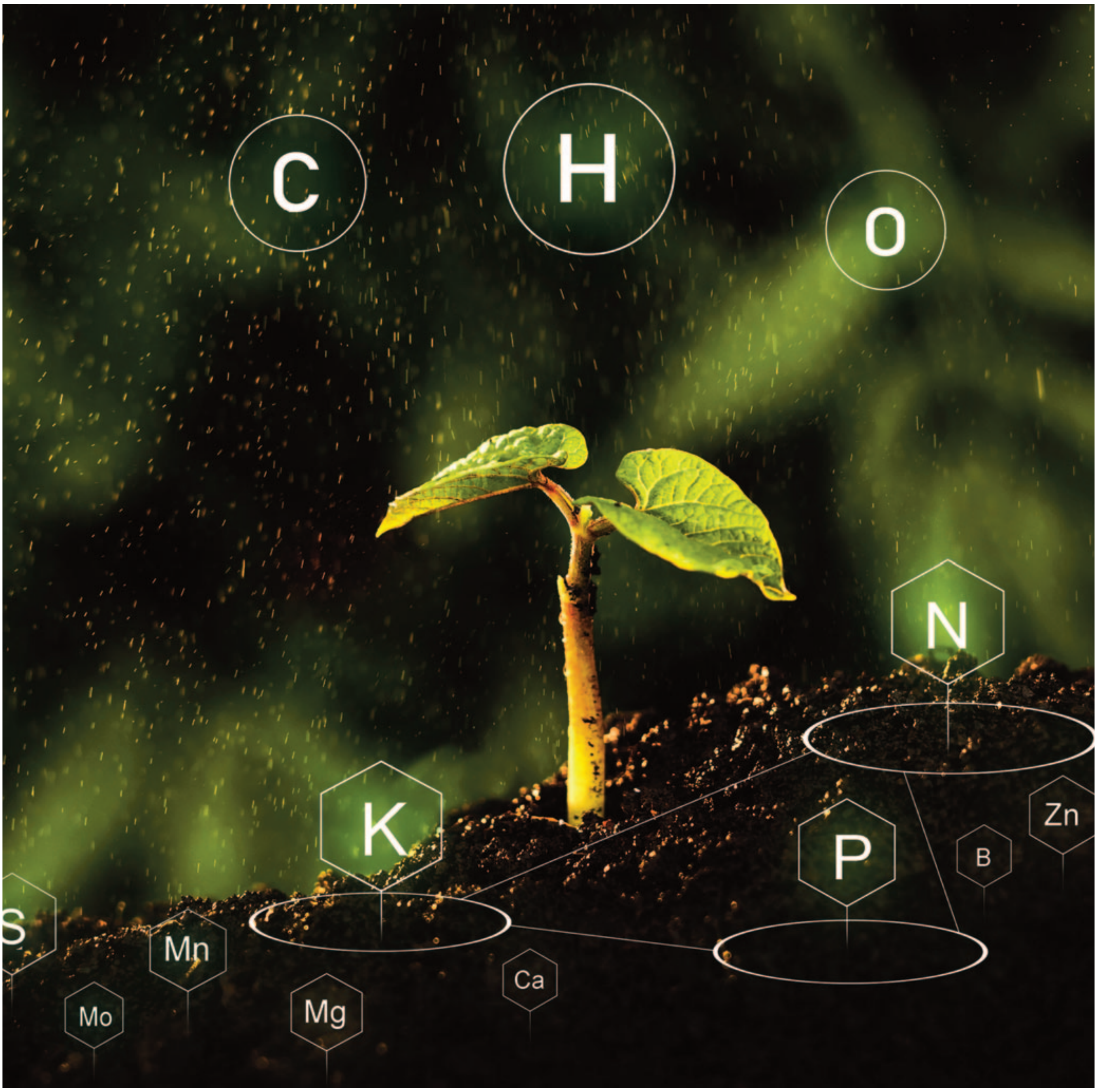
Applied analytics for hydrogen feasibility: use case

"What you can measure, you can manage"
Peter Drucker[65]



Use case: optimal site selection for hydrogen projects

This section presents a Use case focusing on the identification and selection of optimal hydrogen project locations. Implementing this model would enable hydrogen market players to accurately assess the advantages and disadvantages of different renewable hydrogen production sites, thus facilitating more informed and robust decision making.

