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Green Hydrogen Mapping Study in Angola

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Mapeamento de Hidrogênio Verde em Angola

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Resumo

No contexto mais amplo das mudanças climáticas e dos objetivos políticos generalizados de eliminar gradualmente os combustíveis fósseis e substituí-los por energias renováveis, Angola, assim como várias outras nações africanas, está se posicionando para se tornar um ator relevante nesta área. Uma das vias seguidas por Angola é explorar e desenvolver seu potencial para produzir e exportar hidrogênio verde. Este relatório descreve os desenvolvimentos atuais e as perspectivas futuras a esse respeito. Ele fornece informações sobre projetos piloto, principais atores e perspectivas de offtake, analisa oportunidades e desafios e identifica áreas de colaboração entre Angola e os Países Baixos.

Projetos piloto, principais atores e perspectivas de offtake
Existem pelo menos três projetos piloto em andamento, os quais apresentam planos para construir eletrólisadores com capacidades de até 400 MW, utilizando a produção de eletricidade renovável de usinas hidrelétricas existentes.

O maior e mais significativo desses projetos está localizado na costa, ao norte da capital Luanda. O objetivo do projeto é produzir hidrogênio verde, convertê-lo em amônia verde e exportá-lo para a Alemanha. Os principais atores por trás deste projeto são a petrolífera angolana Sonangol, as empresas de engenharia alemãs Gauff e Conjuncta e a desenvolvedora de projetos de energia renovável com sede em Londres, CWP Global. A perspectiva de offtake para este projeto piloto parece depender inteiramente da plataforma H2Global. A H2Global é uma iniciativa do governo alemão com o objetivo principal de criar um mercado global para o hidrogênio verde, facilitando a importação de hidrogênio renovável e derivados de hidrogênio (como amônia) para a Alemanha e a UE. Tanto o governo alemão como o holandês prometeram financiamento à H2Global. Atualmente, este projeto ainda está na fase preparatória, ou seja, a construção ainda não começou.

Os outros dois projetos estão em estágios de desenvolvimento ainda mais iniciais e apenas informações limitadas sobre eles puderam ser encontradas. Um deles visa a produção de amônia verde e é conduzido pela Minbos Resources, uma empresa australiana na área de mineração de fosfato e produção de fertilizantes. O outro visa ônibus movidos a hidrogênio e é conduzido pela Universidade Católica de Angola (UCAN).

Oportunidades e desafios
A análise mostra que as oportunidades surgem, entre outras, de excelentes recursos de energia renovável, ambientes de financiamento nacionais e internacionais benéficos e a presença de expertise relevante na área de infraestruturas de combustíveis relacionados (por exemplo, terminais de exportação de GNL). Ao mesmo tempo, surgem desafios significativos, por exemplo, a produção de hidrogênio verde competindo pela eletricidade renovável que também é necessária localmente, infraestrutura de transmissão e distribuição de eletricidade insuficiente (necessária para disponibilizar os recursos de energia renovável), falta de infraestrutura adequada para transporte e distribuição de hidrogênio, falta de expertise na área de tecnologia de eletrólise e a necessidade de investimentos em treinamento e educação para estabelecer amplamente as habilidades profissionais necessárias.

Áreas de colaboração entre Angola e os Países Baixos
As áreas temáticas de transporte de hidrogênio (portador), desenvolvimento de mercado, políticas e capacitação foram identificadas como as mais relevantes para a potencial colaboração entre Angola e os Países Baixos. Esses tópicos estão relacionados às oportunidades e desafios de Angola para o desenvolvimento de um mercado de hidrogênio verde, enquanto os Países Baixos têm expertise relevante em todos esses tópicos.

Considerações finais e recomendações

A produção e exportação de hidrogênio verde (ou, a longo prazo, produtos renováveis como cimento, aço ou fertilizantes produzidos com o referido hidrogênio verde como matéria-prima) podem ser uma oportunidade econômica atraente para Angola. Para os Paises Baixos, Angola tem o potencial de se tornar um parceiro comercial interessante para o hidrogênio verde no curto/médio prazo e para produtos baseados em hidrogênio renovável no longo prazo. Os Países Baixos podem apoiar Angola no desenvolvimento de seu mercado de hidrogênio verde, com base na expertise holandesa e nas oportunidades e desafios em Angola. Nesse contexto, é importante estar atento às circunstâncias locais e que a eletricidade renovável será necessária tanto para o consumo local quanto para a produção e exportação de hidrogênio verde.

Com base nessas conclusões, temos as seguintes recomendações para os próximos passos:

- Organizar um workshop em Angola com os principais stakeholders para validar as conclusões deste estudo.
- Conectar os principais stakeholders em Angola aos seus homólogos holandeses para explorar oportunidades de colaboração nas areas de transporte de hidrogênio, desenvolvimento de mercado, politicas e capacitação.
- Apoiar os formuladores de políticas angolanos no desenvolvimento de uma estrutura de políticas para o hidrogênio verde.
- Buscar colaborações com a Alemanha e a UE no desenvolvimento do mercado angolano de hidrogênio verde e rotas de importação para a UE.
- Estar atento ao equilíbrio entre o uso de eletricidade renovável para fins locais e para a produção e exportação de hidrogênio verde.

Summary

In the broader context of climate change and widespread policy goals to phase out fossil fuels and replace them by renewable energies, Angola as well as multiple other African nations, are positioning themselves to become relevant actors in this area. One avenue followed by Angola is to explore and develop its potential to produce and export green hydrogen. This report describes current developments and future perspectives in this respect. It provides information about pilot projects, key players, and offtake perspectives, analyzes opportunities and challenges, and identifies collaboration areas between Angola and the Netherlands.

Pilot projects, key players, and offtake perspectives
There are at least three ongoing pilot projects. They feature plans to build elektrolysers in capacity ranges of up to 400 MW, using renewable electricity production from existing hydropower plants.

The largest and most significant of these projects is located at the coastline just north of the capital Luanda. The goal of the project is to produce green hydrogen, convert it to green ammonia and export it to Germany. The key players behind this project are the Angolan oil and gas major Sonangol, the German engineering firms Gauff and Conjuncta and the London based renewable energy project developer CWP Global. The offtake perspective for this pilot project appears to hinge entirely on the H2Global platform. H2Global is an initiative by the German government with the main goal to create a global market for green hydrogen by facilitating the import of renewable hydrogen and hydrogen derivatives (such as ammonia) into Germany and the EU. Both the German and Dutch governments have pledged funding to H2Global. Currently, this project is still in the preparatory phase, i.e., construction has not yet started.

The other two projects are in yet earlier development stages and only limited information about them could be found. One of them aims at green ammonia production and is driven by Minbos Resources, an Australian company in the area of phosphate mining and fertilizer production. The other one aims at hydrogen fueled buses and is driven by the Angolan Catholic University (UCAN).

