a close cooperation with Kenya and provided a total of EUR745 million funding for the energy sector since the beginning of the cooperation in 1976. The EIB Eastern Africa office was opened in Nairobi in 2005, which has strengthened this relationship (EIB, 2023).

3.7.4 Germany

Through various support schemes by the KfW and GIZ, the German Federal Ministry of Economic Cooperation and Development (BMZ) has been financially and technically supporting the R&D and projects in renewable energy generation and green hydrogen production at various scales in Kenya. These include exploratory well drillings, construction as well as the upgrade of Olkaria I, II and IV geothermal power plants with a total budget for all project phases reaching up to EUR128 million. Another geothermal project has been run in the Bogoria-Silali Block with a total budget of EUR80 million. Apart from geothermal energy, the BMZ also supports the development and modernisation of wind, solar and hydro power plants in Kenya, which in total financially corresponded to EUR42.5 million. Another project is being implemented to support the urban and rural electro-mobility with a budget of EUR6.9 million.

In addition to these planned or already implemented projects, Germany and Kenya agreed on Climate and Development Partnership at the COP27. Following this partnership, Germany has pledged in 2022 and 2023 EUR112 million and EUR450 million, respectively, to Kenya to be used in further expansion of renewable energy, power grid and green hydrogen production projects (BMZ, 2022; Sguazzin, 2023). The latter also includes a debt relief of EUR60 million, given that Kenya successfully allocates the funds to renewable energy projects and related fields (Sguazzin, 2023).

In that vein, the BMZ supports green hydrogen production from geothermal power, which is planned for the production of green fertilizer. To showcase such an investment with potential risks and opportunities, the KfW Development Bank commissioned the Fichtner GmbH & Co. KG in 2023 to conduct a pre-feasibility study (GTAI, 2023). With such a report, the KfW aims to encourage private investors to seek out opportunities in geothermal power generation, hydrogen production via electrolysis and ammonia production (Interviewee 5, 2023). The challenge they anticipate is the weak competitive power of the end product, green fertilizer in this case, with the conventional imported fertilizer dominating the domestic market. Due to a current government subsidy scheme, the imported green fertilizer costs KES2,500 (Kenya Shillings) (Aluoch, 2023), whereas the retail price as of October 2023 is around KES4,700 (AfricaFertilizer, 2023). The price of domestically produced green fertilizer, on the other hand, is expected to be KES7,500 – with the provision of subsidies, if implemented (Interviewee 1, 2023).

High initial investment costs in geothermal energy are among the factors that lead to high energy power costs in the country, which also drives the price of green fertilizer up. To reduce

the risks in geothermal energy investment, KfW financially supports the Geothermal Risk Mitigation Facility (GRMF), a funding mechanism initiated by the African Union to facilitate and de-risk the geothermal development in Eastern Africa by providing grants to public and private investors. Supporting Kenyan state authorities like KenGen and Geothermal Development Corporation (GDC) play an important role in bringing the CAPEX down. This represents, for example, one of the topics that the EU GTAF team advises the Kenyan authorities about.

Apart from financial support, establishing a hydrogen market in Kenya, especially one that will be built on green fertilizer, also requires assistance at the policy as well as operational level. For this, through GIZ, the BMZ supports the capacity building in the green hydrogen working group of the Kenyan government in fields like chemical and soil engineering to assist the research on technical processes involved in fertilizer production and application.

3.7.5 Denmark

The Danish Environmental Protection Agency (DEPA) has been supporting sectors, such as food, agriculture, environment, waste management, and maritime in Kenya (Ministry of Foreign Affairs of Denmark, n.d.). An example is the project called Green Growth and Employment Programme from 2016 to 2020 with a total budget of USD53 million. Sustainable use of natural resources and community resilience as well as sustainable growth and jobs from investment and trade were the two pillars of outcomes the project aimed at, for which nine local and national Kenyan institutions worked together. Kenya Climate Innovation Centre (KCIC) was among the project partners of Green Growth and Employment Programme, who contributed to increased commercialization and scale-up of locally relevant climate technologies. By doing so, KCIC further improved its capacity and impact in supporting local climate technologies and became one of the major incubation centres in Kenya in that field. DANIDA continues funding KCIC.

3.7.6 China

Especially in the recent decade, China has become one of the major cooperation partners of many African countries. The launch of the Belt and Road Initiative (BRI) in 2013 has brought particularly energy and infrastructure projects to the centre of China-Africa economic cooperation (Chiyemura et al., 2021). According to the IEA (2016), 56% of the total added capacity of Chinese energy projects between 2010 and 2020 in Sub-Saharan Africa are based on renewable sources, where hydropower alone constitutes approximately half of the renewable energy projects. In comparison to these projects, provision of research funds to local institutions remains limited.

A similar trend can also be observed in Kenya. The state-owned China Road and Bridge Corporation built and financed the Nairobi Expressway, a recent example of public-private partnership in the country with a total of USD668 million investment. Chinese state enterprises also undertake and invest in energy projects in Kenya. According to China's Global Energy Finance Database (Boston University Global Development Policy Center, 2023), between 2006 and 2019, China has invested USD1.4 billion in various energy projects including energy infrastructure and renewable energy generation in the country. One example of the latter is the 55MW Garissa Solar PV project with a USD135 million investment. The financing agreement made the use of Chinese technology mandatory and commissioned a Chinese EPC firm (China Jiangxi Corporation for International Economic and Technical Cooperation) to lead the project, who

mostly preferred Chinese sub-contractors (Lema et al., 2021). Even though this has limited the possibility of technical knowledge transfer, the project enabled the involvement of a Kenyan engineering firm in supportive roles, which made know-how transfer in system design and operation of a large-scale grid-connected solar PV power plant possible (Lema et al., 2021).

Apart from power generation, China has also been exploring green hydrogen production projects on the continent. Although it was previously assumed that China will be self-sufficient, and, hence, was not going to be a hydrogen exporter in the global market, this seems to be changing (Avramuta, 2023). In 2023, two Chinese state-owned enterprises announced some initial agreements to build hydrogen projects with potential exporting goals both in Egypt (Martin, 2023) and Morocco (Yihe, 2023). However, considering Kenya's geographical position, it can be seen as rather unlikely for China to undertake such a green hydrogen production project in Kenya with a similar purpose. Also, no other green hydrogen project with a focus on the domestic market has been announced.

On the other hand, research cooperation between the two countries has gained momentum after the launch of the BRI. Reflecting the needs of the Kenyan economy, the collaboration has concentrated on research fields such as crop technologies, food systems, biodiversity conservation, and sustainable water management. The research at the Kenya-China Joint Laboratory for Crop Molecular Biology mainly aims at increasing crop yield through molecular modifications, and hence, contributing to the food security in the country (Hualing, 2021). Developing modified crops might pose an alternative to domestic fertilizer production, as they are known to be effective in reducing the need not only for pesticides but also for fertilizers.

3.8 Greening the business sector

In 2022, manufacturing corresponded to 7.8% of the Kenyan GDP, representing the first increase of its share since 2011 (World Bank, 2023b). While the Kenya Association of Manufacturers (KAM) (2022) link this to the expanding agro-processing industry in the country, Kenya National Bureau of Statistics reports that processed fish, motor vehicles, trailers and basic metal products have also contributed to the growth in the manufacturing sector (KNBS, 2023). Kenya's heavy industry is considered among the leading ones in the Eastern Africa region, especially in structural galvanized sheets and cement production.