Model introduction

The Chair of Hydrogen Studies at Comillas Pontifical University (ICAI-ICADE), of which Management Solutions is a trustee, has developed an application based on GIS tools[66] (Geographic Information Systems) that allows the optimal location of sites for the construction of renewable hydrogen projects to be identified according to different criteria.

The application makes it possible to calculate a H2 compatibility index to assess the suitability of the sites. The following use case has been developed for Spain, but the technology is applicable to any region, subject, of course, to the availability of the necessary information or, in the absence of it, to the necessary adaptation of the variables to be evaluated.

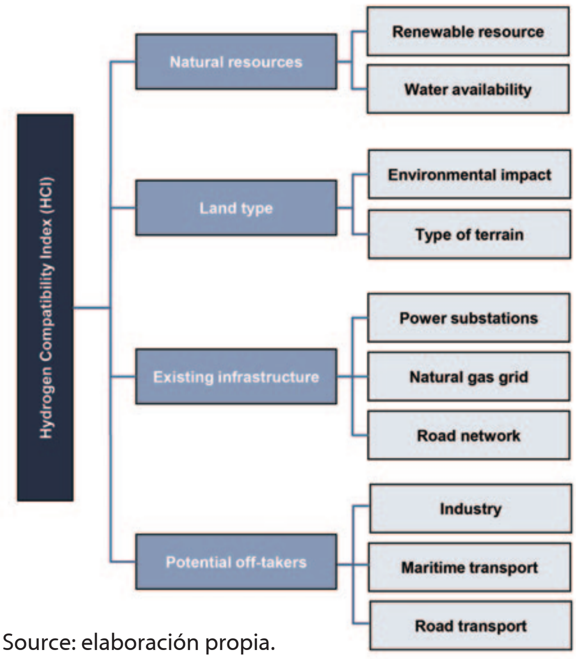
First, the map of Spain was divided into 2x2 km2 squares (although the size could be adjusted depending on the area studied) , and the model generated was used to evaluate hydrogen production compatibility for each of them.

The proposed model would allow hydrogen market participants to identify the strengths and weaknesses of potential locations for renewable hydrogen production, leading to better decision making. In addition, this model could help to answer some questions, such as:

- How do different locations compare in terms of their suitability for renewable hydrogen production?
- What are the most promising locations for green hydrogen production?
- Where are future off-takers expected to be located and what is their potential demand?
- How can the best locations be chosen to avoid conflicts in water use, land use or environmental impact?
- Where can a renewable hydrogen plant be built to maximize efficiency and profitability?
- What is the potential for renewable hydrogen production in different areas?
- How can the costs of transporting green hydrogen from the plant to the points of use be minimized?

[65] Peter Drucker, Known as the father of modern management, Peter Drucker is recognized for his contributions to the field of business management.
[66] Geographic Information Systems

Figure 23. Model variables



Source: elaboración propia.

Model explanation

The model developed to calculate the optimal location for the construction of a hydrogen project is based on the study of a set of variables.

The following is an analysis and development of how these variables are applied as inputs in the model.

Natural resources

Availability of solar and wind energy

The model evaluates H2 production alternatives using solar or wind energy sources according to the capacity factor[67] of each renewable source. Depending on the geographical area, this capacity factor will vary. A higher capacity factor implies a higher potential utilization of the electrolyzer and therefore a higher capacity for hydrogen production by electrolysis.

Because it is sometimes difficult to compare two locations on the basis of capacity factors alone, these can be converted to levelized cost of hydrogen (LCOH). The LCOH is the estimated cost per kg of hydrogen taking into account the investment costs (CAPEX) and hydrogen production, related to the operating hours and therefore the capacity factor.

The lower the LCOH, the cheaper it will be to produce hydrogen at the site studied. In addition, the LCOH allows direct comparison between wind and solar energy for hydrogen production.

