



ANÁLISE DO POTENCIAL LOCAL DE PRODUÇÃO DE HIDROGÉNIO EM PORTUGAL E INJEÇÃO NA REDE DE GÁS

ANALYSIS OF THE LOCAL HYDROGEN PRODUCTION POTENTIAL IN PORTUGAL AND INJECTION IN THE GAS GRID

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RESUMO

Este estudo analisa o potencial de produção local de hidrogénio em Portugal continental, avaliando a disponibilidade e acessibilidade de recursos-chave, incluindo eletricidade renovável e água. A metodologia envolve a agregação e mapeamento de dados relacionados com a rede nacional de gás, incluindo o consumo por município e os principais pontos da rede, em conjunto com a geração de eletricidade renovável e a disponibilidade de água. O estudo identifica as áreas com maior adequação para a produção de hidrogénio junto a pontos de injeção na rede de gás. Os resultados mostram que a produção de eletricidade renovável em Portugal está principalmente concentrada no Sul, no caso da energia solar, no Norte para a energia hídrica, e no interior norte e centro no caso da energia eólica. Relativamente à energia eólica, Portugal conta atualmente com 6,2 GW de capacidade instalada em terra, com uma meta nacional de 12,4 GW até 2030. A energia eólica offshore continua limitada a 25 MW instalados, mas possui um potencial significativo, com um objetivo nacional de 2 GW até 2030. A análise da disponibilidade de água revela que as regiões norte e centro apresentam condições favoráveis à produção de hidrogénio devido a uma maior profundidade de escorrência anual e menor stress hídrico, conforme indicado pelo Índice de Exploração da Água (WEI). Por outro lado, a região sul enfrenta uma pressão hídrica significativa, algo que pode ser um fator limitante para a produção de hidrogénio verde. Ainda assim, a região Sul é a região com maior potencial para produção de energia solar. Esta análise espacial permite uma pré-avaliação da viabilidade prática da implementação de unidades de produção de hidrogénio em Portugal, contribuindo para o planeamento estratégico da integração de gases renováveis na rede nacional de gás.

Palavras-chave: Hidrogénio Renovável, Energia Solar, Energia Eólica, Disponibilidade de Água, Gás Natural

ABSTRACT

This study examines the potential for local hydrogen production in mainland Portugal by evaluating the availability and accessibility of key resources, including renewable electricity and water. The methodology involves the aggregation and mapping of data related to the national gas grid, including consumption by municipality and key network points, alongside renewable electricity generation and water availability. The study identifies areas with greater suitability for hydrogen production near injection points into the gas network. Results show that renewable electricity production in Portugal is mainly concentrated in the southern region for solar energy, the north for hydropower, and the north and central interior for wind energy. Regarding wind power, Portugal currently has 6.2 GW of installed onshore capacity, with a national target of 12.4 GW by 2030. Offshore wind is still limited to 25 MW installed but holds significant potential, with a national goal of 2 GW by 2030. The analysis of water availability reveals that the northern and central regions present favorable conditions for hydrogen production due to higher annual



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runoff water depth and lower hydric stress, as indicated by the Water Exploitation Index (WEI). Conversely, the southern region faces significant hydric pressure, limiting its suitability for large-scale hydrogen production. Still, the southern region has the most potential for solar energy production. This spatial analysis allows for a pre-assessment of the practical viability of deploying hydrogen production facilities in Portugal, contributing to strategic planning for integrating renewable gases into the national gas grid.

Keywords: Renewable Hydrogen, Solar Energy, Wind Energy, Water availability, Natural Gas

1 INTRODUCTION

The purpose of this work is to analyse the distribution and concentration of resources for hydrogen production in mainland Portugal and to cross-reference that information with areas of higher natural gas consumption and potential zones for the introduction of renewable gases into the network. It is known that the plans for Portugal's national gas network involve the gradual integration of renewable gases. The gas network is a valuable national asset. It may enable a gradual and realistic reduction in natural gas consumption, as well as the introduction of hydrogen and biomethane in quantities aligned with realistic and sustainable investment levels. The production of hydrogen depends on the availability and accessibility of certain resources. For example, renewable hydrogen is produced from water and renewable electricity. Therefore, analysing the availability and accessibility of these resources near the production site—which should be nearby to minimize infrastructure and transportation costs—is important. Additionally, the production site should be close to the injection point.