To restore the growth within the manufacturing sector and to increase its value addition, KAM has identified several priority areas. These include job creation, raising the share of manufactured products within the export, reducing the regulatory burden, raising investment, efficient provision of public goods and services, a pro-industry taxation system and raising the country's industrial competitiveness (KAM, 2022). In addition to those, another challenge particularly for the heavy industry is high energy prices, since they limit their ability to grow. To mitigate the adverse impacts of high energy costs, it has become a common practice for many private firms to install renewable captive power units on their production sites. In other words, businesses install off-grid power generation units (mostly waste-heat recovery and solar PV) on their facility to cut down their expenses on energy. In 2022, licensed captive power has reached 350 MW in total, representing an increase by 30% compared to 2021 (KNBS, 2023). Nevertheless, if Kenya were to introduce a carbon tax, for which the Climate Change (Amendment) Act 2023 laid down the first regulatory framework, then it would raise the production costs of businesses significantly. In such a scenario, carbon price, carbon tax, price of carbon credits, following

regulations, how binding they are and the level of firms' accessibility to national and international support mechanisms will be crucial determinant factors in initiating a green transition for the business sector.

3.8.1 Metal industry

Kenya produces and exports many processed iron, steel and aluminium products to the regional market through its well-established metal industry, where many private manufacturing firms are active.

As the exploitation of Kenya's iron ore mines has started only recently, many steel manufacturers use scrap metal to produce steel and related products. In a production cycle based on scrap metals and hence not on iron ore, hydrogen cannot be applied as a reducing agent. Also, for hydrogen to be used as fuel, according to the consulted Kenyan steel manufacturers, the whole production system would have to be renewed. Current high production and energy costs of steel manufacturers and the lack of local and regional demand for green steel provide little incentive for such a transformation.

On the other hand, Devki Steel Mills Limited, the biggest steel manufacturer in Kenya with a market share of over 50%, has recently opened a virgin steel factory, producing steel directly from iron ore. The factory is located in Kwale County, situated not far from several iron ore mines and the Mombasa port. The factory is expected to provide 2,500 direct and 9,000 indirect employment opportunities for the locals (Abdullahi, 2022).

Although it has not been fully integrated and used in the domestic market, Kenya exports iron ore, for which the only destination in 2021 was China with a volume of USD11.8 million (OEC, 2023).

3.8.2 Mineral industry

The cement market in Kenya has been growing steadily. Between 2018 and 2022, domestic cement production has risen by 62% (KNBS, 2023), whereas clinker imports have dropped by 32% (ITC, 2023).This is particularly important as clinker is the intermediate material in the cement manufacturing process, whereas cement is the end product. This trend might continue in the coming years, as the Finance Act 2023 introduced an import tariff of 17.5% of the customs value for clinker and 10% for cement (The Finance Act 2023, 2023). It is noteworthy that the Act has brought similar tariffs to other manufactured goods including iron and steel products to stimulate the domestic manufacturing market.

Yet some domestic cement producers have opposed the import tariff during the negotiations, arguing that they need imported clinker, because the limestone quality in Kenya is not as high (CEMNET, 2023). On the other hand, Devki Group, who is also the biggest clinker producer in Eastern Africa, supported the Finance Bill extensively and yet announced their plans to export up to 80% of their production from their new clinker plant in West Pokot County (CEMNET, 2023). Neighbouring countries in the region will be the main export destinations for Devki's clinker.

With the leading producers in the region, Kenya has one of the few well-developed cement and clinker markets in the African continent. Nevertheless, similar to the iron and steel sector, high energy costs and no regional demand for green products provide no economic incentive for businesses to decarbonize their production. On the other hand, unlike iron and steel, due

to the wide availability of its raw materials (e.g. limestone) across the globe, cement is a locally or at most regionally used product and is not traded globally. Hence, oversees demand for green cement would also not be enough to provide an incentive for the Kenyan manufacturers. In addition, the decarbonisation of the whole clinker production cycle through green hydrogen is accepted to be one of the most challenging processes compared to other industrial decarbonisation applications, as CCS is an indivisible part of it. High machinery costs, lack of knowledge, need for skilled labour and the necessity of a complementary supply chain make a full transition difficult even for the big international producers from developed countries. Although the global market share of green cement has been increasing in recent years, it stemmed mainly from increased adoption of discarded waste like blast furnaces and fly ash (Fortune Business Insight, 2023). In total, government support and priority in the agenda setting for green hydrogen applications have not been given either to the metal or mineral manufacturing sectors, but rather to the chemical industry.

3.8.3 Chemical industry

Currently Kenya produces no ammonia domestically and imported 5,700 tonnes of methanol in 2022 (ITC, 2023). In this context, to substitute imports, the production of green hydrogen derivatives has been chosen as the primary application area in Kenya. As stressed above, green ammonia for fertilizer and green methanol as a feedstock for the industry will be produced as the no-regret options. Increasing concerns on food insecurity and the high shares of agriculture within total employment, but also GDP, increase the importance of the sector for Kenyan economy. Additionally, because a fertilizer market already exists, ammonia production as a derivative of green hydrogen becomes a no-regret option in ramping up the green hydrogen market in Kenya.

As of 2023, there are three major fertilizer production projects in the pipeline in Kenya. The first one is the pilot project from KenGen with an initial foreseen capacity of 5 MW green hydrogen production. The idea is to utilize the geothermal power KenGen already operates in Olkaria, Naivasha, where the pilot project will also be located. Currently, a feasibility study is being conducted to assess the green hydrogen production from geothermal power and its conversion first to ammonia and then the final product of fertilizer. The project is planned to be in operation by 2025.

The second project is developed by Fortescue Future Industries (FFI) to produce green ammonia and hence fertilizer with a green hydrogen generation capacity of 300 MW from geothermal energy. The project had been announced during the COP27, when a framework agreement was signed between Kenya and FFI. Although no feasibility study or plans of such are known publicly to date, we know that an investment support as well as an implementation agreement were signed recently between the Kenyan government and FFI. Most of the produced fertilizer will be first supplied to the Kenyan domestic market, but an export option is also viewed as possible.

The third project can be claimed to be the most advanced one among all green hydrogen projects in the country. A feasibility study has already been completed and the selection of land has also been finalized. The project has been under development by a consortium of MET Development, Industrial Promotion Services (IPS) of Aga Khan Fund and a Norwegian green energy company named Westgass Hydrogen. The target fertilizer production is 200,000 tonnes

by using 100 MW of geothermal power. It is also expected that the facility will provide 300 permanent jobs.

Moreover, it is noteworthy that one of the fertilizer projects which were previously announced and mentioned in the baseline study (Kenya Ministry of Energy and Petroleum, 2022) was cancelled due to changed ownership and the following downsizing of the firm. Even though it can be considered an exceptional example, on site consultations for this report revealed that high investment costs and initial uncertainties related to access to geothermal steam as the clean energy source had posed crucial challenges (Interviewee 13, 2023). Therefore, it showcases the importance of securing access to geothermal steam for smaller firms as an alternative to reach base-load clean energy without the need of drilling geothermal wells.

Another important chemical feedstock Kenya imports is methanol. Similar to ammonia, methanol is also a derivative of hydrogen and can be labelled as green when produced from green hydrogen. In the Green Hydrogen Strategy and Roadmap for Kenya (Kenya Ministry of Energy and Petroleum, 2023) launched in September 2023, a 100% import substitution of methanol is foreseen already in the first phase of the roadmap (2023-2027). Sowitech Kenya, a Germany-based renewable energy project developer specialized in solar and wind power, has been developing a green methanol project with an annual production of 8,000 tonnes. This production will be powered by a combination of solar and geothermal energy to ensure an uninterrupted power supply and hence will also be located in Naivasha. The project is also at a quite advanced stage as the technical feasibility study has already been finalized. Nevertheless, similar to the fertilizer market, substituting an imported grey product with a domestic green one that involves high investment costs will surely induce a higher end price. Therefore, a common challenge that almost every green hydrogen and derivatives project faces is also a critical factor for the Kenyan industry. Agreeing on who will take on the price premium so that the green alternative can smoothly take over the market is decisive for the finalization pace and the future of these projects.