Water availability

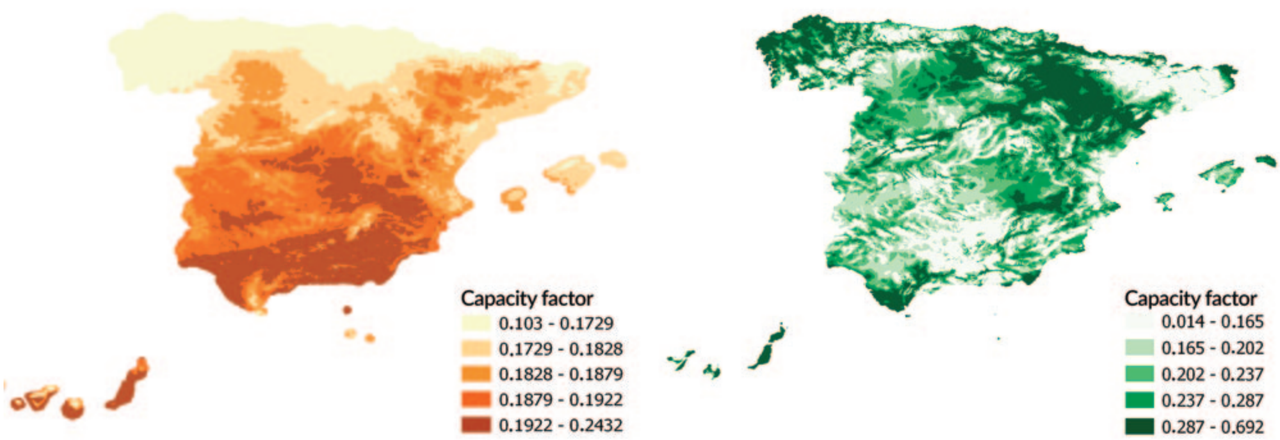
Similarly, water availability is a key feedstock for renewable hydrogen production. In this case, information on surface water availability (Figure 26, left graph) and WWTP locations (wastewater treatment plants; Figure 26, right graph) has been used, but other developer preferences such as distance to water sources or type of water could also be included.

Nature of the land:

Environmental Sensitivity Index (ESI). This index measures the environmental impact of building a renewable energy plant in a given location based on various factors that influence environmental vulnerability such as soil quality or the presence of protected natural areas, among others. The index classifies the territory into five categories of environmental sensitivity (Maximum, Very High, High, Moderate and Low), and locations with maximum sensitivity are excluded from the model.

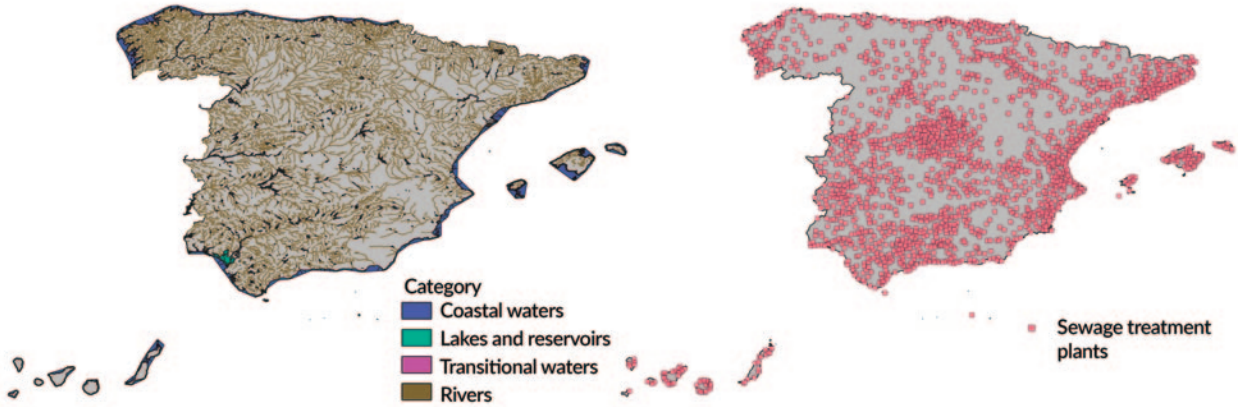
[67] Capacity factor: Measures the frequency with which a plant operates at maximum power. A plant with a capacity factor of 100% produces power all the time.