Opportunities and challenges
The analysis shows that opportunities arise, amongst others, from excellent renewable energy resources, beneficial national and international funding environments, and the presence of relevant expertise in the area of related fuel infrastructures (e.g., LNG export terminals). At the same time significant challenges arise from, e.g., green hydrogen production competing for renewable electricity that is also required locally, insufficient electricity transmission and distribution infrastructure (needed to make the renewable energy resources available), a lack of adequate infrastructure for transporting and distributing hydrogen, a lack of expertise in the area of electrolyser technology and the need for investments in training and education in order to broadly establish the needed professional skills.

Collaboration areas between Angola and the Netherlands

The topic areas of hydrogen (carrier) shipping, market development, policy and capacity building have been identified as the most relevant areas for potential collaboration between Angola and the Netherlands. These topics relate to Angola's opportunities and challenges for the development of a green hydrogen market, while the Netherlands has relevant expertise on all these topics.

Concluding remarks and recommendations

The production and export of green hydrogen (or on the long-term renewable products such as cement, steel or fertilizers produced with said green hydrogen as feedstock) can be an attractive economic opportunity for Angola. For the Netherlands, Angola has the potential to become an interesting trading partner for green hydrogen in the short to medium term and for renewable hydrogen-based products on the longer term. The Netherlands can support Angola in the development of its green hydrogen market, based on the Dutch expertise and the opportunities and challenges in Angola. In this, it is important to remain mindful of local circumstances and that renewable electricity will be required for both local consumption and for the production and export of green hydrogen.

Based on these findings we have the following recommendations for next steps:

- Organize a workshop in Angola with key stakeholders (ANPG, Sonangol, MINEA, etc.) to validate the findings of this study.
- Connect key stakeholders in Angola to Dutch counterparts to explore collaboration opportunities on the topics of hydrogen shipping, market development, and policy and capacity building.
- Support Angolan policy makers with the development of a green hydrogen policy framework.
- Seek out collaborations with Germany and the EU on the development of the Angolan green hydrogen market and import routes to the EU.
- Be mindful of the balance between the use of renewable electricity for local ends and for the production and export of green hydrogen.

Contents

1 Introduction

This report presents the results of a mapping study conducted on behalf of the Embassy of the Kingdom of the Netherlands in Angola, in collaboration with the Netherlands Enterprise Agency (RVO - Rijksdienst voor Ondernemend Nederland). The purpose of this study is to explore the current dynamics and prospects of green hydrogen in Angola, seeking to identify areas of convergence to strengthen collaborations between Angola and the Netherlands, as well as to create new cooperation opportunities.

In Chapter 2, the study objectives and the adopted methodological approach are defined. Then, in Chapter 3, the background activities and the general context of the trade relations between both countries are presented, synthesizing relevant information for this study. In Chapter 4, the potential of green hydrogen in Angola is explored, addressing both the opportunities and the main challenges identified. In Chapter 5, a discussion around recent developments, the interests of different stakeholders, as well as the political and business context for the green hydrogen market is presented. Finally, in Chapter 6, a superficial overview of potential collaborations between Angola and Dutch institutions in the green hydrogen sector is presented, aiming to overcome identified challenges and explore new business opportunities.

This report aims to offer insights not only to direct stakeholders but also to the vast community of Angolan and Dutch companies dedicated to the development of green hydrogen, highlighting the possibilities of collaboration and co-creation that arise between Angola and the Netherlands.

2 Goals and Methodology

2.1 Goals

The objectives of this mapping study are:

- Identify and establish initial relationships with Angolan stakeholders expected to be key partners in the future green hydrogen sector in Angola.
- Gain insights into relevant developments (e.g., national hydrogen development strategy).
- Collect preliminary data on projects and developments in Angola.
- Outline collaboration opportunities with Dutch stakeholders in the green hydrogen sector based on the collected information.

2.2 Methodology

The research methodology consisted of three elements:

- Study of new developments in the sector through the analysis of a significant number of recent publications, from both scientific sources and project developers and companies.
- Interviews with key stakeholders in the current and future hydrogen landscape in Angola.
- Analysis of the information and synthesis into recommendations on future collaboration opportunities.

3 Background

3.1 Current energy mix in Angola

The total energy supply in Angola is currently mainly based on fossil fuels, biofuels, and waste (see Figure 3.1). Oil products are mainly used for transport (115 PJ in 2022) and in the residential sector (78 PJ in 2022), natural gas is used in industry, biofuels and waste are mainly used in the residential sector (216 PJ in 2022), electricity is used in the residential sector (32 PJ in 2022) and industry (17 PJ in 2022) (ibid.).

Angola is the second largest oil producing country in Sub-Saharan Africa, with activities dominated by the exploration of offshore crude oil and natural gas (U.S. International Trade Administration, 2024b). The country has one operational oil refinery and is building three new refineries, with the first expected to start operation in the first quarter of 2025 (Reuters, 2024). With the new refineries Angola aims to increase the domestic supply of finished oil products such as diesel and jet fuel and reduce its current dependence on the imports of these fuels.

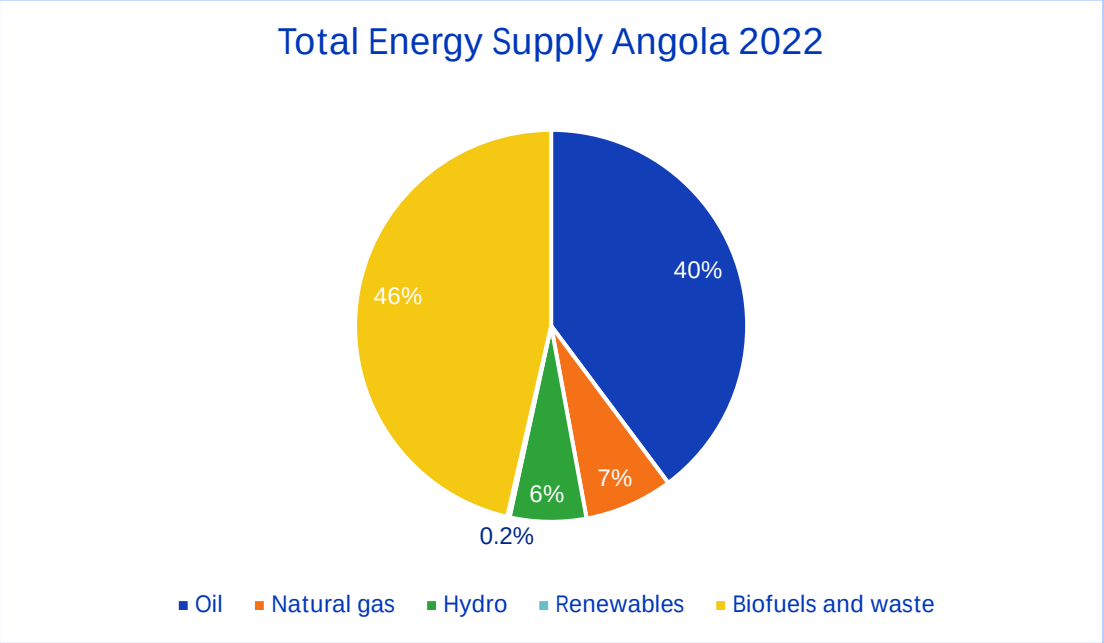

Figure 3.1: Total energy supply mix in Angola in 2022. Based on IEA (IEA, 2024).