Once the economic feasibility is established, it is also possible to add further value with the excess green methanol, since the planned production is higher than the current annual market demand in Kenya. A good option that the market has already been studying is to produce e-fuels either for road vehicles or suitable for other transportation types in the form of sustainable aviation fuel (SAF) and shipping fuel. If these options can be put into practice, it would provide green growth opportunities not only to the Kenyan chemical industry but also to the transport sector through forward linkages.

3.8.4 Transport

Following the historical trend, in 2021, the transport sector in Kenya corresponded to the biggest share of CO_2 emissions only from fuel combustions (hence excluding LULUCF) with 62% (IEA, 2023b). Increasing rates of urbanization compounds the road traffic in the absence of a public transportation system based on electric railways. Therefore, addressing the transport sector has the utmost importance for the country, when aiming for a zero-carbon economy.

However, it has been shown that fuel cell passenger vehicles operating with green hydrogen would not be the most efficient way to tackle the emissions from road vehicles (Rinaldi et al., 2023, p. 7). It has been proven that the battery-based electric cars are more energy efficient and hence more suitable to decarbonize passenger vehicles (SRU, 2021, p. 58).

For trucks, buses and other heavy road vehicles, however, hydrogen and fuel cell applications offer energy efficient solutions due to their increased power and range requirements compared to passenger cars (Green Planet, 2021, p. 5). Although such a transition requires large investment and building up an extensive hydrogen infrastructure, and although it is not on the priority list of the government, a pilot project is already under development in Kenya. A local consortium has collaborated with an American clean vehicle developer, Ronn Motor Group, to deploy hydrogen-electric trucks in Nairobi to be operated in a delivery fleet (Rotich, 2023). According to Ronn Ford, the CEO of the Ronn Motor Group, the first trucks should be delivered in the first quarter of 2024 once the land, tax and other regulatory concessions with the Kenyan government are clarified (Rotich, 2023). In the following phases of the project, to support the further development of hydrogen trucks beyond this specific fleet, a hydrogen hub with improved storage and transport infrastructure is aimed for (Rotich, 2023).

Due to the Mombasa port's crucial role in Kenya's as well as the whole region's international trade, maritime is another well-established transport sector in the country. In addition to Mombasa port, Lamu port has been gaining importance and is being expanded as part of the LAPPSET project.

While these ports grow, so does their negative environmental impact. To mitigate the environmental degradation happening in Mombasa port and its surroundings, in 2016, Kenya Ports Authority (KPA) initiated Green Port Policy in financial and scientific collaboration with TradeMark East Africa (TMEA). Some of the identified problems included greenhouse gas (GHG) emissions, asbestos emissions from roofs, harmful dust and air pollution caused by improper handling of cargo, coal and clinker as well as the lack of sewerage and a waste management system (KPA, 2020). In the last several years, different internal studies were conducted to assess the feasibility of alternative solutions to address some of those problems. One of the priority areas was the GHG emission.

To support the decarbonisation plans and to utilize the green energy demand of the Mombasa port, HDF Energy is developping a baseload green hydrogen power plant with 180 MW solar power capacity and 500 MWh hydrogen-based storage (HDF Energy, 2023). The project was announced during the Africa Climate Summit held in Nairobi in September 2023 and is expected to be in operation in 2027. The project is unique in the sense that, if implemented, thanks to hydrogen storage, it will provide baseload green energy to Mombasa where geothermal or hydro power is not available.

Decarbonisation efforts in Africa's aviation sector have seen some notable milestones. In 2016, South Africa Airlines Group conducted the continent's first flight fuelled by a blend of 30% aviation biofuel (Boeing, 2016). Despite initial progress, sustainable aviation fuel (SAF) adoption faced challenges. In May 2023, Kenya Airlines operated the first long-haul commercial flight from Nairobi to Amsterdam using a 2% SAF blend in partnership with Eni, signalling a potential long-term collaboration (Eni, 2023).

As seen in the examples above, the use and production of biofuel-based SAF have been mostly initiated in Africa by global producers. Especially the sensitive discussions around biofuels from agricultural crops and the difficulty to have a constant supply of used cooking oil point out the challenges related to a biofuel-based SAF supply chain on the continent (Interviewee 1, 2023). However, with the growing domestic chemical industry and the capacities it builds, Kenya is in the position to target producing SAF from green hydrogen in the long-term. Even though decarbonisation of the aviation sector is not a priority for Kenya and the commercial air traffic in

the region is much smaller than that of the Global North, SAF poses an opportunity to produce hydrogen derivatives with more value creation. In fact, a 1 GW green hydrogen project is already under early phase of development to solely produce SAF in Kenya. The project partners include a European energy company as well as a local Kenyan company, who already brings substantial experience in renewable energy and has developed a cutting-edge technology to supply water for the electrolysers. To generate 1 GW of electricity, the project will be located in the arid parts of northern Kenya where wind and solar powers are in abundance, but water is not. The project is particularly important, as it showcases the technical problem-solving capacities of Kenyan firms. Moreover, to provide a platform for the discussion on green hydrogen-based SAF, GIZ Kenya has been organizing workshops where Kenya Civil Aviation Authority (KCAA), Kenya Airways as well as other actors of the aviation sector participate.

Although Kenya's aims to decarbonize the transport sector are not in the forefront and are rather part of a long-term perspective, all the projects mentioned above reveal Kenya's dedication, when it comes to establishing a hydrogen economy that goes beyond the domestic fertilizer market. Developing a green transport infrastructure with priorities given to maritime and aviation should be seen as strategic investments to strengthen Kenya's future position in the global green hydrogen market.

3.9 Challenges

3.9.1 Core social, political and economic challenges

In 2023, Kenya had a population of over 55 million people and ranked among the ten most populated nations in Africa (World Bank, 2023d). The share of the urban population has been increasing at a constant rate over the past decade, with more than 29% of the population living in cities in 2023, resulting in increasing challenges related to urbanization, such as the provision of affordable housing, access to public goods and services as well as water, sanitation, transport and electricity infrastructure (Statista, 2025). The county of Nairobi, the area formed by the country's capital and its surroundings, is the most populated county in Kenya, with a population of over 4.3 million inhabitants (Friedrich-Ebert-Stiftung, 2022). Of the 47 counties in Kenya, 18 have a population of more than one million people and are facing challenges and opportunities related to urbanisation trends.

Moreover, Kenya has also been grappling with the problem of unbalanced regional development even after decades of experimenting with different economic and social policies. On the one hand, wide economic disparities exist between and within urban and rural regions. As of 2020, the poverty rate for individual households in Kenya was estimated at 38.6%, with 32.2% living in rural areas and 26.8% in urban centres. About 5.8% of people in Kenya lived in extreme poverty, the majority of those in rural areas (KNBS, 2021). Kenya's unemployment rate in 2022 was at about 5% of the country's labour force, with youth unemployment being significantly higher at 13% (Statista, 2022b).