Figure 24. Solar and wind capacity factor in Spain in 2021.



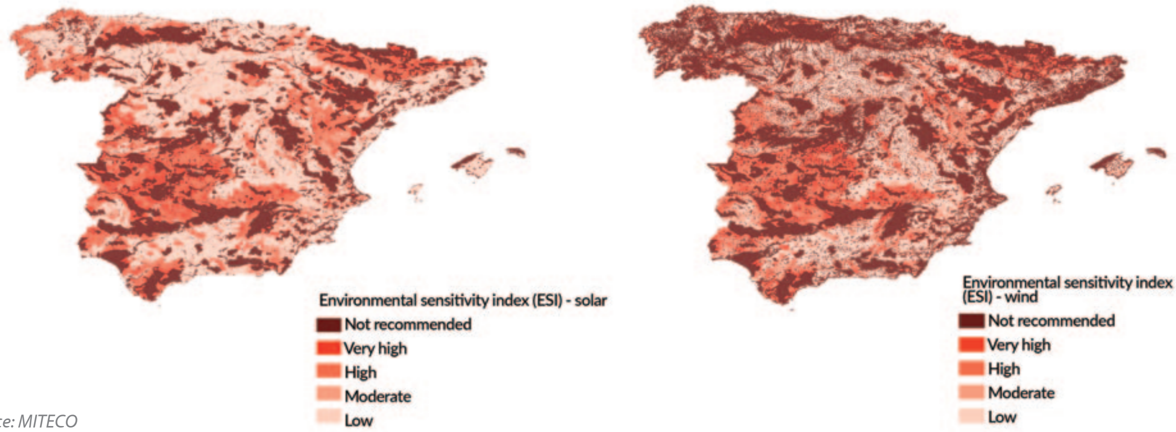
Source: Global Solar Atlas and Global Wind Atlas

Figure 25. Distance to different water supplies in Spain.



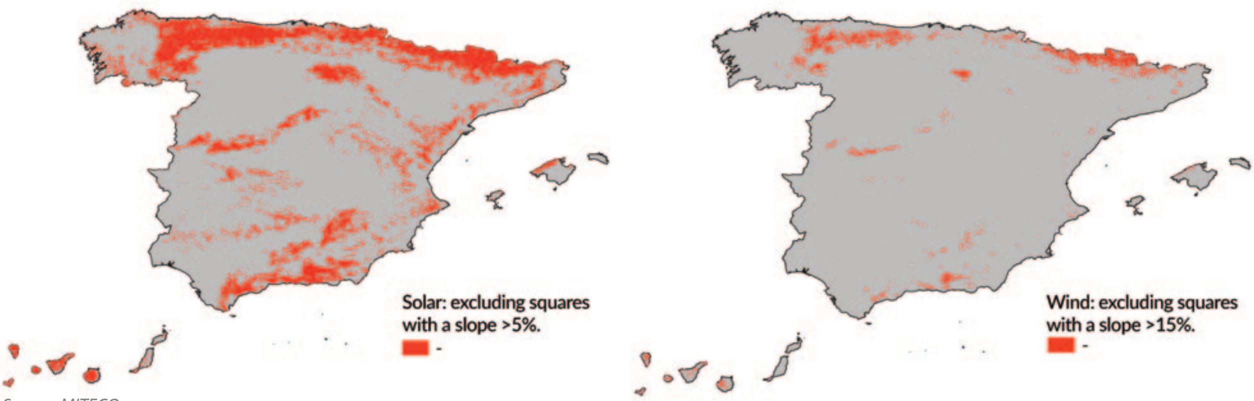
Source: MITECO

Figure 26. Environmental sensitivity index (ESI) in Spain.



