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Green hydrogen in Algeria: A mapping study

TNO Public › TNO 2023 P11783
22 September 2023

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TNO 2023 P11783 – 22 September 2023

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Classification report	TNO Public
Title	TNO Public
Report text	TNO Public
Number of pages	24 (excl. front and back cover)
Number of appendices	0
Sponsor	RVO
Project name	Green hydrogen mapping study Algeria
Project number	060.56307

Contents

1 Introduction

This report describes the insights of a mapping study on behalf of the Embassy of the Kingdom of the Netherlands in Algeria through the Dutch Enterprise Agency (RVO). It provides the current developments and perspectives in the area of green hydrogen[1] in Algeria with the aim of identifying development areas with potential for collaboration between Algeria and The Netherlands.

Chapter 2 lists the goals and explains the methodological approach of this study. Chapter 3 provides background and context by summarizing relevant facts collected during a desk study of recent publications. Chapter 4 assesses the potential of green hydrogen in Algeria and addresses opportunities and challenges. Chapter 5 provides an outlook into the future by describing developments in pilot projects and sketching the field of stakeholders as well as the political and business environment. Finally, chapter 6 describes development perspectives by collaborations with Dutch stakeholders in the green hydrogen sector to overcome current challenges. This information is relevant for the large community of Dutch companies being active in the area of green hydrogen development. The report also serves as advice for the continuation of the CERF program by RVO and as support for the green hydrogen strategy of the Dutch Mission in Algiers.

[1] For the EU definition of green hydrogen see, e.g., https://www.energymonitor.ai/hydrogen/eu-sets-out-rules-for-green-hydrogen-inviting-promise-and-peril/?cf-view

2 Goals and methodology

2.1 Goals

The goals of this study were to:

- identify and build initial relationships with Algerian stakeholders who are expected to be key partners in the future green hydrogen sector of Algeria
- gain insight into relevant developments (e.g., national hydrogen development strategy)
- collect preliminary case study data from pilot projects
- sketch collaboration opportunities with Dutch stakeholders in the green hydrogen sector based on gathered information

2.2 Methodology

The research methodology consisted of three elements:

- desk study during which a significant number of recent publications was studied, both from scientific sources as well as from sources of mainstream and investigative journalism
- work visit to Algiers[2] for discussions with key Algerian stakeholders
- analysis of information and synthesis into advice on future collaboration opportunities

[2] The program of the work visit was arranged via Prof. Yassaa (Commissioner for Renewable Energy and Energy efficiency in Algeria) and put together by Dr. Sellami from the Commissariat for Renewable Energy and Energy Efficiency (CEREFE). The meetings were hosted by Dr. Sellami, Mr. Medjelled (Ministry of Energy and Mines) and Mr. Kallache (Sonatrach). The authors want to express their sincere gratitude for these excellent arrangements.

3 Background

3.1 Algeria/Europe import/export relations

Algeria is among the 10 largest natural gas producers and exporters worldwide and a main supplier for Europe since decades. In 2021, 78% of the Algerian natural gas exports were delivered to Europe (EIA, 2023). The exports are realized via the MedGaz pipeline to Spain, the TransMed pipeline to Italy and in the form of LNG deliveries. In total, the gas supply from Algeria corresponded to 10% of the European gas imports in 2020/2021 (Farrand, Against the flow: Europe's role in kickstarting Algeria's green transition, 2022 a). So, Algeria and Europe have a long history of import/export relations in the area of energy.

3.2 Algeria and The Netherlands: reliance on natural gas

Both Algeria and The Netherlands share a heavy reliance on natural gas as the backbone of the energy system in the past decades. In fact, the domestic energy system of Algeria today is still almost entirely (> 99%) based on fossil fuels with natural gas being the most significant energy carrier by far (65%) (IEA, 2020 a). The share of renewable energies is < 1%. Around 90% of Algeria’s export revenues and 50% of the state budget have been sourced from the sales of fossil fuels in recent decades (Farrand, 2022 a).

Also in The Netherlands, the domestic energy system remains currently still overwhelmingly dominated by natural gas, oil and coal (> 85%) with natural gas in the first position (45%) (IEA, 2020 b). However, with the increasing ambitions of the European Commission and of the Dutch government to reduce greenhouse gas emissions, recent policies and legislation aim to change this rapidly. The share of renewables in the Dutch energy system is expected to approximately triple to around 40% by 2030.