On the other hand, disparities exist between regions in the country. Historically, the population living below the absolute poverty line has been lowest in Central Kenya followed by the Rift Valley region, and highest in the country's Northern and North-eastern regions (Friedrich-Ebert-Stiftung, 2012). Kenya is culturally diverse, with no single ethnic group constituting more than 17% of the population. During the British occupation, the colonial rule led to physical,

political and economic divisions among Kenyan Africans, shaping ethnic identities and territorial notions (Friedrich-Ebert-Stiftung, 2012). After independence, economic disparities persisted among ethnic groups, fuelling perceptions of inequality between different communities and contributing to political tensions (Muhula 2009). Particularly conflicts over land and benefit-sharing in relation to (renewable) energy projects persist to this day. This is particularly (but not exclusively) true for the Northern region of the country.

In the past, Northern Kenya was part of the 'Northern Frontier District' during British colonial rule, which was considered a low-potential, arid, and pastoralist region. During British colonial rule, the area served as a buffer zone between Ethiopia and Kenya's agricultural heartland, leading to limited investment in infrastructure and education. This lack of development, coupled with security challenges and local conflicts, created a legacy of inequality. In recent years, Northern Kenya has seen a transformation, becoming a focus of significant power, infrastructure and state-led development projects. The region is now integral to the Kenyan government's Vision 2030, aiming to elevate Kenya to a middle-income country. Investments in renewable energy, particularly wind and geothermal projects, have been scaled up, and the discovery of oil in Turkana County has further fuelled expectations of Northern Kenya becoming a driving force in the country's economic development. Additionally, plans for a regional transport network and oil pipeline, known as LAPSSET, have bolstered the region's potential as a key economic hub (Cormack & Kurewa, 2018).

Lake Turkana Wind Power represented a broader shift toward major infrastructure projects in historically marginalized pastoralist regions (Interviewee 19, 2023). This trend includes oil exploration in Kenya's Turkana County and the Gilgel Gibe 3 Dam in Ethiopia's Omo River region. Once side-lined in national development, these areas now hold a central position in national economic strategies. Nevertheless, it is noteworthy to highlight some of Kenya’s past socio-economic conflicts over land arising from green energy infrastructure (Cormack & Kurewa, 2018). One of the most visible disputes has been over Lake Turkana Wind Park (LTWP), which faced societal and legal challenges related to land acquisition even as the project was supplying power to the grid. Initiated in 2006, LTWP is located in Loiyangalani District in Marsabit County in the Northern part of the country. Over a decade, LTWP has evolved into the largest public-private investment in Kenyan history and the biggest wind farm in Africa with various different investments by private (foreign) companies and governments (LTWP, n.d.). To construct its facility, LTWP leased 150,000 acres of land in Loiyangalani ward of Laisamis constituency in Marsabit County, extending to the border between Marsabit and Samburu Counties and over a valley providing access to Lake Turkana. This area, which was historically shared by Samburu, Turkana, and Rendille pastoralists became the project's concession area. While LTWP maintains robust environmental credentials, social concerns have emerged. Human rights organizations and journalists have highlighted issues related to insufficient information, land rights, indigenous rights, and the involuntary resettlement of a Turkana village within the project concession (Osano, 2021). The 'Sarima Indigenous People’s Land Forum' (SIPLF), a local advocacy group, has actively contested the project's impact on communities, sparking debates about land value, identity, and entitlement among the local population and beyond (Cormack & Kurewa, 2018). Similar debates have arisen around other renewable energy projects, such as Kinangop Wind Park (KWP) in Nyandarua County (Osano, 2021; Reuters, 2016) and KenGen's Olkaria IV and V geothermal energy projects in the Great Rift Valley (Salau, 2019).

3.9.2 Potential lines of conflicts

The following identifies potential areas of conflict within a GH2 economy. It is important to note that the issues outlined in this working paper do not guarantee conflicts but rather underscore sectors where the development of national policies and international partnerships should prioritize addressing potential sources of disagreement and discontent during the development of a green hydrogen economy in Kenya. Based on the research conducted for this report, four potential areas of conflict need to be highlighted.

First, potential land disputes due to increased and large-scale renewable energy infrastructure projects could significantly delay or hinder the scaling up of green hydrogen development in the country. According to the 2022 baseline study conducted by the Kenyan government, land requirements for electrolysis and H_2 storage are relatively low for sizes that will likely be relevant in Kenya, ranging from 4,000 to 5,000 m^3 for a 100 MW electrolyser with 3-4 hours of storage (equivalent to approximately 30 to 50 m^3 per MW of electrolyser capacity). These calculations depend on the type of storage (pressure) and other facility needs. It's important to note that these figures do not include land for renewable energy (RE) capacity, which is typically located at sites with sufficient resources and connected via existing transmission lines (Kenya Ministry of Energy and Petroleum, 2022).

The land needs vary across different types of renewable energy sources. Geothermal plants have relatively low land requirements. In contrast, PV systems require higher land allocation, typically in the range of 5,000 to 10,000 m^3 per MW of installed capacity. Wind energy requires even more land, ranging from 10 to 15 times the requirement for PV. However, it is worth mentioning that some of this land might still be available for other uses, especially in the case of PV installations (Kenya Ministry of Energy and Petroleum, 2022).

Land acquisition challenges have historically plagued power projects in Kenya, whether initiated by the government or private developers (see previous section) (Interviewee 17, 2023; Interviewee 19, 2023). These issues often lead to significant delays and costs. The Community Land Act of 2016 as well as the National Energy Policy 2018 have aimed to solve some of the challenges surrounding land acquisition for energy projects. According to the Community Land Act, communities must self-identify and organize to obtain communal land rights, a complex process often tied to cultural, geographic, and livelihood factors. While the law aims to legalize customary land rights, only a few communities have successfully navigated its requirements, leaving many land areas unregistered under the new legislation and subject to potential land acquisition by the government according to the National Energy Policy (Interviewee 19, 2023). Green hydrogen projects need to take these potential challenges into account and devise and co-create strategies to create co-benefit sharing opportunities with local communities early in the planning phase. Finding a balance between incentives for foreign and domestic investors in need of land for their projects and the needs and demands of local populations is thus one of the key roles for the Kenyan government in the development of a green hydrogen market.

Second, concerns about fresh water need to be considered in the planning and implementation of a green hydrogen economy: In the realm of green hydrogen production, water is comparatively less critical from both technical and economic standpoints, especially when compared to other crucial factors such as the demands for renewable electricity supply and hydrogen storage and transportation challenges. While specific technical requirements exist for water used in green hydrogen production, solutions are available with a relatively low-cost share, typically ranging between 1% and 5% of the overall costs of green hydrogen. It is essential, however, to

consider water availability, considering variations induced by seasons or climate change (Kenya Ministry of Energy and Petroleum, 2022).

Green hydrogen production may thus present challenges in some regions in Kenya due to water scarcity and the diversion of water resources for electrolysis. Kenya is a water-scarce country, and water supply, primarily reliant on surface runoff water, is limited and often insufficient for human use leading to acute shortages during dry seasons in some regions of the country (Interviewee 19, 2023). Using this scarce resource for hydrogen production needs a compelling case. Green hydrogen projects must demonstrate significant additional benefits beyond energy supply for electrolysis to justify their water usage in water-scarce regions or allow for a dual-use of water produced in desalination plants for both electrolysis and household consumption.

Third, national electricity supply runs a risk to compete with the development of large-scale green hydrogen production. Access to electricity has increased dramatically in Kenya over the past 20 years, reaching almost 3/4 of the population today. However, approximately 23% of the population remains without regular and affordable access to electricity for its day-to-day use (World Bank, 2023b). The Kenyan Constitution under Article 42 guarantees the right of every person to a clean and healthy environment and according to the Energy Act 2019, the Kenyan government is responsible for facilitating the provision "of affordable energy services to all persons in Kenya" (The Republic of Kenya, 2019). Next to access, affordable energy tariffs remain a huge obstacle for many. The challenge lies in balancing increased renewable energy generation for green hydrogen with decentralized renewable electricity, potentially leading to conflicts regarding acceptance and socio-economic development.