2 METHODOLOGY

The aggregation of data related to the gas network is performed, namely, natural gas consumption by municipality (DGEG, 2023), the georeferenced gas network, key points of the gas network, and the location of autonomous gas units, was carried out to create an overview of the gas infrastructure and its current use. Following this, an analysis was conducted to identify points of interest regarding renewable electricity production and areas with high potential water consumption for the production of renewable hydrogen. The results are presented in the form of maps, with all data aggregated. The data was aggregated and then fed to a dashboard created in Power BI to visualize the data in an integrated way. The ArcGIS Pro software was used to create maps to visualize the georeferenced data. The ArcGIS Pro maps were integrated into the Power BI dashboard, and the data is all interactive and integrated to generate all sorts of scenarios to analyse the penetration of renewable gases in the Portuguese gas grid.

Besides the data on natural gas consumption and the Portuguese gas grid, data on renewable energy power installed were also gathered, by municipality (DGEG, 2023). To analyse the viability of producing hydrogen, data on water availability were also studied.

3 RESULTS AND DISCUSSION

Figure 1 shows the current structure of the Portuguese transmission gas network, highlighting key points of interest, the locations of entities interested in injecting renewable gases into the network, as well as natural gas consumption by municipality and



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autonomous units of gas (UAG). In Figure 2, the installed capacity of renewable electricity production is shown, along with the sources that make up the total installed capacity.

The natural gas consumption is higher in the coastal region and, generally, near the gas network, where some urbanizations and industrial hubs are located. To identify the best regions to proceed with the installation of a hydrogen production facility, some factors need to be considered, such as land availability, water availability, renewable energy availability, proximity to the gas network, and proximity to demand.

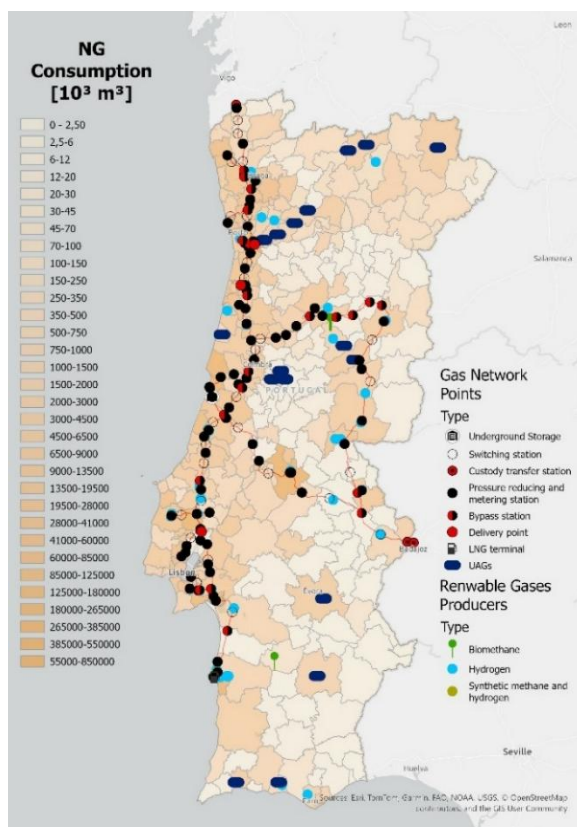


Figure 1 – Portuguese gas grid and natural gas consumption



Figure 2 – Renewable power installed in Portugal

The installed renewable electricity capacity in Portugal is distributed as follows:

- Higher concentration of solar in the lower half of the Portuguese territory (South and Alentejo), an area with higher global horizontal irradiance potential;
- Higher concentration of hydropower in the northern region, where there is also greater hydroelectric potential (areas with dense river basins and steep terrain);
- High wind energy (onshore) potential also in the northern area and the interior of the central region.



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The actual landscape of electric renewable energy installed in Portugal is what is described above and perceptible in Figure 2. Some key points should be noted, as the current structure and distribution of renewable energy installations across the country are continuously evolving. Solar energy, PV, as an example, is in a fast track growing across all the territory, not only the areas with major prevalence of Global Horizontal Irradiation (GHI), as can be seen in figure 3, but also in the centre and north of Portugal (reference). In Figure 3, it is possible to see why to a high prevalence of solar PV installation and investment in the south region of Portugal. The GHI has a higher incidence in the southern regions, and since Portugal is a country with a prevalent Mediterranean climate, the GHI has acceptable and interesting values in the northern regions too. There are currently around 6.2 GW of PV solar energy installed in the country, and according to the national plan for energy and climate (PNEC 2030), the target is to achieve 20.8 GW of solar power installed by 2030 (including already installed capacity for hydrogen production) (Portugal, 2024). Assuming a scenario with 20% of hydrogen injected in the gas grid and considering a natural gas consumption identical to the year of 2023, it would be needed 2.8 GW of PV solar power installed solely to produce the required electricity to meet the demand for hydrogen. This prediction assuming the average 19% solar capacity factor of Portugal.