The electricity generation in Angola is dominated by hydropower, responsible for over 70% of production in 2022 (see Figure 3.2). Oil and gas are the other major fuels used for electricity generation in Angola. The production of electricity from other renewable sources is still limited in Angola, with only a 2.5% contribution from solar PV in 2022. Yet the Angolan Government has ambitions to increase the share of renewables in the electricity mix.

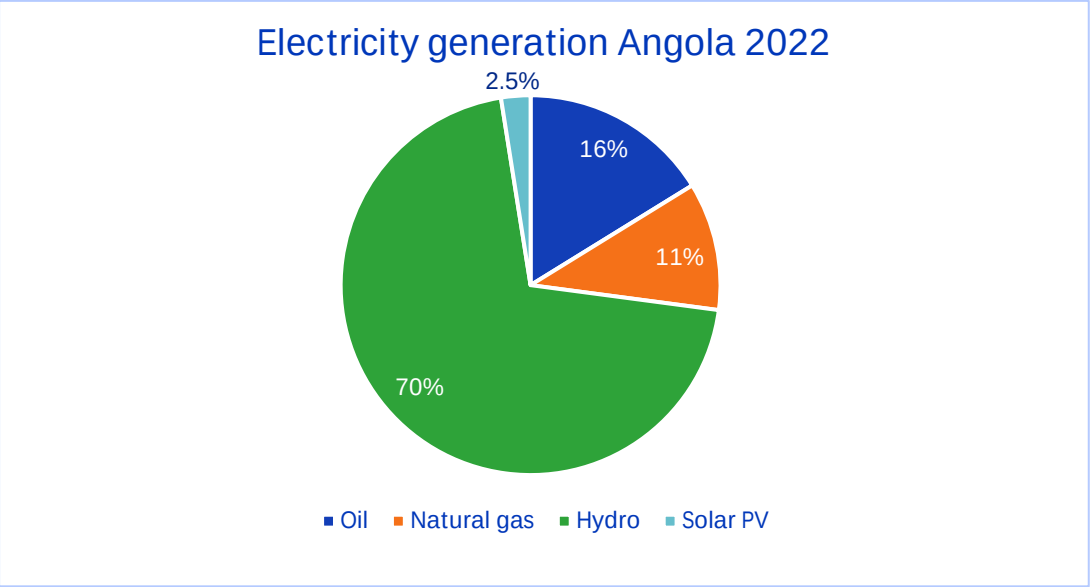

Figure 3.2: Electricity generation in Angola in 2022. Based on IEA (IEA, 2024).

3.2 Angolan exports

The Angolan economy relies heavily on the export of oil, representing around 80-90% of total export value in the period from 2018-2023 (RVO, 2020; Worldbank, 2024; CTI, 2021; UN Comtrade, 2024). Natural gas and diamonds are the next two largest exports in Angola, representing around 5% of yearly exports (RVO, 2020; Worldbank, 2024; UN Comtrade, 2024). China and India are major trading partners for Angola (UN Comtrade, 2024). In 2022 and 2023, the Netherlands became a top-five trading partner with around 5-6% of oil exports from Angola going to the Netherlands, compared to <1% in 2018-2021 (UN Comtrade, 2024).

The Carbon Tracker Initiative (CTI) has listed Angola in their group of petroleum producing countries most vulnerable to a decline in revenues from oil exports in a low-carbon scenario for the period 2021-2040 (CTI, 2021; CTI, 2023). On the one hand Angola is considered vulnerable due to a high dependence on oil and gas revenues (56% of total government revenues in 2015-2018 and approaching 70% in the 2023 update). On the other hand, Angola is considered vulnerable due to the amount of potential revenue that would be missed at a low oil price in a low-carbon scenario compared to historic prices. The CTI analysis considers economic diversification as a key risk mitigation strategy for countries such as Angola in the face of potential declining revenue from oil and gas exports.

3.3 Climate Change, Renewable Energies, and Sustainable Policies in Angola

Angola faces considerable challenges due to climate change, which has a direct impact on the country's landscape and communities. Since 2012, studies have pointed to an increase in the frequency and severity of drought periods, especially in the southern provinces, affecting water supply, agriculture, and livestock. Water scarcity in these areas is identified as a critical factor by the United Nations Development Programme (UNDP) (Jornal de Angola, 2018). Furthermore, the 2022 Climate Survey by the European Investment Bank (EIB) revealed that 75% of Angolans interviewed stated that climate change already affects their daily lives, with 57% reporting a reduction in income or livelihood sources due to these changes (EIB, 2022).

In the face of these challenges, the Angolan government demonstrates a strong commitment to the development of renewable energies as part of its strategy to address climate impacts. The Angolan government plans to install 800 MW of new renewables (small hydro, solar, wind and biomass), aiming for these renewable energies to represent more than 7.5% of the electricity produced by 2025 (MINEA, 2015a). The potential of renewable energies and current developments are discussed in more detail in Section 4.2.

Angola's intentions, aligned with the Paris Agreement and approved by Angolan authorities in November 2020, reflect a solid commitment to reducing carbon emissions and developing renewable energies. President João Lourenço reiterated these intentions in various official speeches, highlighting the country's transition to a more sustainable economy. In a recent statement at the COP29 in Baku, the Angolan Vice-President highlighted the Angolan efforts that have increased the share of renewable energy (hydro and PV) in the national energy mix to 66% currently and stated the ambition to increase this to 72% by the end of 2027 (Republic of Angola, 2024).

These initiatives reflect the country's commitment to harnessing its renewable energy sources and diversifying its energy mix, contributing to reducing dependency on fossil fuels and ensuring long-term environmental sustainability. Based on interviews with stakeholders, it was highlighted that despite these efforts, regulatory challenges and the need for significant private investments still pose obstacles to overcome in achieving the ambitious goals set by the Angolan government in the field of renewable energies.

3.4 Potential of Green Hydrogen

As most global economies seek to reduce their dependence on fossil fuels, green hydrogen emerges as a potential major energy carrier of the future, standing out for its sustainability, storage capability, and high energy potential. When combined with oxygen, hydrogen generates energy, producing only water and heat without emitting carbon dioxide (CO_2). Its energy density makes it ideal for powering energy-intensive industrial processes that are difficult to electrify, and it can serve as a raw material in various industrial applications such as refining. Additionally, as a clean energy carrier, green hydrogen can be stored for long periods and transported more flexibly than grid-connected renewable electricity, enabling its use in locations distant from renewable energy sources.