Fourth, knowledge and capacity-building to increase benefits along local and national value chains need to be part of a socially just green hydrogen strategy. In the realm of renewable energy projects in Kenya, citizen involvement emerges as a pivotal factor. It is not merely about ownership being exclusively Kenyan; rather, it is the active participation and consideration of various needs of Kenyan citizens that holds substantial weight. Dynamics of investment also play a significant role in this regard. Notably, in major renewable energy initiatives, foreign entities dominate the shareholding landscape. This foreign presence, while bringing in essential capital, raises questions about the equitable distribution of benefits. Transparency in procurement processes, prioritizing local economic interests and ensuring the active participation of communities in the economic development linked to green hydrogen projects are critical steps forward (Interviewee 20, 2023; Interviewee 22, 2023). Moreover, the influx of (technological) knowledge is a good starting point, but needs to be kept and developed within the country, underscoring the necessity for collaborative efforts, where expertise as well as economic value is not only brought into the country but also shared and cultivated locally (Interviewee 18, 2023; Interviewee 21, 2023).

Amidst this drive for citizen and stakeholder participation in the emerging green hydrogen economy in Kenya, these are pressing challenges. Finally, the country's demographic landscape is shifting, with the younger generation showing a distinct preference for industrial jobs over labour-intensive agriculture. The question looming large is whether the industrial sector is generating a significant number of jobs to meet this demand. Moreover, the agricultural sector, essential for food production, is being ushered into the future through advanced technology

(Interviewee 21, 2023). This dual transition, though promising, raises concerns about the adequacy of job creation and the need for sustainable agricultural practices to meet the needs of the growing economy.

3.9.3 Acceptance of new technologies and large-scale projects

It is premature to try to gauge the overall public perception of green hydrogen in Kenya. However, a 2019 survey in the south-eastern regions highlights encouraging trends. Both urban and rural Kenyan citizens expressed strong support for renewable energy technologies (73%) and believed these innovations would lower electricity costs (91%). Additionally, 69.5% of respondents demonstrated a high awareness of renewable energy terminology (Oluoch, 2020). At the moment, attitudes towards the development of green hydrogen in the country by public and business stakeholders seem to be favourable. This is conditional in that stakeholders see the development of robust regulatory frameworks and the establishment of international (government and business) partnerships as a necessary foundation for the national investment security needed in order to move from pilot projects to a scaled-up hydrogen industry for (in the initial phase) predominantly domestic agricultural use.

Past experiences with renewable infrastructure underscore the importance of involving civil society and local populations in the planning, implementation, and sharing of benefits. Individuals and communities have the option to address land conflicts within the country's robust legal framework and established judicial system. Land disputes are typically filed either at the civil court registry of a lower or magistrate's court, or at the Environment and Land Court (ELC). The ELC, established as a superior court with High Court status, aims to resolve disputes related to the environment, land use, occupation, and land title, thereby improving efficacy in land ownership and management (Mutuku, 2022). While parties are encouraged to settle out of court, if an agreement cannot be reached, the matter proceeds to a technical hearing process, a course of action several communities have taken in recent years (see Turkana Wind project or the geothermal plant in Ol Karia). Concerns and potential disputes about the accessibility and availability of freshwater sources for various uses could exacerbate existing land and natural resource conflicts, negatively impacting public and stakeholder acceptance.

3.10 Business and investment climate

Kenya ranks 56th in Doing Business Index and improves its score steadily in almost every indicator of the index (World Bank, 2020a). According to the same index, it takes 23 days to start a business in Kenya, just above the Sub-Saharan average of 21.5 days (World Bank, 2020a). However, the Kenyan government has been working on improving the business and investment climate in Kenya to strengthen the green hydrogen market ramp-up. Other than the policies and regulations discussed in the previous chapters, some other steps taken in this regard include the development of a one-stop-shop concept and of de-risking mechanisms.

The one-stop-shop approach refers to the idea that all required preparatory steps, such as governmental approvals both in the project planning and implementation phases, are supported by one central government office. The aim is to expedite the regulatory procedures and to assist the project developers in minimizing project risks and costs for green hydrogen. However, although it would facilitate the project development, having all the bureaucratic scrutiny of project proposals done by the central government, leaves little to no room for the county governments, where projects would take place.

De-risking mechanisms are also developed in a similar vein to alleviate the project planning phase in Kenya. However, different from the one-stop-shop, de-risking is an approach that the Kenyan government has already been employing in other energy projects and that was repeatedly referred to both in the National Energy Policy 2018 and Energy Sector Roadmap 2040. Two common de-risking practices that the government has been supporting for renewable energy projects seem to be continued for the green hydrogen project as well (Interviewee 1, 2023; Interviewee 16, 2023; Interviewee 8, 2023). The first of them is land acquisitions. Securing the land with no conflict potential with the local community would enable project developers to mitigate their risks and reduce costs. In theory, the government acquires or buys privately owned land and allocates it to the project owners. However, neither the allocation criteria nor the provision of fair compensation for the community is clear, particularly in cases of non-registered customary land rights. It would be coherent if a community development agreement, as Climate Change Act 2023 for carbon projects suggests, was also a prerequisite for the green hydrogen projects.

The second important de-risking practice is to eliminate the risks related to geothermal sources. Although exploratory analyses may indicate a rich geothermal reservoir in a location, today's technology cannot guarantee it for each well. This means that projects requiring the exploitation of new geothermal reservoirs would potentially cost more time and money. To minimize these risks and to encourage potential investors in the exploitation of this baseload energy source, the central government undertakes the well-drilling process through KenGen and Geothermal Development Company (GDC) and awards contracts to independent power producers (IPPs) for the construction and operation of power plants. This approach also increases available renewable energy for green hydrogen production. Nevertheless, it is noteworthy that drilling geothermal wells with commercially good reservoirs is a lengthy process also for the public authorities.

3.10.1 Effectiveness of market mechanisms

Like in other cases, the effective market mechanisms in Kenya depend on whether the government adjusts its market interventionist policies accordingly, when green hydrogen products enter the market. In this sense, the first example of market effectiveness will be tested with fertilizers in Kenya.

As mentioned previously, Kenya produces no fertilizer domestically, and the government subsidizes the imported fertilizers to ensure a low price and hence food security in the country. Although as of October 2023, the retail price of one bag of fertilizer is around KES4,700 (Kenya Shillings) (AfricaFertilizer, 2023), due to the current government subsidy scheme (e-voucher programme), the imported green fertilizer costs KES2,500 (Aluoch, 2023). The anticipated cost of domestic fertilizer produced from green hydrogen will be around 3 to 4 times that of imported fertilizer (without subsidy) for the initial phase (Interviewee 1, 2023). Given this huge difference in the production costs of conventional and green fertilizers, it is not possible for the latter to survive in the market conditions, if not subsidized. Even with a subsidy, the price of green fertilizer is expected to be KES7,500 (Interviewee 1, 2023). Even the introduction of new subsidies would most likely not be enough to promote the green fertilizer. The subsidy on the conventional fertilizer needs to be removed simultaneously in order to increase its current sale price. The anticipated numbers reveal two challenges: First, even with a shifted subsidy scheme, green fertilizer remains more expensive than the conventional one. Second, if the subsidy on conventional fertilizer is in fact shifted to the green one, it would result in a drastically

increased end price for the fertilizers, which is a significant policy decision as it would affect the food production in the country. Therefore, the remaining price difference should be covered by another national or international mechanism, so that food security is not jeopardized. It should be, however, noted that these calculations are based on educated guesses of consulted experts and any cost prediction is difficult due to the nascent stage of the green hydrogen market.