Figure 3 – Global Horizontal Irradiance [kWh/m^2] in Portugal (SOLARGIS, 2021).

Regarding wind energy, there is, at the moment, 6 GW of wind power installed (APREN, 2025), and there is the pretension, according to the national plan for energy and climate (PNEC 2030), to achieve 12.4 GW of wind power installed by 2030 (Portugal, 2024). According to the Portuguese plan, it is expected that onshore wind power will continue to grow consistently, but with a slightly lower rate due to the limited opportunities for growth by exploring new locations. The growth will be linked with the hybridization of wind farms (integrating PV solar energy) and investment in more powerful equipment in locations where the equipment is older or not optimized to its full potential capacity. In Figure 4, it is possible to see the locations in



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Portugal where the wind intensity is higher, like the interior northern region, often associated with places with higher orography. In Figure 5, it is possible to see all the locations of wind farms placed in Portugal. The places and zones of higher potential are already well exploited, so the opportunities to develop and install new wind farms in Portugal are now limited. A solution deeply studied and discussed in recent years is the investment in offshore wind farm technology. The technology is costlier than onshore technology, and it is important to note that the fact that the Atlantic Ocean is deeply profound around the Portuguese Coastal area is a characteristic that implies that the technology and investment are even higher since the wind turbine will not be place in the ocean ground, but in buoyant platforms (which increase the price of investment). In Figure 6, there is a map of Portugal's wind intensity around its coast. It can be viewed as a map of potential for the offshore wind implementation. There is a lot of potential in almost all the areas covered by the coast, but with emphasis on the north and centre regions. There are already 25 MW of offshore wind turbines installed in Portugal, but still way below the 2030 target defined by the national plan for energy and climate of 2 GW.

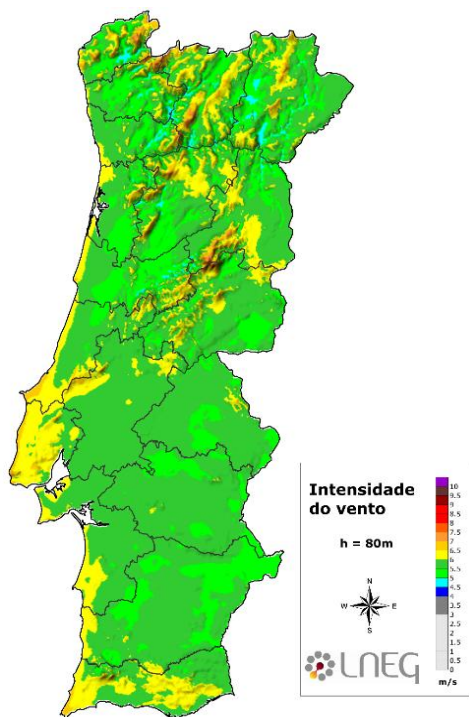


Figure 4 – Wind intensity in Portugal (LNEG, 2019).

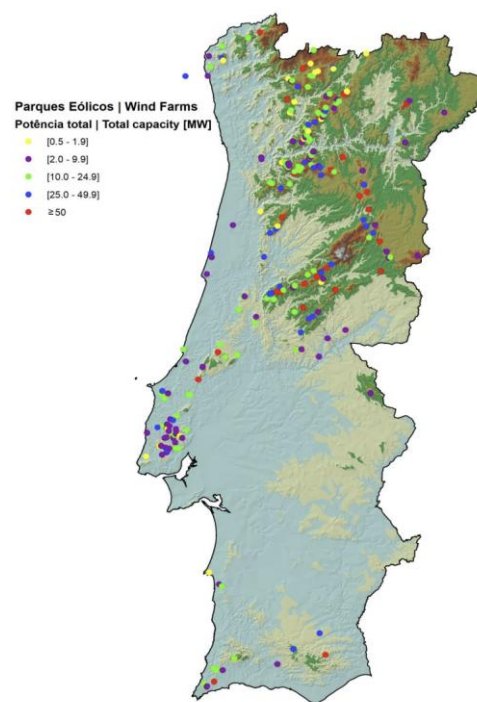


Figure 5 – Wind Farms, Portugal (LNEG, 2019).