3.3 Climate change and renewable energy policies

The ever increasing and serious challenges of climate change around the world also lead to increasingly dire consequences in Algeria. These are described in a recent report (Bensmaine, 2022) and include longer drought periods and decreased rainfall resulting in exacerbated desertification, among others. This is one of the reasons that plans to increase renewable energies and energy efficiency are being pursued in Algeria. Another reason is diversification of (future) energy export perspectives. Based on the revised goal of Algeria to install over 16 GW of renewables in its electricity system by 2035 (Enerdata, 2021), GIZ estimates that Algeria can achieve a share of around 27% renewables in its electricity system by 2030 (Heinemann, et al., 2022) (Drenkard & Mirakyan, 2021).

The EU has set goals to accelerate the reduction of greenhouse gas emissions and to phase out fossil fuels. Recently, the Fit for 55 policy package was passed (2021). New policy frameworks, such as RePowerEU, the recently revised Renewable Energy Directive (RED) and

Energy Efficiency Directive (EED) raise the goals for the domestic production and possible need for large imports of renewable energy as well as energy efficiency. For example, the revised RED aims at a share of 42,5 – 45 % of renewable energies in gross final energy consumption across Europe by 2030 (European Commission, 2023). In 2021 this percentage was at 22% which means a doubling of the share of renewables in less than 10 years.

So, there are significantly increasing aims and related policies in the area of renewable energies and climate change in the EU and also in Algeria, and these topics are receiving more and more attention. In this context the development of green hydrogen as a renewable energy carrier with perspectives for import/export markets ranks high on the policy agenda, both in Algeria and the EU. This leads to opportunities for co-development and collaboration.

4 Potential, opportunities and challenges of green hydrogen in Algeria

4.1 Ambitions, policies and incentives in the EU and Algeria

Europe

As part of the mentioned policy frameworks for enhancing the share of renewable energies, the European Union's goal for green hydrogen is to produce 10 million tonnes of green hydrogen by 2030 and to import another 10 million tonnes from outside the EU (European Commission, 2023). In terms of energy content this corresponds to approximately 2 400 PJ of green hydrogen by 2030. For comparison: the gross available energy[3] of natural gas in the EU was around 15 000 PJ in 2021 (Eurostat, 2023). So, within the next 10 years the EU demand for natural gas can be expected to significantly decline and that for green hydrogen to increase. Furthermore, since the long term goal is to completely decarbonize the EU economy by 2050, this trend is set to continue. This being said, in 2022, the EU has been searching actively and successfully for additional natural gas supplies from the Middle East and Africa in order to compensate for the phase out of supplies from Russia as a reaction to the Russian invasion in Ukraine. This extra demand from Europe – though intended to be temporary - was noted as mixed signals in these countries including in Algeria (Farrand, 2022 a) since it is seemingly in contradiction to the earlier stated decline in natural gas demand. So, the timescale on which the demand decline is going to take place is perceived as uncertain.

Algeria

Algeria has two main motifs for developing a green hydrogen sector. One is to potentially uphold the capacity to generate significant revenues from energy exports when demand for natural gas declines. Another one is to mitigate the adverse effects of climate change. Furthermore, for the future export perspectives of the Algerian economy as a whole to the EU the transition to a clean energy supply is increasingly important due to the recently introduced carbon border adjustment mechanism (CBAM). CBAM puts a price on the carbon emitted during the production of carbon intensive goods that are entering the EU with the intention to encourage cleaner industrial production in non-EU countries and create a level playing field for EU industries facing increasing carbon pricing through the Emission Trading System (ETS) (European Commission, n.d.). In Algeria, CBAM will affect, e.g., the fertilizer export industry.

[3] Gross available energy = overall supply of energy for all activities on the territory of the country. It includes energy needs for energy transformation (including generating electricity from combustible fuels), support operations of the energy sector itself, transmission and distribution losses, final energy consumption (industry, transport, households, services, agriculture, ...) and the use of fossil fuel products for non-energy purposes (e.g. in the chemical industry). It also includes fuel purchased within the country that is used elsewhere (e.g. international aviation, international maritime bunkers and, in the case of road transport "fuel tourism").

Ambitions in Algeria and the Netherlands (hydrogen roadmaps)
Both Algeria and The Netherlands have recently published roadmaps for the national development plans of a green hydrogen sector. The Algerian roadmap has not yet been published in English. But we received a handout of an executive summary which sketches three development phases (until 2030, 2030-2040 and 2040-2050). The focus in the first phase is on skills development, pilot projects and regulations. The second phase aims at larger scale projects with a production of up to 1 million tonnes green hydrogen per year for export. Domestic use is foreseen on a level of around 0.2 million tonnes per year (e.g. for the production of steel, cement and ammonia/fertilizers). In the third phase, Algeria's goal is to become one of the largest producers and exporters of green hydrogen globally. The Dutch hydrogen roadmap has been published in 2022 (in English) (Nationaal Waterstof Programma, 2022). It formulates among others the ambition of the Netherlands to maintain and strengthen its position as energy hub of Northwest Europe Nederland via the import and transit of green hydrogen (derivatives). Furthermore, a recent publication contains an extensive list of Dutch players in the area of green hydrogen development (RVO, FME and TKI New Gas, 2022).