A similar problem might also arise for other hydrogen derivatives, as long as the energy price remains high in Kenya. As the most important determinant of the levelized cost of hydrogen (LCoH), renewable energy cost plays a crucial role in the market ramp-up and the competitiveness of green hydrogen derivatives in the market. Even though geothermal energy provides baseload power with high-capacity factors, initial high costs and the limited number of exploited sites keep the energy price high.

3.10.2 Energy as a public good

The most important driving force for the Kenyan government in establishing a hydrogen market in the country is promoting food security. Access to affordable food for all has been a long-time goal, and hence has historically occupied high priorities on the political agenda. The same can be said for President Ruto's current government. Although the initial pilot projects for green hydrogen were initiated by the Kenyatta government, President Ruto and his cabinet have accelerated the process by engaging in diversified international collaborations and mainstreaming climate-oriented policies.

Nevertheless, for fertilizer production or other green hydrogen projects in the pipeline, additional renewable energy capacities are needed. Some early studies on the green hydrogen production potential in Kenya reported that there is excess baseload renewable energy in Kenya (Kenya Ministry of Energy and Petroleum, 2022), pointing out the possibility to have easy access to renewable and cheap power with no additionality concern for projects. Interviews conducted with experts for this report, however, revealed that the excess power might not be enough to provide the flexibility a grid would normally require to scale up green hydrogen production in the country at reasonable costs (Interviewee 1, 2023; Interviewee 16, 2023).

Data from the 2022/2023 financial year shows that, despite 3,246 MW total installed capacity in the country, the effective interconnected capacity was 3,127 MW (KPLC, 2023b, p. 50), while the average available capacity recorded for the 2021/2022 financial year was 2,035 MW (KPLC, 2023a). Even assuming that the average available capacity increased in 2022/2023 to cover the then peak demand of 2,149 MW (KPLC, 2023b, p. 225), there was hardly any excess power in the system. This is also referred to as *reserve margin*, which measures the extent of available spare capacity within the system during peak demand periods, represented as a percentage of the highest demand (IEA, 2022). An analysis by Africa Energy (2023) points out that the reserve margin in Kenya had fallen to 4% in December 2022. To avoid power cuts and to have an uninterrupted power supply, a reserve margin of 20-35% is the global standard (Lee & Cho, 2022). Even though IEA (2022) suggests that the reserve margin approach should be replaced with other adequacy assessment methods to reflect the changing norm within energy transitions, this means that the electricity system in Kenya does not generate enough excess power that can be utilized for green hydrogen production. In fact, the power purchased by thermal power producers to cover the peak demand has almost doubled in the 2022/2023 period, compared to 2018/2019, while the imports tripled in the same period (KPLC, 2023b, pp. 223–

224). Experts also confirm that the use of medium speed kerosene generators has become a common practice for peak electricity consumption periods (Interviewee 16, 2023).

When looking at demand projections, KenGen is basing its calculations on the status quo and normal population growth and not on additional demand that will be created by green hydrogen (Interviewee 16, 2023). This is why it takes longer for KenGen to build up additional baseload capacity for the coming demand from green hydrogen producers (Interviewee 16, 2023). Therefore, it can be said that as much as the government is pushing the green hydrogen agenda and hence tries to establish a favouring environment for the market to grow, KenGen's current priority lies on covering the peak demand with their own clean energy generation to ensure energy security.

3.10.3 Electricity infrastructure

Despite ongoing improvement attempts, the power grid in Kenya continues to be a source of severe inefficiencies. In 2022, 2,955.7 GWh of 10,008 GWh total domestic power supply was lost due to poor transmission and distribution infrastructure, accounting for 30% (KNBS, 2023). Apart from the losses, outdated infrastructure has led to three major nation-wide blackouts in the last quarter of 2023, last of which also hit Jomo Kenyatta International Airport (Dahir, 2023).

The problems are mostly associated with certain structural challenges that KPLC, the owner and operator of the majority of the transmission and distribution system, is facing. The first one of these challenges is related to financial constraints. In the 2022-2023 financial year, the company has had a net loss of KES3.2 billion despite the KES19 billion of operating profits in the same period (KPLC, 2023b). The loss was attributed to the depreciation of the Kenyan Shilling from June 2022 to June 2023 by 19%, which increased the financing costs for the company (KPLC, 2023b). In its annual report, the company also received reduced electricity tariffs by the government, increased expected credit losses, high fuel processes and declined customer payment rate responsible for the net loss (KPLC, 2023b). Even the growth in both number of customers and power sale revenues by 4.4% and 21%, respectively (KPLC, 2023b), were not enough to cover the losses. Moreover, consulted experts pointed out that these effects could become more severe in the near future, since the market limits for expanding the customer base might soon be reached (Interviewee 8, 2023), despite the 23.5% of the population with no electricity access (World Bank, 2023b). The rationale behind this argument is the fact that the remaining population lives mostly in remote rural areas, where the costs of grid expansion exceed expected revenue from such households. Also, due to high energy prices and severe power cuts, large customers like the industry tend to increase their captive power units, which results in demand and revenue loss for the KPLC.

The financial challenges, therefore, hinder the company's ability to fund the necessary maintenance and expansion in the grid, which can also be identified as the second major challenge leading to poor power infrastructure. However, the recent financial losses are not the only reason behind the inefficiencies that the KPLC seems to be unable to address. In 2008, KETRACO was founded by the Kenyan government to overtake the ownership, operation, construction, planning and maintenance of the high voltage transmission grids and substations from KPLC (KETRACO, n.d.). The aim was to promote the demand by large customers through an open access transmission system, where large customers can purchase power directly from generators, and not reflecting high costs of transmission line construction and maintenance to the

customers (KETRACO, n.d.). Although, since its foundation, KETRACO has extended and improved the infrastructure under its mandate, their share corresponds to 37.5% of the high voltage transmission grid (KETRACO, n.d.). To alleviate some of the operational challenges and to create further revenue in return, in November 2023 KPLC, requested that some of its assets together with operation and maintenance duties be temporarily transferred to KETRACO for a period of 10 years (KPLC, 2023c). In its 2021 report, African Development Bank suggested that the transmission network and all assets are transferred to an independent system operator, which could provide impartial arbitration between power generation and distribution (African Development Bank, 2021). Even though the regulatory framework for such a transfer was prepared by the Energy Act enacted in 2019, the reasons for the government's reluctance to pave the way for breaking its monopoly are not clear. It remains to be seen whether the measures taken so far will enable KPLC to tackle these challenges. The public pressure on President Ruto following the recent blackouts to create a sustainable solution for these structural problems is growing.

Although some green hydrogen projects will be relying on offline power, inefficiencies and instabilities in the grid might negatively affect power supply in those projects. Furthermore, even though insufficient power supply is one of the main challenges deepening the problems KPLC faces (Makaa, 2023), the company lacks the resources and capacity to fully accommodate any increase in the power supply or to transmit it to the end customers. This might also be experienced in the case of additional renewable energy generation fed to the grid for green hydrogen production. Consequently, increasing the system efficiency of the power transmission and distribution network plays a key role in addressing some of the technical challenges that may also be relevant for the coming hydrogen market in Kenya.

4 Outlook and Policy Conclusions

4.1 Potential areas for policy action

Tackling high energy prices

As discussed in the report, high energy prices affect the economy adversely, as energy is the main input in almost all sectors, and it significantly increases the cost of living in the country. High energy prices are, however, especially critical in energy-intensive manufacturing sectors like steel and cement. Moreover, the cost of energy is the number one factor in determining the levelized cost of green hydrogen (LCoH), making green hydrogen production in Kenya not only less competitive, but also making it difficult for the manufacturing industry to consider using green hydrogen in their production.