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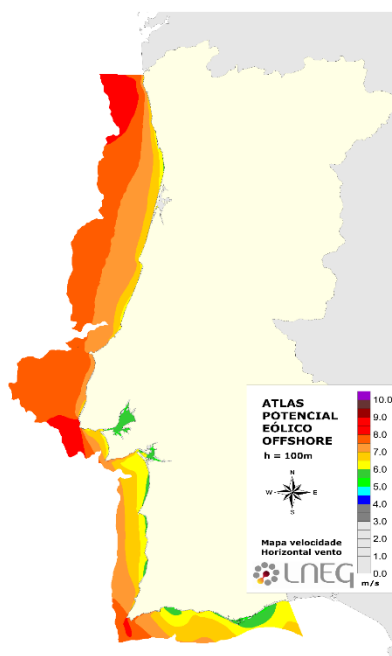


Figure 6 – Offshore wind intensity in Portugal (LNEG,2019).

Reviewed the accessibility and availability of renewable energy. It is important to access what is the water availability across the Portuguese territory to be part of the altogether major and macro view of the pre-assessment of the availability of all the resources needed to produce renewable hydrogen.

In addition to the availability of electricity, water is also a critical factor when considering production via water electrolysis. Even though hydrogen production projects prioritize the use of wastewater, water availability must be assessed from an integrated perspective. Observing Figure 7, it is possible to visualize the annual runoff water depth (in mm) across Portugal's continental territory. Regions with average values superior to 500 mm can be regarded as humid regions with high availability of water, which is the case in many regions in North and Central Portugal. The South region looks depleted when concerning to this parameter, with limited runoff values associated with lower pluviosity and drier climate.

Another interesting parameter to analyse water availability is the water exploitation index (WEI), which measures the pressure on the hydric resources of a determined region and is measured by the total water captured in a location divided by the water available. Values of WEI below 20% reveal a sustainable use of water, values until 40% indicate a moderate hydric pressure in the location, and values above that value are already represent a hydric stress situation. In Figure 8, there is a representation of WEI across Portuguese continental territory. The indicator was measured as an average of 25 years of monitoring data and shows that the majority of the Portuguese territory is under moderate hydric pressure, so there is a sustainable situation of usage going on. The same cannot be said about the southern region, which is under great hydric stress.

This water availability study shows that the north and centre regions of the country would only be slightly affected by the presence of a hydrogen production plant, since the water availability is reasonable. The same cannot be said about the southern region of Portugal, which is currently being targeted by several plans to reduce the hydric pressure over the region.



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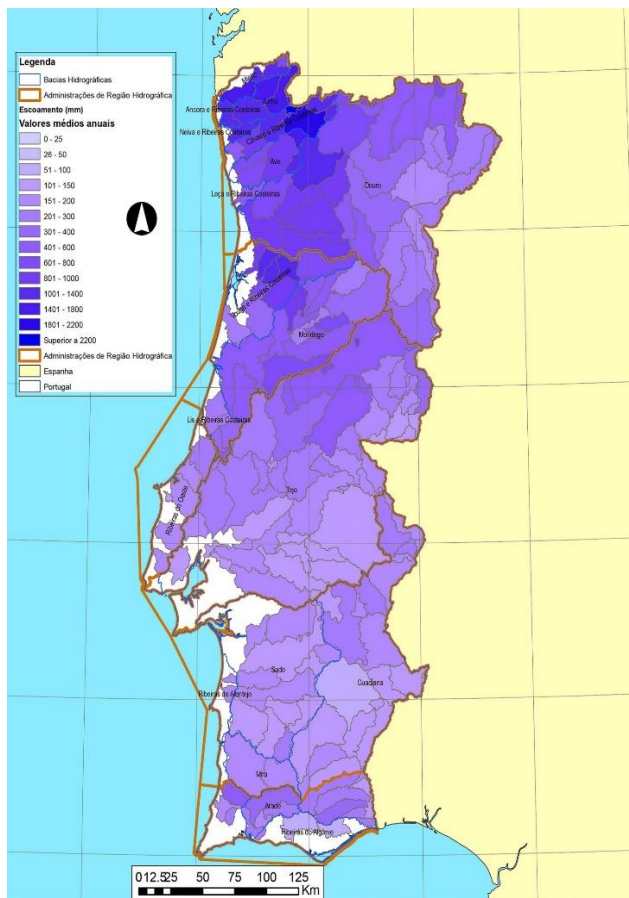


Figure 7 – Annual runoff depth (mm) (SNIRH,2017).