Countries with abundant renewable resources such as solar, wind, and hydropower have the potential to become significant producers of green hydrogen. According to the International Renewable Energy Agency (IRENA), low and middle-income nations in Africa, the Middle East, South Asia, and western regions of South America are particularly promising for the production of this type of hydrogen due to the availability of these natural resources (IRENA, 2023). This production can drive industrial development with zero emissions, create jobs, attract investments, and strengthen the economic resilience of these countries. Hydrogen can be exported to countries with a high hydrogen demand (e.g., the Netherlands or Germany), providing an economic benefit to the producing and exporting country.

The production of renewable (or low-carbon[1]) hydrogen also provides the opportunity to set up new domestic industries based on renewable hydrogen such as hydrogen-based direct reduction of iron ore to produce iron and steel, fertilizers, the production of renewable fuels and various chemicals. The industrial products can then be used for domestic consumption and for exports for a further boost of the local economy.

[1] Here we mean hydrogen produced from natural gas coupled with carbon capture and storage (CCS).

4 Opportunities and challenges of developing green hydrogen in Angola

4.1 Ambitions and Incentives in the Relationship Between the European Union and Angola

The relationship between the European Union (EU) and Angola holds significant ambitions and incentives in the context of green hydrogen production. Between 2019 and 2022, the country established a Program for Renewable Energy (Programa de Energias Sustentáveis de Angola – AREP) with the intention to invest in independent producers of energy (Produtores Independentes de Energia – IPPs), specially for solar and hydro energy. The program received around 1 million USD from the Sustainable Energy Fund for Africa (SEFA), a fund that is managed by the African Development Bank (AFDB, 2023). This program aims to boost the private investment in the renewable energy sector in Angola and to develop capacity for conceptualization, implementation, and monitoring of new projects. Additionally, partnerships with the Angolan Catholic University (UCA) aim to promote the use of green hydrogen in various sectors, including public transportation, highlighting the Angolan government's interest in adopting sustainable technologies.

The strategic approach involves collaborations with German companies and banks, reflecting an international willingness to drive sectoral development. The German consultancy company Roland Berger was hired by the Angolan government to build a strategy for the development of green hydrogen production in the country and in June 2022 the Angolan company Sonangol signed a memorandum of understanding (MoU) with the German companies Gauff GmbH and Conjuncta GmbH. The MoU includes actions to develop, fund, build and operate a green hydrogen production plant with capacity of 280 kilotonnes/year of green ammonia in Angola. The production would serve both internal demand and the international market (ANGOP, 2023), (Novo Jornal, 2023).

In respect to infrastructure, some stakeholders mentioned during interviews that Angola plans to leverage its experience in liquefied natural gas (LNG) terminals to develop green hydrogen distribution, indicating an adaptive and innovative approach to address logistical aspects of the value chain. However, they expect significant challenges, such as the need for appropriate technology and regulations, as well as local capacity development in renewable energy. They also highlighted the importance of a policy framework around renewable hydrogen that supports agreements with investors that are also beneficial to the Angolan economy the establishment of such regulations might be held through a lengthy process. Nevertheless, the potential for collaboration and incentives in the green hydrogen sector is promising, laying a solid foundation for future partnerships between the EU and Angola in this field.

4.2 Developments in Renewable Energy in Angola

Angola has substantial potential for developing various renewable energy technologies, offering a significant opportunity to diversify its energy matrix and reduce dependence on non-renewable sources (see Figure 4.1). With an estimated national potential of 18 GW in hydropower, 55 GW in solar energy, 4 GW in biomass, and 4 GW in wind energy, the country has a strong base to explore these clean and sustainable energy sources (MINEA, 2015b; MINEA, 2015a). The Renewable Energy Atlas identified 17.3 GW of potential at suitable locations (MINEA, 2015b) (ALER & ASAER, 2022). The hydropower potential is remarkable, with rivers like the Cunene, Kwanza, and Zambezi providing opportunities for large-scale hydropower plant development. The Angolan government targets are to install 4 GW of hydropower, 100 MW small hydro (<10 MW), 100 MW solar PV, 100 MW wind, 450 MW agro-industrial biomass projects and 50 MW urban waste by 2025 (ALER & ASAER, 2022). Sonangol has set an own target to produce electricity from 450 MW of renewable sources in 2027 and 1 GW in 2030 (Sonangol, 2022). TotalEnergies expects hydropower capacity to grow from 4 GW in 2022 to 12 GW in 2040 and expect solar capacity will rise to 7 GW in 2040 (TotalEnergies, 2022).

The largest project under development is the Caculo Cabaça hydropower plant that will have a capacity of 2171 MW (U.S. International Trade Administration, 2024a; ALER & ASAER, 2022). There are also several solar PV projects operational and under development. These include hybrid plants, combining solar PV with diesel generators (U.S. International Trade Administration, 2024a; ALER & ASAER, 2022). There is also a portfolio of 370 MWp (peak capacity) of projects that has been developed by Sun Africa LLC and Grupo MCA (U.S. International Trade Administration, 2024a; ALER & ASAER, 2022). Sun Africa LLC an Omatapalo have another three large scale solar PV projects in development, good for a combined 724 MWp (ALER & ASAER, 2022). In addition, Solenova, a joint venture between Eni[2] and Sonangol, inaugurated the first 25 MW of their 50 MW project at Caraculo (Solenova, 2023). Total Eren, a TotalEnergies affiliate, is examining plans to build solar power plants (TotalEnergies, 2024). In 2021 and 2022 there were signed agreements with Sonangol and Greentech to develop a 40 MWp plant in Lubango (ALER & ASAER, 2022). The status of the project is unknown. Total Eren also declared their intention to develop other solar plants in partnership with Sonangol (ALER & ASAER, 2022). Masdar (UAE) has announced plans to develop a 150 MW solar PV project in the south of Angola (Masdar, 2023).

V&V Rending has announced interest to develop the first two onshore wind parks in Malanje, Angola, with a planned capacity of 62 MW and 42 MW respectively (ALER & ASAER, 2022; Portal, 2019).

However, despite the promising potential, Angola faces significant challenges in its energy distribution and transmission infrastructure. Currently, there are three major energy distribution and transmission networks: central-north, east, and south (TotalEnergies, 2022). The central-north network is the most developed, supplying electricity to major cities and connecting the country's main energy generation centres. On the other hand, the southern and eastern networks are relatively underdeveloped, posing an obstacle to fully harnessing the solar and wind production potential, especially in the south where abundant resources of these energy sources are located – as shown in Figure 4.1 and Figure 4.2.

[2] Since 2022 Solenova is a JV between Sonangol and Azule Energy, the latter being a JV between Eni and BP.