Energy prices in Kenya remain high for several reasons. Despite renewables accounting for 90% of power generation, oil and oil products still make up 28.7% of the total final energy consumption in the country. This dependence leaves Kenya's economy vulnerable to rising global oil prices. Furthermore, the devaluation of the Kenyan Shilling over the past two years has heightened the domestic market's susceptibility to global crises. In addition to external shocks, other factors contributing to high energy costs in Kenya include droughts that reduced hydropower generation, losses from inadequate energy infrastructure and high upfront costs associated with geothermal power. Lastly, Rotich and others (2024) add the monopoly on distribution causing lack of competition and inefficiencies.

To tackle these factors, increasing Kenya's renewable energy capacity is found to be a common recommendation in the literature. As discussed in Chapter 1, this is already a goal that the government is working on through different policies and instruments. Yet, given the inefficiencies of the energy infrastructure, solely increasing the power capacity may not suffice to address high energy prices. Therefore, a more sustainable solution to this problem should definitely include improving energy efficiency in Kenya.

Despite current high energy prices, Müller et al. (2023) highlight that Kenya actually has the potential to produce green hydrogen at a competitive cost, particularly by utilizing solar and wind power. In their study, the authors model the green hydrogen production cost across various locations in Kenya, reporting that prices between EUR3.7 and EUR9.9 per kg are achievable, with the lowest costs found in the south and south-east of Turkana Lake. Moreover, their model predicts that hydrogen production costs could drop to as low as EUR1.8 per kg by 2030 due to anticipated techno-economic improvements. Therefore, by further leveraging solar and wind power potential, Kenya could not only enhance its competitiveness in the global hydrogen market, but also reduce domestic energy prices and strengthen its resilience to external shocks.

Creating local demand through a robust political framework

Both for green hydrogen production but also for renewable energy generation, Kenyan government has been signalling that the country will considerably increase its supply capacities in the medium to long-term. For renewable energy generation capacity, the Energy Sector Roadmap aims at 100 GW by 2040 (Ministry of Energy and Petroleum, 2022), whereas the Green Hydrogen Strategy and Roadmap for Kenya foresees 150-250 MW electrolyser capacity by 2032 (Kenya Ministry of Energy and Petroleum, 2023). Even though it is technically possible

for Kenya to tap into these potentials, economic feasibility of such targets is what makes them ambitious.

Bankability of renewable energy and green hydrogen projects depends on several factors, but major challenges consist of developing a robust political framework, clarifying additional need in regard to renewable energy production and securing demand for green hydrogen and its derivatives. Since green hydrogen exports from Africa (esp. Eastern Africa) to Europe are not foreseen in the short term, there must be stable local demand to ramp up green hydrogen markets. In Kenya, the short-term application of green hydrogen products is foreseen in the chemical industry to produce fertilizer and methanol. Nevertheless, without a clear strategy of who will pay the premium for those new green products to compete with the fossil fuel-based alternatives, it is difficult to foresee how a domestic market for green fertilizers will function.

One additional application sector in the long-term - with several projects already in the pipeline - is the e-fuels sector, in particular sustainable aviation fuel (SAF). Alongside the domestic fertilizer production, projects on SAF should gain priority and more support from public authorities to help grow Kenya's capacity and knowledge.

Similarly, the green hydrogen power generation project, which is developed by the HDF, is another good example of alternative local uses of green hydrogen. Green hydrogen will be used in this project to produce electricity during peak hours, when renewable energies are not enough to meet electricity demand. This will serve both as a grid stabilizer but also to achieve 100% green power in Kenya's grid. However, the phasing out of thermal power plants, which currently supply the additional power needed, should be planned simultaneously.

Furthermore, at the time of writing this report, there are limited economic incentives for Kenya's heavy industry, like iron, steel and cement manufacturers, to decarbonize their production via green hydrogen applications due to uncertainties in regard to investment costs and prices. In the absence of market-led demand, the Kenyan government needs to develop robust policy frameworks to stimulate local industrial demand. These might include developing industrial standards and certification for green industrial products, which would assure local but also foreign investors of the quality and sustainability of such products. Additionally, the Kenyan government can either invest in capacity-building and technical assistance programmes or prioritize them in project agreements with foreign investors to help local businesses transition into producing green and decarbonized industrial products. This includes providing training, technology transfer, and access to financing for innovation as well as research and development. Last but not least, government procurement policies that prioritize the purchase of green industrial products for public projects would create a guaranteed market, stimulating demand and encouraging local manufacturers.

Developing debt-free financing models through revised PPPs

Not only in Kenya, but also in many other African countries, the weight of foreign debt has been steadily increasing, particularly in recent years, hindering those governments from channelling their means into essential public services. As of 2023, the external debt-to-GDP ratio in Kenya has reached 38%, whereas the same ratio for total public debt was as high as 70% (Central Bank of Kenya, 2023).

Despite such high levels of public debt, some innovative financing models have been developed to keep much needed investments happening. Public-private partnership (PPP) models constitute a good example of such financial instruments, especially in countries with limited

financial state capacities to undertake certain infrastructure projects. For Kenya, PPPs are not a new financial model. Especially in the energy sector, there are already many examples of finalized PPP projects, including recent wind farms like Lake Turkana, Kipeto and Aelous-Ngong. To support and accelerate the implementation of PPPs, Kenya has been improving its regulatory framework for this model, including PPP (Project Facilitation Fund) Regulations in 2017, PPP Fiscal Commitments and Contingent Liabilities Management Framework in 2018 and the update of PPP Act in 2021. These and similar regulations have not only brought clarity to the shared responsibilities among public authorities, but also allowed county governments to prioritize their own needs by implementing local PPPs.

The PPP model can also be extended to green hydrogen projects if criticism of these models and lessons learned from the past – particularly in regard inefficiency, land rights and socio-economic benefit-sharing with local communities – are considered in policy and programme design as well as the planning and implementation phases of new projects (Cormack & Kurewa, 2018, p. 90; Adongo, 2012, p. 53.). Land rights and socio-economic benefit-sharing mechanisms with local communities should become compulsory practices in both planning and implementation phases of new projects. At the same time, land compensations should not be just an instrument to exclude communities from the project and their land. On the contrary, they should be equivalent and matching to what the communities are giving up. Additionally, it is important that any agreement with the public should follow the Free Prior Informed Consent (FPIC) Framework as suggested by the World Bank (n.d.). Moreover, to improve transparency in PPP processes, the PPP Disclosure Portal that the Kenyan government launched in 2018 should be reactivated (UNECA, 2023, p. 14).

Additionally, PPPs can address small-scale electrification needs in remote and grid-isolated areas through mini-grids, where green hydrogen can be used as an energy carrier for a more stable off-grid supply. PPPs in this areas can be instrumental in handling grid inefficiencies that the responsible public authorities fail to tackle due to lack of financial means. Also, if such projects are co-developed together with community representatives as well as an external international development partner, who would ensure the implementation of international standards like FPIC or ESG, it might help to improve the reputation of PPP projects among the wider public, while hopefully ensuring co-benefits for all affected groups. In addition to PPPs, the use of certain restructured financing could increase Kenya's ability to undergo development projects without increasing the immediate debt distress. An example of such mechanisms is expanding the access to rechannelled Special Drawing Rights mechanisms for nations like Kenya, as suggested by the UN General-Secretary.