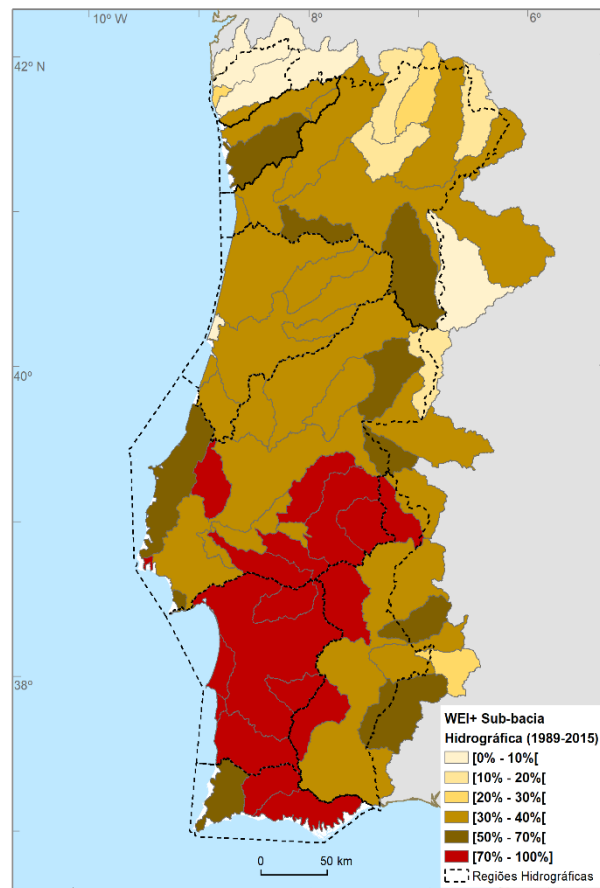


Figure 8 – Water exploitation index (WEI) (APA,2024).

4 CONCLUSIONS

The conducted analysis highlights that the northern and central regions of mainland Portugal present the most favourable conditions for local hydrogen production, due to both higher availability of renewable electricity and greater water resources. Solar energy remains predominant in the southern regions, yet its increasing expansion in the central and northern areas improves the feasibility of hydrogen production outside traditionally solar-intensive zones. Regarding wind energy, both onshore and offshore resources provide significant potential to meet national targets established in the PNEC 2030, although further investment and infrastructure development are required to accelerate offshore implementation.

Water availability emerges as a critical factor for hydrogen production. Runoff water depth analysis and the Water Exploitation Index (WEI) indicate sustainable water use in the northern and central regions, contrasting with the southern region, which faces significant hydric stress. Consequently, the establishment of large-scale hydrogen production facilities in the south could exacerbate existing water scarcity challenges.



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Overall, the cross-analysis of resource availability with gas network infrastructure enables the identification of optimal zones for hydrogen production and injection into the national gas grid. These insights contribute to more efficient planning and investment decisions, supporting Portugal's strategic goals for decarbonization and energy transition through the integration of renewable gases.

REFERENCES

- APA. Escassez de água. Disponível em: <https://rea.apambiente.pt/content/escassez-de-%C3%A1gua>. Acesso em: 15 de Jul. 2025.
- APREN. Evolução da Potência Instalada em Portugal Continental. Disponível em: <https://www.apren.pt/pt/energias-renovaveis/potencia>. Acesso em: 15 Jul. 2025
- LNEG. Energia Eólica. Disponível em: <https://www.lneg.pt/service/consultoria-estudos-e-pareceres/energia-eolica/>. Acesso em 15 Jul. 2025.
- Portugal. Plano Nacional Para a Energia e Clima 2030 (PNEC 2030). Disponível em: https://www.dgeg.gov.pt/media/vqkdv3ms/20241118_pnec2030_para_aprov_ar.pdf. Acesso em: 15 Jul. 2025.
- SNIRH. Boletim de Escoamento. Disponível em: <https://snirh.apambiente.pt/index.php?idMain=1&idItem=1.2>. Acesso em: 15 Jul. 2025.
- SOLARGIS. Solar resource maps of Portugal. Disponível em: <https://solargis.com/resources/free-maps-and-gis-data?locality=portugal>. Acesso em: 15 Jul. 2025.