The Angolan Government has published plans to increase electrification from 30% (2009) to 60% in 2025 (MINEA, 2015a). Current status is not exactly known, but online sources refer to 43% electrification in 2021-2024 (U.S. International Trade Administration, 2024a; Power Africa, 2021). Even if the 60% electrification target in 2025 is achieved, additional investments are still needed to expand and modernize the energy infrastructure and to create a robust and efficient network capable of meeting the growing demand for renewable energy in Angola.

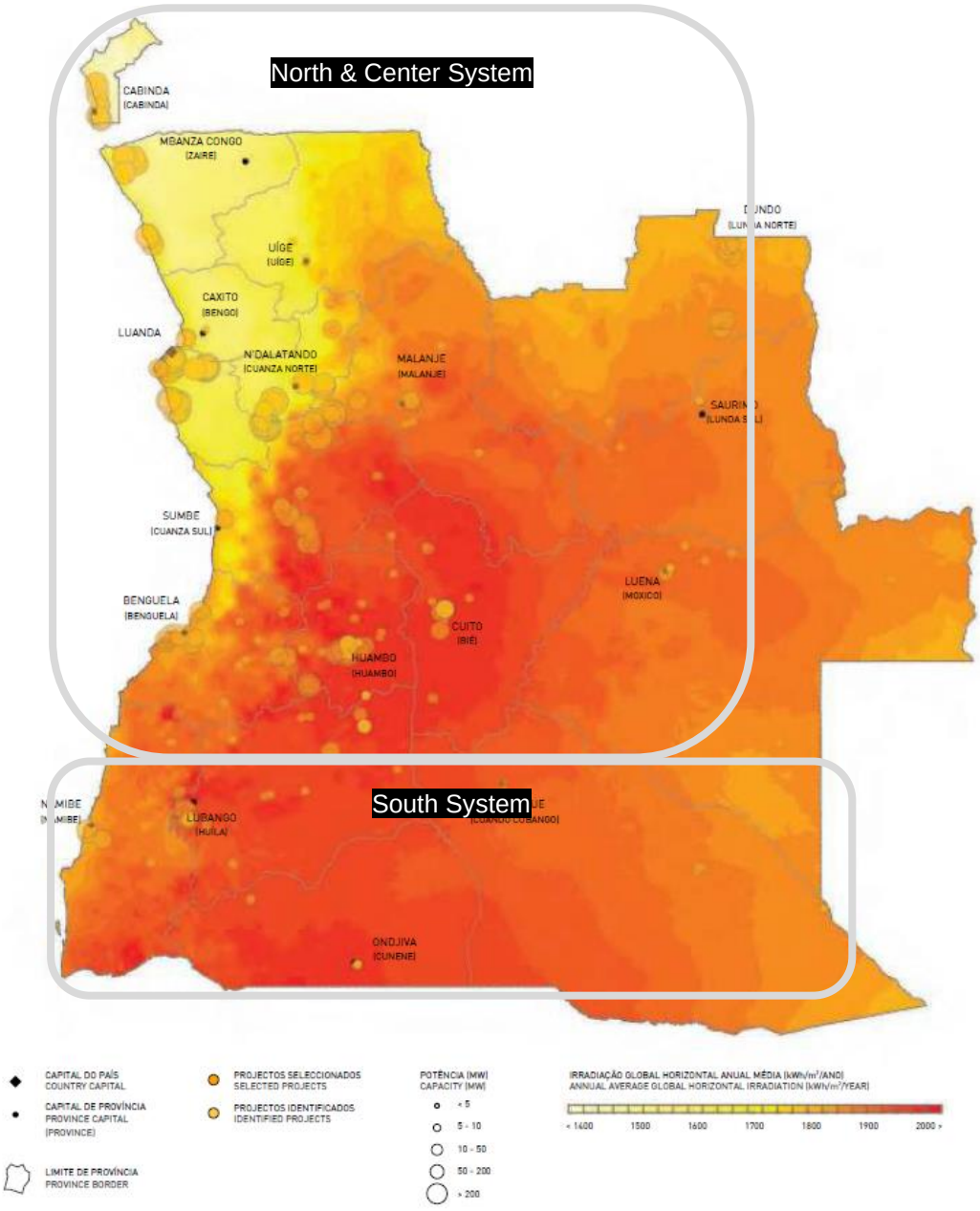

Figure 4.1: Map of solar resources in relation to existing network distribution systems in the north/center and south of Angola (MINEA, 2015b).