Special Drawing Rights (SDRs) are an international reserve asset created by the International Monetary Fund (IMF) to supplement the official reserves of its member countries. SDRs are not a currency but can be exchanged between countries for freely usable currencies (such as US dollars) to help countries manage their balance of payments, pay-off debt, or stabilize their economies in times of crisis. In July 2023, Kenya already secured the access to rechannelled SDR funding worth USD551.4 million through the Resilience and Sustainability Facility (RSF) mechanism of the IMF. In addition to this, in June 2024, the second review under the RSF unlocked the access to a further USD120 million. It should be, however, noted that RSF provides no grant, but rather long-term low-interest concessionary financing to strengthen countries' ability to withstand external shocks.

One potential use of RSF financing could be for supporting the developing green fertilizer market in Kenya against the risks discussed in this report, namely increased overall fertilizer price and threatened food security. Given the high upfront costs of transitioning to green technologies (such as green hydrogen-based fertilizers), RSF could offer lower-income countries, like Kenya, access to much-needed financing to support this transition without solely relying on subsidies from their domestic budgets. By using RSF, Kenya could avoid a sharp increase in the price of fertilizers, which would otherwise burden farmers and compromise food security.

4.2 Recommendation for international cooperation

Development of a good contracting framework

One of the potential areas where intergovernmental collaboration could be beneficial is good contracting – well-structured, transparent and fair contractual agreements that facilitate the successful development, implementation, and operation of projects related to green hydrogen production. This involves creating legal and commercial frameworks that also address the unique aspects and challenges associated with green hydrogen.

According to the Green Hydrogen Organisation (Green Hydrogen Organisation, 2022), international cooperation can be particularly instrumental in supporting some of the activities in Kenya. For example, (i) clear policy and regulation formulation promoting predictability and certainty would signal that each step in the green hydrogen value chain is suitably and coherently regulated. This requires a long-term perspective as well as clear and coherent target-setting in line with other major sectors of the country. While Kenya prepares itself to host many green hydrogen projects, it is still not clear which exact regulations these projects will be subject to. Similarly, (ii) an appropriate risk allocation is crucial for all parties involved, especially for the financing decision. Hence, third-party sponsors or international insurers might step in to undertake some of the risks along the hydrogen value chain, thus increasing the bankability of projects in Kenya. It is equally important (iii) to set suitable fiscal terms today that will have an impact on future government revenues. International cooperation might again support the Kenyan government, if necessary, in preparing the right mix of incentives, profits and taxes that will ensure a thriving green hydrogen market also in the long term.

While there are already development cooperation organizations, like GIZ Kenya, that support and are constantly in exchange with the Kenyan government on the first three elements of good contracting that are mentioned above, some other elements of the concept receive rather limited attention. These include (iv) community engagement, (v) land acquisitions and use, (vi) infrastructure access and common use and (vii) dispute resolution (Green Hydrogen Organisation, 2022). This set of good contracting practices is particularly important in managing expectations in developing countries like Kenya, where conflicts with local communities are not a rare incidence, especially in energy projects with high demand on local resources. Despite their importance, it is, however, difficult to sufficiently implement these practices through only international cooperation, as regional dedication and multi-level as well as multi-player collaboration is an inherent part of resolving some of these conflicts. In other words, even if a country like Kenya set its regulatory framework in such a way that only meeting these criteria granted a private entity the right to establish its green hydrogen production facility, there would be no investor at the table to negotiate these terms with. It takes other countries from the continent with similar aims and challenges to cooperate in solidarity to set a suitable mix of those practices. The African Green Hydrogen Alliance is a good example of such a regional cooperation

that can serve as a platform for unitedly negotiating similar terms. The international cooperation organizations, who already actively support the Alliance, can make sure that good contracting climbs up on the priority list of the member states.

Benefit-sharing mechanisms

To complement the implementation of good contracting, benefit sharing mechanisms co-shaped through community engagement can support public acceptance and the contribution of green hydrogen to a just (global) energy transition. Benefit-sharing mechanisms refer to arrangements or frameworks ensuring equitable distribution of benefits derived from the development and utilisation of energy resources or infrastructure among various stakeholders, including local communities, governments, and project developers. These mechanisms aim to promote social, economic, and environmental sustainability by addressing potential inequities, mitigating negative impacts and fostering cooperation and collaboration among stakeholders. Some common practices in this regard include revenue sharing, community ownership, direct compensation, infrastructure development, employment and skills development and environmental conservation and restoration. However, making benefit-sharing a part of project development is not easy. Similar to good contracting, international cooperation should support the regional collaboration platforms in jointly making benefit-sharing an inseparable part of hydrogen projects in Sub-Saharan Africa.

Inclusive growth

The implementation of both good contracting and benefit-sharing mechanisms can encourage an equal distribution of created wealth from Kenya's resources among local communities. On the other hand, establishing a green hydrogen economy which ensures inclusive growth is equally important. Inclusive growth is essential in sustaining a rapid poverty reduction by allowing people not just to benefit from the economic growth but also to contribute to it (Ianchovichina & Lundstrom, 2009, p. 2). In its 2023 Economic Update, the World Bank suggested a three-pronged strategy for Kenya to achieve inclusive growth: (i) increasing the productivity of the private sector, (ii) connecting the vulnerable and poor to the growth and (iii) strengthening households' resilience to extreme weather shocks (World Bank, 2023a, p. 27).

Through benefit-sharing mechanisms and fertilizer production, green hydrogen economy can directly support the last two pillars to achieve inclusive growth in Kenya. The first one, on the other hand, being the most challenging among others, has the potential to transform the Kenyan economy structurally. Increasing numbers of STEM graduates can help to shift the economy from the service sector to high tech manufacturing by allowing a bigger supply of researchers and skilled labour for firms, for example, to involve in green hydrogen economy. Beyond capacity building training, international cooperation can support the Kenyan public authorities financially and content-wise in improving the higher education system and increasing the number of programmes offered in STEM fields. Additionally, in order to prevent a possible brain drain of STEM graduates, there should be suitable job opportunities for skilled labour in the domestic economy. Removing barriers to competition, including reassessing the footprint of the state in the private sector, would not just increase the number of skilled job opportunities, but also improve productivity (World Bank, 2023a, p. 28). If demanded by the Kenyan government, international cooperation can also address such improvement needs by providing expertise to legally enable these processes. And lastly, access to either start-up capital or other types of finance is one of the key constraints faced by many SMEs, also preventing

them from starting and maintaining a business in sectors with high CAPEX and OPEX, e.g. manufacturing and energy. In addition to sustainable finance, programmes of international development banks like KfW can be extended to also include network building, improving management skills and provision of support to become operational in markets and export value chains (World Bank, 2023a, p. 31) e.g. via off-take agreements. Similarly, the accelerated implementation of goals like Enterprise Development Incubators as identified in the Third Medium Term Plan (Republic of Kenya, 2018, p. 83), can support innovation, research and development in Kenya.

The above-discussed PPP model would be a good opportunity to put those suggestions into practice. If the participation of the Kenyan private sector (e.g. SMEs) is stimulated particularly for small-scale PPP projects, they may gain experience and grow their capacities in green hydrogen projects, allowing them to become crucial actors in establishing a strong domestic green hydrogen market, thereby increasing domestic value along a global hydrogen supply chain.

Regional collaboration

As emphasized, regional collaboration is an overarching strategy to successfully implement various common practices by the nations of Sub-Saharan Africa. In addition to above mentioned practices like good contracting and benefit-sharing, it can also be instrumental for building up green hydrogen infrastructure. International cooperation should activate the regional collaboration on the construction of expensive and technically demanding trans-border infrastructure networks that would address the storage and transportation of green hydrogen within and beyond the continent. In the long term, it would expand Africa's position in becoming an exporter of green hydrogen in the global market.

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