4.2 Opportunities and challenges

The solar resource in the Sahara desert and throughout Algeria is characterized by high irradiation intensity and large amount of sunshine hours, which translates into an excellent annual solar power potential of ≥ 1800 kWh/KWp (Solargis, 2020). In fact, Algeria is one of the sunniest countries on earth. This presents a huge opportunity for low-cost photovoltaic electricity generation (Drenkard & Mirakyan, 2021). Similarly promising conditions also apply to the wind resources (Drenkard & Mirakyan, 2021). Since the cost of green hydrogen depends critically on the electricity price as well as to running hours of the electrolyzers, Algeria is definitely a promising location for producing green hydrogen. Furthermore, based on its history with natural gas, Algeria has extensive expertise with gaseous energy carriers as well as an advanced infrastructure: there are both domestic pipelines and transnational ones connecting to Europe (Spain and Italy). There are also perspectives for potential offtake markets for green hydrogen, both domestically (e.g. ammonia/urea fertilizer industry), and internationally (e.g. the EU). Opportunities also include the changes in the business environment aiming to create a competitive and business-friendly climate to attract foreign investors in the energy sector. Changes include the removal of the 51/49% rule, requiring Algerian majority shareholding; the new investment law; the Law on free zones and the amendment of the commercial code (BakerMcKenzie, 2022)

Challenges to these perspectives are related to the current Algerian electricity mix as well as the technical feasibility and economics of green hydrogen:

- With regard to the electricity mix it is important to note that it features today only a very small amount of renewables. Approximately 600 MW renewable electricity capacity is currently installed (mainly photovoltaics) which is equivalent with a renewable electricity production of > 1 TWh per year. For comparison, the total electricity consumption of Algeria is on the order of 80 TWh per year (Heinemann, et al., 2022) and the electricity demand for producing 1 million tonnes of green hydrogen (= the goal of the second phase of Algeria's hydrogen roadmap in the period of 2030 – 2040) is on the order of 55 TWh (De Vries, Jongsma, Van den Toorn, & Voulis, 2022). So, for this 1 million tonnes production target of green hydrogen, the renewable electricity capacity needs to be expanded by almost two orders of magnitude. The current plans to reach 16 GW renewable electricity capacity by 2030 is a good step in this direction but will need to be scaled up further in order to reach a production of 55 TWh. Another question in the context of future

renewable electricity production is, how much of it will actually be available for green hydrogen production rather than for “direct” domestic electricity consumption.

- Regarding technical feasibility and economics enabling future export perspectives the question is how to realize a viable and cost-efficient transport to Europe. One optional plan by the Algerian government is to use the existing TransMed and MedGaz pipelines and to first add to, and then replace, the natural gas supplied to Europe through these pipelines with green hydrogen. The main technical question in relation to this plan is how the pipelines can be feasibly repurposed. Transport options, e.g. as gas via pipelines or as liquefied hydrogen or hydrogen derivatives via shipping are currently evaluated technologically and economically. Note: a recent report for Corporate Europe Observatory (Barnard, 2022) raises questions about the economic viability of the green hydrogen plans altogether as long as prices for natural gas are much lower than those for green hydrogen by a factor of 5 – 10 (on an energy basis).

5 An outlook into the future: Stakeholders, business environment and developments

5.1 Key stakeholders in Algeria, international collaboration partners and political & business environment

5.1.1 Algerian stakeholders in the areas of policy, research and industry

Based on the information examined in the frame of this mapping study, it appears that the development of green hydrogen in Algeria is at this stage coordinated by the following small team of key players:

- On the policy side these are the Ministry of Energy and Mines (MEM), the Ministry of Environment and Renewable Energies (MERE) and the Commissariat for Renewable Energy and Energy Efficiency (CEREFE).
- On the research side, the Renewable Energy Development Centre (CDER) is playing a central role.
- Another key player is Sonelgaz, the state-owned utility in charge of electricity and natural gas distribution.
- The central key player is Sonatrach, Algeria's state-owned, vertically integrated oil & gas company. It is active across almost the entire oil & gas value chain including ports and ships and 154 subsidiaries. With this, it is the largest company in Africa and among the biggest oil and gas companies worldwide. Sonatrach is in the lead for the development of the green hydrogen pilot projects (see section 5.2) in cooperation with the other key players.
- A national hydrogen committee has been established, comprising several sectors, including the Ministry of Energy and Mines (MEM), Sonatrach, Sonelgaz and its agencies, the Ministry of Environment and Renewable Energies, the Ministry of Industry, the Ministry of Higher Education, the Ministry of Interior and Local Governments, the Ministry of Finance, as well as the CEREFE Commission.