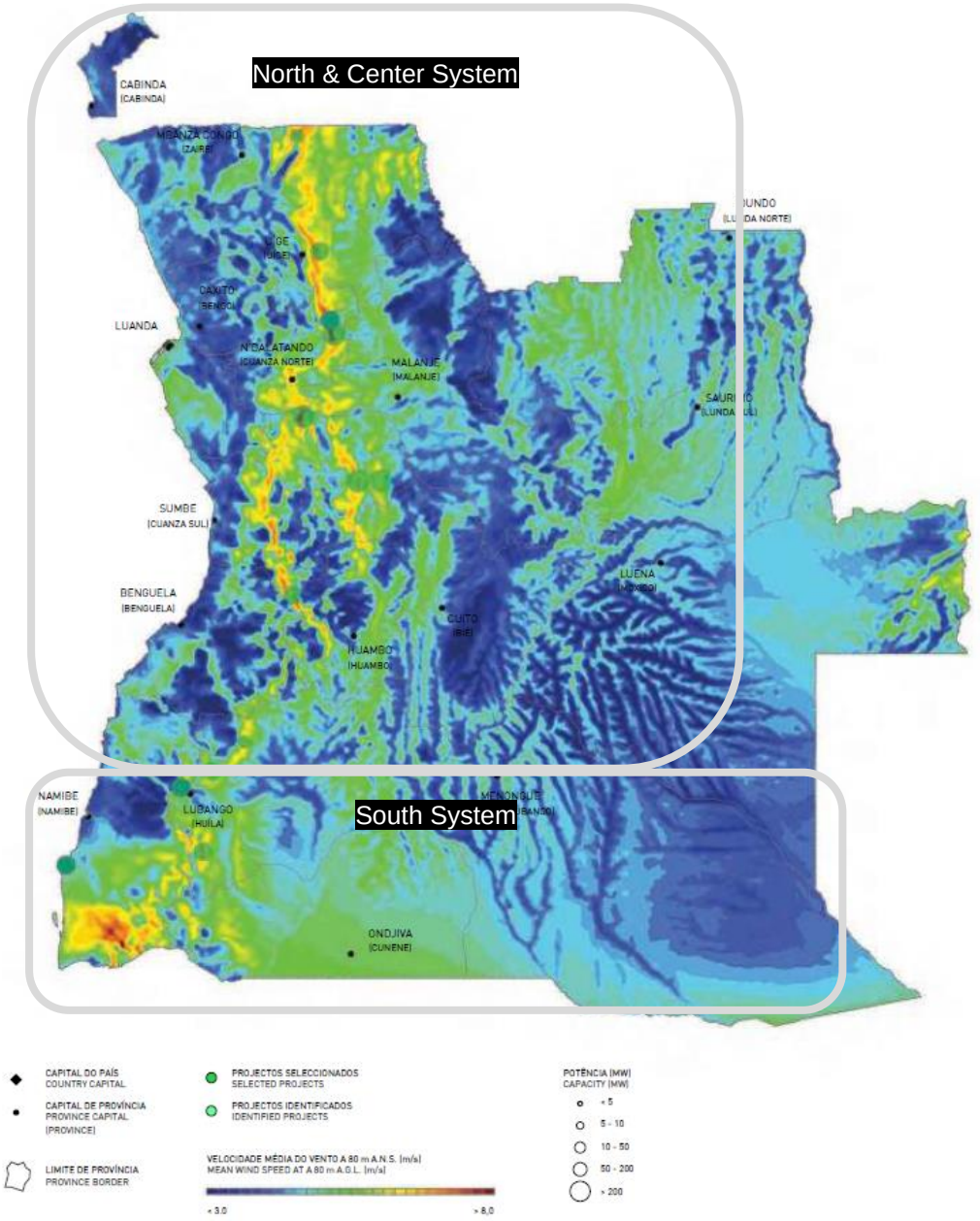

Figure 4.2: Map of wind resources in relation to existing network distribution systems in the north/center and south of Angola (MINEA, 2015b).

4.2.1 Green hydrogen projects

There are at least three green hydrogen projects in development in Angola. The first and most concrete of the three is based on a declaration of intent signed by Sonangol and German firms Conjuncta and Gauff (Gauff Engineering, 2022). The 400 MW electrolyser is to be built at the Barra do Dande Ocean Terminal, using electricity from the 2 GW Luanda hydropower plant (Hydrogen Insight, 2023). The aim is to convert the green hydrogen to ammonia and sell the green ammonia to Germany via the H2Global green hydrogen programme (Hydrogen Insight, 2023). Germany's H2Global buys green hydrogen from outside the EU through an intermediary (Hydrogen Intermediary Company GmbH, Hintco) and auctions the hydrogen off to offtakers in Europe (H2Global Stiftung, 2024). The H2Global programme compensates the price difference between the bought and sold hydrogen.

Both the German and the Dutch governments have pledged funding for the programme (H2Global Stiftung, 2024). In October 2024 CWP Global joined the project consortium (CWP Global, 2024).

The second project is being developed by Minbos Resources using 200 MW hydropower from the Capanda dam (520 MW) in the north of Angola (Minbos Resources, 2024a; Minbos Resources, 2022). The ammonia is expected to be used locally to produce fertilizers and to be used to produce explosives for the mining industry (Minbos Resources, 2022). As of December 2024, the project is still in the feasibility phase (Minbos Resources, 2023; Minbos Resources, 2024b).

According to interviews there is a third initiative lead by the Angolan Catholic University (UCAN) related to hydrogen buses. The intention is to use hydrogen buses for internal transportation the new international airport in Luanda that is currently being constructed. Further information and status of the project are not known to the authors of this report.

4.3 Identified opportunities and challenges

Based on literature review, existing projects, European demands, and expert interviews, we have identified several crucial opportunities and challenges for the development of the green hydrogen sector in Angola.

The main challenges and opportunities identified in this study for Angola regarding green hydrogen development are further detailed below.

Opportunities

1. **Funding and international cooperation initiatives**: Angola is receiving support from the Sustainable Energy Fund for Africa (SEFA) to develop its renewable energy sector. Additionally, German companies and banks are seeking supply agreements with the Angolan government, presenting investment opportunities.
2. **Significant Renewable Generation Potential for Green Hydrogen Production:** The idea of green hydrogen production is gaining prominence, especially given the availability of renewable resources in Angola. There are considerable expansion plans for hydropower, solar, and wind capacity.
3. **Infrastructure development:** Experience with LNG terminals can be leveraged for the development of the necessary infrastructure for the export of green hydrogen. ANPG plans to assess the capability and suitability of Angolan ports for the export of new materials in feasibility studies (ANPG, 2024).
4. **Anticipated future domestic demand from cement, steel, and fertilizer industry**: The expectation of future domestic demand arises from the possibility of installing new sustainable industries in sectors such as cement, steel, and fertilizers. Studies on these facilities can drive internal consumption and promote green hydrogen production within the country.

Challenges

1. **Technology provision**: Lack of developed electrolysis technology in the country may hinder large-scale green hydrogen development. Strategic partnerships and investments are needed in this area.
2. **Regulation and Contracts:** Clear regulations enabling mutually beneficial contracts between foreign investors and the Angolan government are essential to attract investments and drive sectoral growth.
3. **Energy Mix Composition:** Angola's currently still relies on fossil fuels for about 50% of the energy supply. Renewable hydrogen production for export will therefore compete with domestic use of renewable electricity and other measures to lower the local greenhouse gas emissions – such as the electrification of transport and other energy use. Hydrogen production for export will also compete with domestic use of renewable hydrogen for decarbonization of sectors such as oil refining.
4. **Distribution and Export Infrastructure:** The lack of adequate infrastructure for transporting and distributing green hydrogen, both domestically and for export, poses a significant challenge that needs to be addressed for market development.
5. **Capacity Building and Education**: Investments in training and education are crucial to prepare the local workforce for the development of the renewable energy and green hydrogen sector. This may involve training programs and partnerships with local and international educational institutions.
6. **Electricity Transmission and Distribution Network Development:** Expanding the electricity distribution network in Angola faces challenges, as only a portion of the territory is covered. To harness the country's renewable resources effectively, infrastructure development is necessary to connect renewable electricity generation with national demand, including future demand driven by hydrogen production.

In summary, the identified opportunities and challenges for Angola in green hydrogen production reflect a complex landscape. While funding and international cooperation initiatives provide a promising boost for renewable energy development in the country, including green hydrogen production, challenges related to infrastructure, regulation, and capacity underscore the need for comprehensive and collaborative approaches. It is evident that Angola has the potential to become a significant player in the global transition to cleaner energies, leveraging its renewable resources and establishing strategic partnerships. However, the success of this endeavor will depend on the country's ability to overcome the identified challenges and fully capitalize on the available opportunities.

5 Summary of main stakeholders

In this chapter, we provide an overview of the identified key players in Angola with activities related to or relevant for the green hydrogen market. An overview is provided in Table 5.1.