5.1.2 The pivotal role of Sonatrach

Sonatrach is not only the anchor point in terms of market development and business, but also plays an important role in R&D. The financial possibilities to shoulder significant investments and run complex projects are certainly a basis for this key role of Sonatrach.
On one hand, this simplifies the pathway for any interested player from outside Algeria to connect to the green hydrogen developments there. On the other hand it seems clear that there can be conflicting interests between the export of natural gas and its replacement by green hydrogen. It seems fair to state that as long as an entity with main interests in the fossil fuel sector is in the driver's seat for the development of green hydrogen, there is a risk that this development is compromised by these conflicting interests and/or delayed. Furthermore, it remains to be seen to which extent Algeria and Sonatrach are willing to collaborate with international players, especially domestically. The green hydrogen value chain is long including renewable energy production, hydrogen production, transport, storage and distribution – via intermediate products - towards off-takers and end-users and products. Numerous parts within this value chain require technology - such as solar panels, wind turbines, electrolyzes etc. – where international expertise is deemed to be valuable. International collaboration is an ambivalent topic in Algeria. On one hand it is experienced as a threat which will lower, e.g., the high local content value in the energy sector that Algeria has today and aims to continue. On the other hand it is seen as a potential accelerator to produce the most cost-competitive green hydrogen or derivatives which is required to secure solid long-term international offtake agreements.

5.1.3 International collaborations and partners

Below a selection of notable international collaborations is given:

- There is an initiative by European TSO's for the realization of a major hydrogen gas pipeline of around 3 300 km length and a capacity of around 4 million tonnes of hydrogen per year connecting Algeria via Tunesia to Sicily and from there to Austria and Southern Germany (Biogradlija, 2023). The initiative named "South2 Corridor Project" is led by Snam S.p.A. (Italy) and includes Austria's Gasconnect-Austria and Trans Austria Gasleitung GmbH as well as Germany's Bayernets GmbH. The emphasis is on repurposing existing infrastructure, accounting for around 70% of the planned pipeline.
- There is substantial collaboration between the Algerian government and the German Gesellschaft für International Zusammenarbeit (GiZ). GiZ published an exploratory study on the potential of green hydrogen and power-to-X technologies in 2021 (Drenkard & Mirakyan, 2021) which also served as a basis for the Algerian hydrogen development strategy.
- Algeria further collaborates intensely with the Italian oil and gas multinational Eni which comprises – next to further developments in the area of fossil fuels – also hydrogen projects, e.g. in relation to pipeline transport (Eni, 2022). Another strategic collaboration exists with the US corporation General Electric in the area of gas turbines, i.e., how to adapt those turbines so that they can be operated with mixtures of natural gas and hydrogen or, ultimately, with pure hydrogen (see also sections 5.2 and 6).
- More plans for collaboration between Algeria and international players in the area of green hydrogen are in an early planning phase, among others with the Port of Amsterdam for import/export with a particular focus on shipping hydrogen as liquid organic hydrogen carriers (LOHCs).

5.1.4 Political & business environment in the energy sector

Algeria has for a long time been characterized as an isolated, inscrutable country, but not anymore (Ferrand, 2002, Ghiles 2023). Over the last two years Algeria itself have opened up new prospects and triggered a flood of international interest. Current global geopolitical changes, e.g. the increasing economic interconnections and interdependencies via the process of globalization, have changed its sharply inward position and Algeria's energy sector plays an important role in this. Fossil fuel exports are the anchor of Algeria's economic model ensuring citizens' well-being, social stability and economic prosperity for a long time. National content and economic value in the fossil fuel sector is high and a source of national pride and independence. Therefore, the removal of the 51/49% rule, requiring Algerian majority shareholding; the new investment law; the Law on free zones and the amendment of the commercial code are a strong signal of Algeria to create a competitive and business-friendly climate to attract foreign investors in the energy sector (Baker McKenzie, 2022). Nonetheless, any new business, especially in the energy sector, is measured against the yardstick of independence (by the national government) and the ambition of Algeria to maintain a high level of national content and value is explicit and clear.

Recently, in the scramble for alternative energy sources triggered among others by Russia's invasion of Ukraine, international interest in Algeria's enormous potentials in the context of energy is sharply increasing (Farrand, 2022 b). On the short-term this quest and interest of Europe is focused on natural gas. The longer-term interest of Europe is focused on sustainable energy such as green hydrogen in line with Europe's climate and energy ambitions like the Green Deal. Today, multiple countries are positioning themselves as the reliable future energy partner of the EU that can accommodate this upcoming demand from the world largest trading bloc Europe. Algeria is well positioned to remain one of these partners if it is able to transition as well and keep incorporating a perspective for the country itself.

5.2 Pilot projects

Three pilot projects in the area of green hydrogen are currently under development in Algeria. Sonatrach is in the lead of all three projects. Electricity for electrolyzers is sourced from a combination of photovoltaic and wind power installations with capacities in the range of up to 10 MW. The projects feature electrolyzers on the multi-MW scale. At least one project includes storage technologies, i.e., batteries for electricity and salt caverns for hydrogen. Below some more information about goals and configurations is given per pilot project:

The first one will focus on the hydrogen production chain and blending hydrogen in natural gas pipelines and in a gas turbine. The plans consist of a 1-2 MW electrolyzer, 2-4 MW solar PV, 1-2 MW wind energy and both batteries for electricity storage and hydrogen storage. The pilot is in the site selection phase and will next go into the feasibility study and the design phase of the pilot.

The second pilot is a collaboration with Eni at an existing oil and gas field in Bir Rebaa North, where there is also an existing 10 MW PV plant. For this pilot also a 1-2 MW electrolyzer is

envisioned. The existing solar capacity can be increased with another 10 MW as part of the pilot. The project is currently in the feasibility stage.

The third pilot is a larger project with a 50 MW electrolyzer. A challenge in the development area are the space constraints for the development of solar PV and wind energy projects. The goal of this pilot is to blend the hydrogen in existing ammonia production in the Western zone of the country. The production of liquid organic hydrogen carriers (LOHCs) is also considered in this area. The development of the pilot is at an early stage with Sonatrach aiming to start the feasibility study in 2024.

A common denominator of all three pilot projects is the goal of Algeria for skills development across a broad range of relevant green hydrogen technologies. A noteworthy fact in this context is the ambition of Algeria for a high level of domestic involvement throughout the entire green hydrogen value chain. The rationale behind this is to maximize domestic employment and economic value creation.

5.3 Potential areas of collaboration

Based on the plans for pilot projects that were discussed with Sonatrach we identify 6 research topics that will serve as a basis for the potential areas of collaboration in the next chapter:

1. Hydrogen blending in natural gas pipelines
2. Hydrogen shipping
3. Market development (including the use of green hydrogen for fertilizer production)
4. Hydrogen blending in natural gas turbines
5. Overall design of pilot projects
6. Technical and safety certification of equipment

Hydrogen blending in natural gas pipelines, with 100% hydrogen as ultimate target, is an important focus in Algeria to explore the possibilities for repurposing natural gas pipelines for domestic use and for exporting hydrogen.

With the long-term goal of Algeria to become a large hydrogen exporter, pipeline transport alone might not be sufficient. Hence, Algeria will also be exploring the options and associated challenges and opportunities to ship hydrogen. As ammonia is already produced in Algeria and since there is already an international (shipping) market for ammonia, we expect that the main research and development interests will be on the less mature shipping forms of LOHCs and liquid hydrogen.

During the study some Algerian parties expressed concern about the international market development for green hydrogen. The implementation of CBAM is expected to have a stimulating impact in this respect. In order to realize the goal of becoming a large hydrogen exporter, the formation of sufficient demand for green hydrogen is a point of attention. We see both the creation of a local market for green hydrogen and understanding the market development in neighboring Europe as interesting areas for further exploration.

The application of green hydrogen in gas turbines by blending with, and ultimately completely replacing natural gas, is driven by the significant number of relatively new gas turbines currently operational in Algeria and the intention to keep operating these turbines until the end of their service life.

Since all three projects feature on-site electrolyzers operated with electricity generated by solar panels and/or wind turbines, fluctuating electricity profiles are a configurational feature on the electricity input side for the electrolyzers (unlike when operating the electrolyzers with electricity from the grid). For that reason the choice of the best suited electrolyzer technology is of significant interest to all pilot projects. The available options are alkaline (1), proton exchange membrane (2) or solid oxide (3) electrolyzers. Among those, alkaline electrolyzers currently have the highest technology readiness level (TRL) and lowest cost. However, proton exchange membrane electrolyzers have been reported to be potentially better suited for fluctuating electricity input. Dutch expertise for the identification of the best match of electrolyzer technology and pilot project can speed up project development. Lastly, also the certification of equipment is important, particularly when it comes to safety.