5.1 Important local stakeholders

The Angolan government has a significant presence along the green hydrogen value chain in Angola. There are three public utilities operating under the Ministry of Water and Energy (MINEA). They are responsible for the production (PRODEL), transmission (RNT) and distribution (ENDE) of electricity. National oil company Sonangol is active in oil and gas activities, but also in several renewable electricity projects and in the largest green hydrogen project in Angola to date. These local stakeholders are expected to be most relevant for future green hydrogen production in Angola.

Additional relevant players include the electricity sector regulator (IRSEA), the Ministry of Mineral Resources Oil and Gas (mirimpet) and regulatory agencies for upstream (ANPG) and downstream (IRDP) activities in the oil and gas sector.

Finally, if a hydrogen export supply chain is to be set up, local transport and logistics stakeholders will become relevant for the green hydrogen market as well. We have not been able to identify important players involved in domestic energy transport other than the already mentioned national companies such as Sonangol. The Lobito corridor railway initiative could prove relevant by providing an option for the transport of hydrogen (carriers) by railway. In addition, some of the major ports in Angola could become relevant for setting up hydrogen export infrastructure. The Barra do Dande Ocean Terminal has been linked to the Sonangol consortium green hydrogen project. The authors are not aware of any other ports already actively pursuing opportunities to establish hydrogen export infrastructure.

5.2 Important international stakeholders

There are many international stakeholders active in Angola. Most prominently these are international oil and gas companies, such as TotalEnergies, ENI, Chevron, ExxonMobil, BP, and Equinor. Some of these are also active in the electricity sector. Besides these companies, there are more international players involved in the renewable electricity sector in Angola. These are mostly related to hydroelectric projects and solar PV projects. These players are relevant for increasing the renewable electricity production that a green hydrogen market in Angola will require. As previously mentioned, there are some international players active in the first green hydrogen projects in Angola. These include Gauff Engineering, CWP Global and Conjuncta, who are involved in a consortium with Sonangol. Minbos Resources is also developing a green hydrogen project in Angola.

Finally, there are a number of international players active in a more general role supporting the development of the energy sector in Angola, such as Power Africa, the African Development Bank and German development agency (GIZ). The German Global Hydrogen Diplomacy (H2-Diplo) is also actively engaged in a dialogue on the development of a green hydrogen market in Angola.

Table 5.1. Non-exhaustive overview of identified stakeholders.

Supply chain element	Sector	Stakeholders
Electricity production	Energy	• PRODEL (Empresa Pública de Produção de Electricidade); • Sonangol • Angola Ministry of Water and Energy (MINEA) • TotalEnergies • Sun Africa • ENI • Azule Energy • LTP Energias • MCA Group • Omatapalo • Solenova (Azule + Sonangol) • Total Eren • Greentech • Masdar • V&V Rending
Electricity transport and distribution	Energy	• RNT (Empresa Rede Nacional de Transporte de Electricidade); • ENDE (Empresa Nacional de Distribuição de Electricidade)
Hydrogen production	Energy	• Sonangol • TotalEnergies • Gauff Engineering, CWP Global, Conjuncta (consortium developing hydrogen/ ammonia project in Angola) • Minbos resources
Hydrogen carrier production (e.g., ammonia)	Energy	• Sonangol • Gauff Engineering, Conjuncta and CWP Global • Minbos resources
Domestic transport	Transport & logistics	• Lobito corridor railway
Shipping	Transport & logistics	• Luanda Port Authority • Unicargas • Multiparques • Barra do Dande Ocean Terminal • Porto do Lobito • Port of Cabinda • Port of Mocamedes (Namibe)
Policy & regulation	Government	• Angola Ministry of Water and Energy (MINEA) • Instituto Regulador dos Serviços de Electricidade e Águas (IRSEA) • Ministry of Mineral Resources, Oil and Gas (mirimpet) • Petroleum Derivatives Regulatory Institute (IRDP) • Agencia Nacional de Petroleo, Gas e Biocombustiveis (ANPG)
Research	Academics	• Three universities signed agreements with ANPG: – Universidade Agostinho Neto – Catholic University of Angola – Instituto Superior Plitecnico de Technologias e Ciencias
Other foreign parties		• Power Africa (US) • African Development Bank • Odebrecht (BR) • Global Hydrogen Diplomacy (GER) • GIZ (GER)

6 Collaboration opportunities with the Netherlands

The identified opportunities for green hydrogen development in Angola also showcase some potential areas for collaboration between the Netherlands and Angola. A list of collaboration areas is given below. The list is not exhaustive.

Hydrogen (carrier) shipping is a key focus point for Angola as a means to export green hydrogen. Hydrogen can be shipped attached to a carrier (Liquid Organic Hydrogen Carriers - LOHCs), as derivate (e.g., ammonia, methanol, or e-fuel), or in liquid form. Worldwide, only ammonia is currently shipped in large quantities, yet shipping liquid hydrogen or LOHCs show similarities to the shipping of LNG and oil products. Angola has much experience with shipping LNG and oil products. The Netherlands also has significant experience with shipping and there are initiatives aimed at the import (and re-export) of hydrogen by for example the Port of Rotterdam (ammonia, liquid hydrogen and LOHC) and the Port of Amsterdam (LOHC and liquid hydrogen). There are opportunities for collaboration and shared learning, in particular in the shipping of liquid hydrogen and LOHCs, which are not shipped at scale today.

Key players in the Netherlands include (but are not limited to): Port of Rotterdam, Port of Amsterdam, Groningen Seaports, Royal Vopak.

Market development, especially off-take, policy, and regulation: the cost of green hydrogen today is still much higher than that of natural gas and the green hydrogen market is still in its earliest infancy. The pathway and timeline to mature offtake markets is still uncertain but explicitly based on policy goals, notably the import goal of the EU for 10 million tonnes green hydrogen by 2030 (European Commission, 2024). As indicated in Chapter 4, there is also a desire to increase domestic demand for green hydrogen in Angola from the establishment of new industries such as cement, fertilizers, and steel. Current developments are struggling with the so-called “chicken and egg“ dilemma regarding green hydrogen supply and actual demand by off-takers. Various initiatives such as H2Global (see 4.2.1) are now being developed trying to solve this. Solid offtake agreements and actual interest from EU off-takers in green hydrogen is crucial to them with to take serious steps. Thus, Angolan and EU or Dutch collaboration in the area of market development will serve the interests of both producers and users.

In addition, ANPG has indicated the desire for support on the development of a policy framework on hydrogen. Multiple government agencies, consultancies and research institutes in the Netherlands have expertise in this field from the development of the policy framework in the Netherlands and the EU.

Key players in the Netherlands include (but are not limited to): Berenschot, CE Delft, Guidehouse, Ministry of Climate and Green Growth, PBL, PwC, TNO, TwynstraGudde, Witteveen+Bos.