6 Development perspectives by collaboration with Dutch parties to overcome challenges

The pilot projects are a good basis for the identification of development areas with potential for collaboration between Algeria and The Netherlands. The collaboration can be related to expertise in areas such as technology, regulation or skills development, for example. The discussions in Algiers revealed that there is a significant number of valuable collaboration perspectives with issues related to pipeline transport being on top of the priority list. A list of collaboration areas resulting from the discussions in Algiers is given below:

Repurposing of pipelines to make them suitable for transporting mixtures of natural gas and hydrogen and, ultimately, pure hydrogen is of high interest to Algeria. A gas pipeline test center is being set up in Algeria (600 km south of Algiers). The Netherlands has expertise and practical experience in this area which is therefore a good area for collaborations. A repurposed natural gas pipeline between two industrial sites has been operational since 2018 (Gasunie, 2018). It is estimated that about 85% of the 1.400 km Dutch national hydrogen network (backbone) will consist of repurposed natural pipelines (Gasunie, 2023). It is expected that the natural gas pipelines can be repurposed, but there are some areas of attention: leakage (mainly at valves), contaminations, lower energy density of hydrogen, defect growth due to pressure fluctuations and ignition risks (Strategy&, 2021). Solutions to address these areas of concern, such as replacing valves and metering equipment, cleaning existing pipelines, replacing compressors, checking operational conditions and training technicians for hydrogen handling, are being explored by Gasunie and partners for the construction of the Hydrogen Network Netherlands.

Together with Germany, far-reaching plans have been developed with the aim of producing green hydrogen offshore and transporting it to major industrial clusters, such as the Ruhr area. There are also plans to capture CO2 from the industrial sites there, transport it to Rotterdam and then store it in empty gas fields under the North Sea. Many existing pipelines are suitable or can be adapted for this purpose, while some new infrastructure will be required. (TNO, 2023). Growing attention to the role of hydrogen as GHG, means that emissions of hydrogen will need to be monitored and controlled.

Examples of public research projects & initiatives:

- North Sea Energy Program: North Sea Energy is a public-private research programme, which benefits from the cooperation of more than 30 international parties from the energy value chain. These parties are active in and around the North Sea. The programme was launched in 2017 and investigates the North Sea’ s potential for an

integrated energy system. The reuse of empty gas fields, infrastructures and platforms is an area on which considerable attention is being focused in this program.

- PostHydon: On a Neptune Energy platform, which was used for many years to extract gas from the North Sea, experiments are being carried out to produce green hydrogen using wind power. The wind energy is transmitted via a power cable to the platform, where desalinated seawater is split into hydrogen and oxygen using an electrolyser. The hydrogen is then carried to land via an existing pipeline. Fourteen parties are working together on this project, the world's first demonstration of offshore green hydrogen production from renewable energy. (TNO, 2023)
- HY3 Decarbonizing the Dutch and German Industry through Hydrogen: HY3 is a collaboration between German and Dutch research institutes that execute the project: Forschungszentrum Jülich, DENA and TNO and supported by an industry partner group. The collaboration envisages using an adapted pipeline network, around 5,000 kilometres in length, to transport the hydrogen produced using wind power in the German and Dutch parts of the North Sea to industrial clusters in both countries and to store some of this hydrogen. Dozens of empty salt caverns on land can be adapted to make them suitable for such storage. TNO has demonstrated that this can be done safely. https://hy3.eu/
- TNO is conducting research and testing for various asset owners in Europe on reuse of gaspipelines. These projects are not public.

Key players in the Netherlands include (but not limited to): Gasunie, KIWA, Bilfinger Tebodin, AVIV, DNV GL, PwC, TNO.

Hydrogen (carrier) shipping is a focus point next to the transport of hydrogen through pipelines, particularly after 2030 when Algeria is aiming at becoming a large exporter of hydrogen. Hydrogen can be shipped attached to a carrier (LOHC), 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. Algeria, and particularly Sonatrach, has much experience with shipping LNG, LPG, crude oil and petroleum 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). The Port of Amsterdam has signed a MoU for the development of hydrogen value chains together with Algerian, Dutch and German stakeholders, i.e., Sonatrach (Algeria), HyCC (NL), Zenith Energy (NL), Hydrogenius (Germany), GiZ (Germany). 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 not limited to): Port of Rotterdam, Port of Amsterdam, Groningen Seaports, Royal Vopak.

Market development, especially off-take: as noted in section 2.5 the cost of green hydrogen today is still much higher than that of natural gas and the 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 (see section 2.4). Domestic demand in Algeria from the ammonia and fertilizer industry represents additional perspectives for offtake markets. Current developments are struggling with the so-called "chicken and egg" dilemma with regard to green hydrogen supply and actual demand by off-takers. Various initiatives such as H2Global are now being developed trying to solve this. Algerian players made clear to the authors that solid off-taker agreements and actual interest from EU off-takers in green hydrogen is crucial to them with to take serious

steps. Thus Algerian and EU or Dutch collaboration in the area of market development will serve the interests of both producers and users.
Key players in the Netherlands include (but not limited to): Berenschot, CE Delft, Guidehouse, PwC, TNO, TwynstraGudde, Witteveen+Bos.

Overall design of pilot projects (innovative configurations): as noted in section 4.1, there are three significant green hydrogen pilot projects under development in Algeria. Innovative configurations are being explored and Dutch expertise across the entire green hydrogen value chains relevant to these configurations can be beneficial. Collaboration opportunities come mainly in the form of shared research programs and involving Dutch companies in the design, engineering and operations of pilot projects. Areas of Dutch expertise include e.g.:

- Choice of electrolyzer technology
- Challenge for the operation of electrolyzers as well as wind turbines and PV plants in desert locations (Sahara)
- O&M aspects
- Salt cavern hydrogen storage
- Integration of green hydrogen in ammonia and fertilizer production

Developments in the Netherlands (not exhaustive):

- A one 1 MW PEM electrolyser has been running for 2 years at ITM and Gasunie (ITM Power, 2021).
- Shell has taken FID for a 200 MW PEM electrolyser in the Port of Rotterdam. It is expected to be operational in 2025 and will be Europe's largest renewable hydrogen plant (Shell, 2022).
- A 2.6 MW electrolyser is in commissioning stage at Neste's renewable products refinery in Rotterdam. This is a alkaline electrolyser coupled to 50 MW solar park (EnergyTech, 2023).
- TNO has 1 MW electrolyser on land that will go offshore next year in the PosHYdon[4] project to be coupled with offshore windfarms (TNO, 2023)
- TNO has a 250 kW PEM electrolyser and a 250 kW alkaline electrolyser in Groningen[5]. These are for R&D purposes and not running long duration tests.
- Pilot project Synnewetterstof investigates the potential of hydrogen production to alleviate congestion in the electricity net associated with, e.g., from solar energy peak periods.

  Key players in the Netherlands include (but not limited to): TNO, TKI New Gas, ABB, Air Products Netherlands B.V., ISPT, HYGRO, Royal HaskoningDHV, Shell, Siemens Energy B.V., OCI Nitrogen, Yara Sluiskil B.V.

Technical and safety certification of equipment: due to the early development stage, especially of more innovative hydrogen technologies, collaboration in the area of equipment certification in terms of technical functionality as well as safety is deemed to be fruitful.

There are a number of research programs that have been conducted or are running in the Netherlands momentarily. A few examples are (non-exhaustive list):

- The Waterstof Veiligheid Innovatieprogramma (Hydrogen safety innovation program) (RVO, 2019) (Topsector Energie, 2020). A large consortium of over 30 companies, knowledge institutes, public organizations and government agencies were involved in

[4] Poshydon | Green Hydrogen Energy
[5] Research centre CO2-free hydrogen production | TNO

the program. The program looked at permitting, safety and risks, risk management, incident management and regulation and policy.

- Large scale green hydrogen inherent safety practices (ISPT, 2022). A project aimed at deepening the understanding of potential risks of large-scale electrolysis and how to identify cost-effective safety measures. The project consortium consisted of ISPT, HyCC, Ørsted, Shell, Yara, DNV, RHDHV and TNO.
- The Hydelta project[6] research program contains a work package focused on hydrogen safety. The project has published multiple reports on hydrogen technology and safety. The consortium includes TKI Nieuw Gas, Gasunie, Netbeheer Nederland, New Energy Coalition, TNO, DNV, KIWA and Hanzehogeschool Groningen.

Key players in the Netherlands include (but not limited to): TNO, TKI Nieuw Gas, DNV, Gasunie, Royal HaskoningDHV, KIWA, Witteveen+Bos.

Application of (green) hydrogen in natural gas turbines: due to the relatively large number of new natural gas turbines in Algeria, there is an intention to make them fit for operation with mixtures of natural gas and hydrogen, and ultimately pure hydrogen. In the Netherlands, natural gas blending is not being considered as a dedicated hydrogen pipeline network is being developed. Using blended hydrogen in gas turbines is therefore also not a topic receiving much attention. However, there is significant experience with the design of gas turbines and this experience can serve as a basis for collaboration on the application of green hydrogen in gas turbines. Repurposing existing gas turbines for the use of 100% hydrogen is receiving more attention recently as the Netherlands is starting to think about how to achieve a CO_2-free electricity system by 2035 or 2040 (Rooijers, Jongsma, & Voulis, 2022) (de Wildt, Hers, & Sijm, 2023). Gas turbines operating on 100% hydrogen are not expected to be available by 2030 (Rooijers, Jongsma, & Voulis, 2022), but it is expected that the topic will receive more attention in the Netherlands in the next few years.
Key players in the Netherlands include (but not limited to): AECOM, Ansaldo Thomassen BV, TU Delft.