Capacity building and education are crucial to prepare the required workforce for an Angolan green hydrogen industry. TNO has experience with supporting capacity building infrastructure development in the field of renewable energy, such as the Renewable Energy Training Centre (RETC) Indonesia (Donker, van Tilburg, Gamboa Palacios, & Derks, 2022) but also in actual knowledge transfer or joint applied knowledge development with local knowledge institutions or governmental organizations in African (Mozambique, Kenya, Morocco, Algeria, South-Africa) and Asia on various energy transition technologies, innovations, models and enabling environment.

Dutch universities (University of Groningen, TU Delft a.o.) and universities of applied science (i.e., Hanze University of Applied Sciences) have world-class academic knowledge and track record on international technical and vocational education and training (TVET) on the topic of energy transition and renewable energy including student exchanges, joint research etc.

The Netherlands has first class maritime & logistics knowledge, as import and export via ports are a dominant component of the Dutch economy. The Netherlands provides training and support on the topic of ports and ports logistics and the role of energy in ports, by among others STC Group International.

Key players in the Netherlands include (but are not limited to): TNO, TU Delft, University of Groningen, HanzeHogeschool, Enercy.

In the identified areas for potential collaboration there are also other (international) players active and distinctive strengths of the Dutch players will need to be identified on a case-to-case level that go beyond the scope of this report. The organization of a workshop to specify concrete value propositions for collaborations is recommendable.

Mission H2 (an initiative by Gasunie, Shell Netherlands, Remeha, Stedin, Toyota, Port of Amsterdam and Groningen Seaports (MissieH2, 2024)) has compiled a comprehensive and up-to-date map of the Netherlands with the many initiatives that already exist in the field of hydrogen, see Figure 6.1. This the interactive map offers the unique opportunity to travel through time to see the development of the Netherlands as the Hydrogen Country 2030. Many initiatives can also be found on the RVO website hydrogen international[3].

[3] Hydrogen International (rvo.nl)

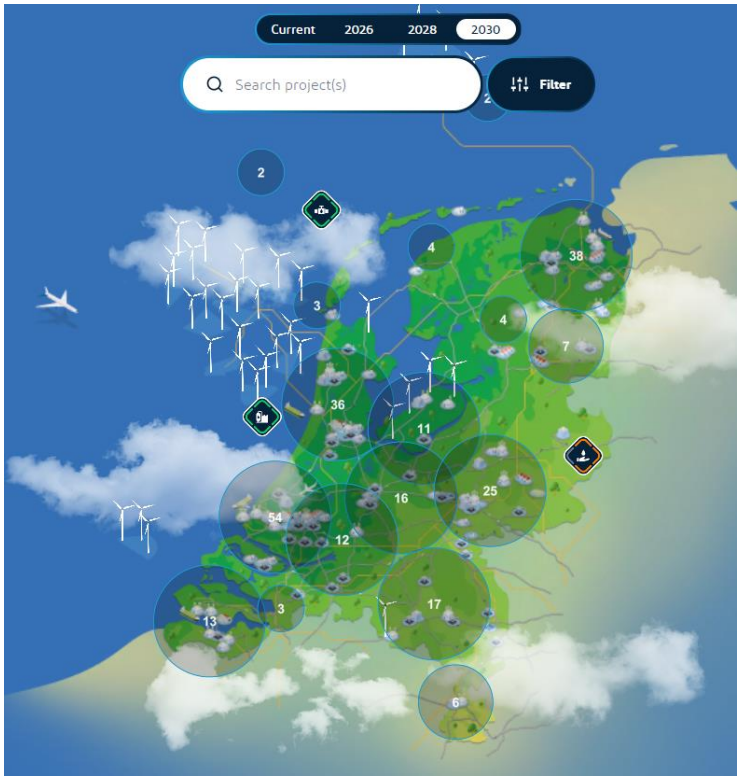

Figure 6.1: Screenshot of interactive map with an overview of initiatives related to hydrogen in the Netherlands. Source: https://www.missieh2.nl/en/

7 Conclusions and recommendations

Angola has a large potential for the production of renewable electricity and by extension also green hydrogen produced from this electricity. Angola can leverage experience with LNG export terminals for future export of green hydrogen. The green hydrogen market in Angola is in its infancy, with the first major project being announced in a consortium led by the national oil and gas company Sonangol. A mix of national and international players relevant for the green hydrogen value chain in Angola were identified in this study. The national players are mainly linked to government (e.g., Sonangol, the national utilities, ministries, and regulators). National ports will also be relevant for hydrogen export ambitions. The international players are mainly oil and gas corporations, renewable electricity project developers and the consortium linked to the Sonangol green hydrogen project. There are also a number of international organizations more generally supporting the development of the energy sector in Angola, which could also play a role in the development of a green hydrogen market.

The production and export of green hydrogen (e.g., to the Netherlands, Germany or elsewhere in the EU) can be an attractive economic opportunity for Angola. On the short term, the green hydrogen could be directly exported, but on the long term there is an opportunity to set up new local renewable industries such as cement, iron and steel, and fertilizers. Setting up local industries can decrease the dependency on imports of industrial products such as steel and fertilizers, but also create opportunities for the export of high-value products.

Yet the production of green hydrogen requires renewable electricity. As the Angolan economy is not yet fully electrified, the electricity mix is not yet fully renewable, and electricity demand is expected to grow in the coming decades, building a green hydrogen market requires finding the right balance between local development and economic opportunities coming forth from export of green hydrogen or renewable products. The country's electricity transmission and distribution network need to be expanded both to increase access to electricity for the local population and businesses, and to make possible further growth of renewable electricity production. The latter is also a requirement to produce green hydrogen. Additional challenges for the creation of a green hydrogen market include access to technology, capacity building, the need for regulations, the need for foreign investment, and a lack of infrastructure for the transport and distribution of hydrogen.

For the Netherlands, Angola has the potential to become an interesting trading partner for green hydrogen in the short to medium term and for renewable hydrogen-based products on the longer term. The Netherlands has relevant expertise to support Angola in the development of its hydrogen market, based on the identified opportunities and challenges. The topic areas of hydrogen (carrier) shipping, market development, policy and capacity building have been identified as the most relevant areas for potential collaboration between Angola and the Netherlands. Joint efforts with Germany and the European Union can provide additional opportunities for collaboration, further stimulate the development of a green hydrogen market in Angola and build the foundation for a future green hydrogen trade relation between Angola and the EU.

Based on these findings we have the following recommendations for next steps:

- Organize a workshop in Angola with key stakeholders (ANPG, Sonangol, MINEA, etc.) to validate the findings of this study.
- Connect key stakeholders in Angola to Dutch counterparts to explore collaboration opportunities on the topics of hydrogen shipping, market development, and policy and capacity building.
- Support Angolan policy makers with the development of a green hydrogen policy framework.
- Seek out collaborations with Germany and the EU on the development of the Angolan green hydrogen market and import routes to the EU.
- Be mindful of the balance between the use of renewable electricity for local ends and for the production and export of green hydrogen.

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