In particular for the repurposing of natural gas pipelines, the Netherlands is a frontrunner. Similarly, in the area of salt cavern storage the Dutch expertise is internationally highly competitive. In the other 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 (see next section).

Mission H2 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 (Hydrogen and ICEP: Exploration Stage (rvo.nl) ; International hydrogen guide presented to minister Schreinemacher (rvo.nl)).

[6] https://hydelta.nl/

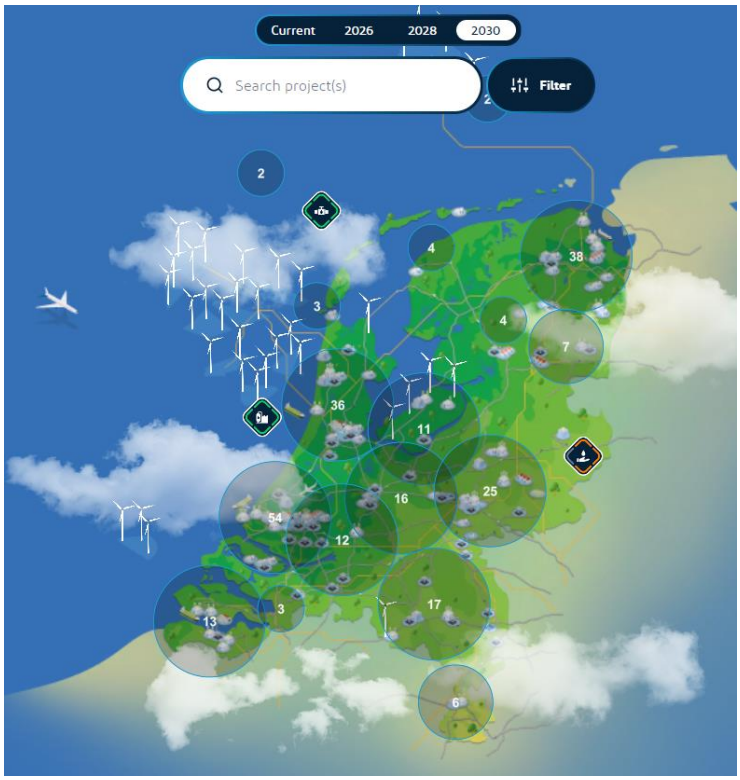

Figure 6.1: Screenshot of interactive map with an overview of initiatives related to hydrogen in the Netherlands. Source: https://www.missieh2.nl/en/

7 Conclusions & recommendations

This report documents the insights of a mapping study regarding the green hydrogen developments in Algeria. The goal was to identify mutually beneficial collaboration opportunities between Algeria and The Netherlands as well as Algerian key players in this respect.

Both countries have a history of heavy reliance on natural gas in their energy and economic system. Therefore extensive infrastructure and expertise in the area of gaseous energy carriers is present which provides a good outlook for the transition to a green hydrogen sector. Currently the sector is still in its earliest infancy and there are roadmaps and pilot projects to steer the developments. The EU has set a target of importing 10 million tonnes of green hydrogen by 2030 which represents a first perspective of a sizeable export market for Algeria.

There is a limited number of key players driving the developments in Algeria at this stage. The figurehead among them is Sonatrach, the state-owned oil and gas corporation (which implies a risk of conflicting interests). The development of the green hydrogen sector in Algeria is further coordinated between the Ministry of Energy and Mines (MEM), the Ministry of Environment and Renewable Energies (MERE), the Commission for Renewable Energies and Energy Efficiency (CEREFE), the Renewable Energy Development Centre (CDER) and Sonelgaz, the national utility for electricity and natural gas distribution.

Essential in the current development of the green hydrogen sector in Algeria are three pilot projects exploring not only the production but also applications and transport of green hydrogen. These projects define a large range of potential areas for collaboration. Among those large interest was expressed for Dutch expertise in the area of repurposing natural gas pipelines for transporting hydrogen. Next to that there is a wide range of further collaboration areas, including market development, technical and safety certification of equipment, overall pilot project design and the application of hydrogen in natural gas turbines.

<u>As next steps, the following recommendations are suggested:</u>

- Organization of a workshop with Dutch players interested and knowledgeable in the six collaboration areas identified in this report (section 6). Goal of the workshop is to elaborate specific value propositions for collaboration. TNO has an excellent network in the Dutch green hydrogen sector and is therefore well positioned to organize and host such an event.
- Set up structural knowledge exchange between CDER and relevant Dutch knowledge organizations (CE Delft, TNO, …)
- Support Algerian policy makers with the organization of tenders for the expansion of renewable energy capacity (EZK)

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