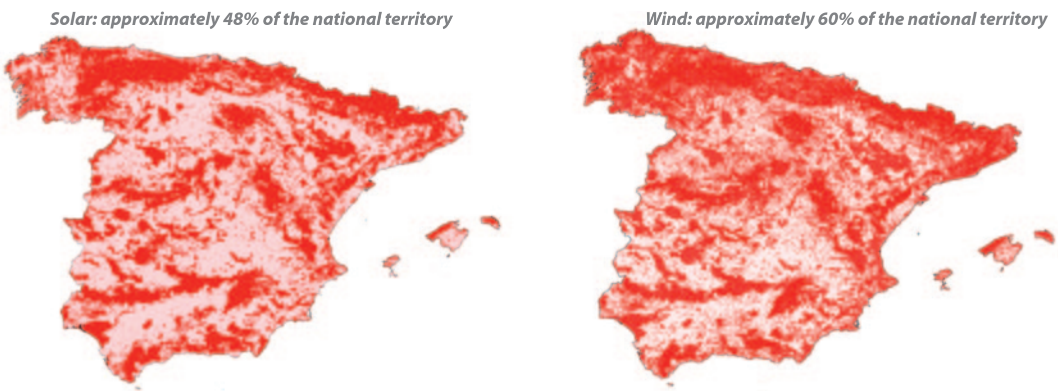
Source: MITECO

Figura 27. Excluded sites based on their slope.



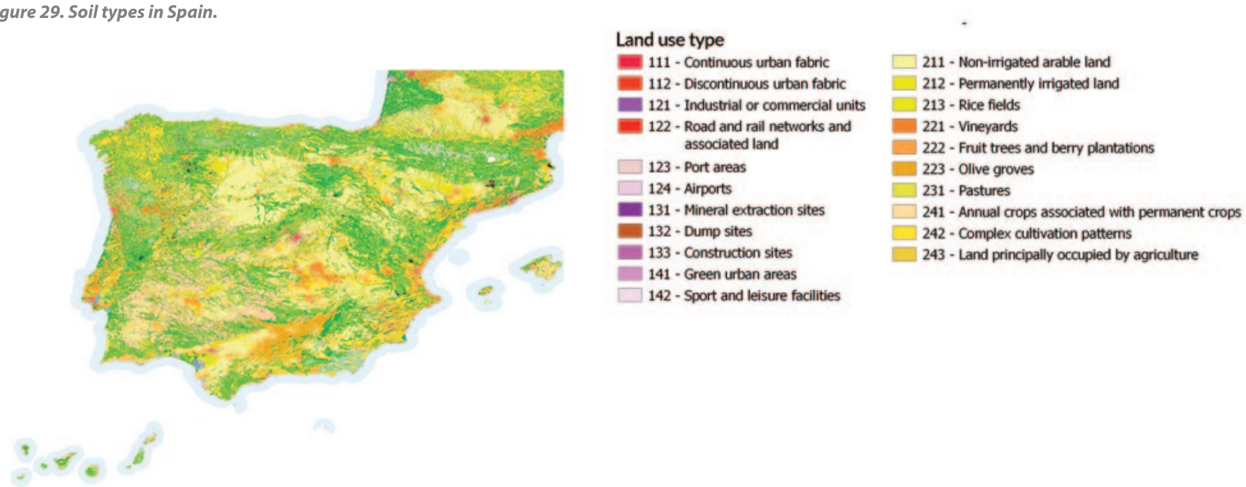
Source: MITECO

Figure 28. Land suitability in Spain.



Source: MITECO

Figure 29. Soil types in Spain.



Source: Copernicus program.

This factor is relevant for hydrogen production plants with dedicated renewable sources, as the environmental impact study is one of the most complex administrative processes for this type of project. Although the model does not exempt from the relevant environmental assessment procedure, it does allow for an indicative approach from the early stages of the project.

Slope of the site. Based on existing scientific literature, sites above a certain slope (greater than 5% for the construction ofsolar plants and 15% for wind plants) are excluded.

Land suitability. Combining the sites excluded because of their ISA with those excluded because of their slope, about 48% of the grid squares would be excluded for hydrogen production from dedicated renewable energy and about 60% for wind energy production. These figures reflect the areas that would not be suitable for installing dedicated renewable hydrogen production facilities due to environmental and topographical constraints.

Land type. For each of the grids, the type of land is characterized according to its use (dry land, irrigated land, natural grasslands, meadows, urban centers, etc.).

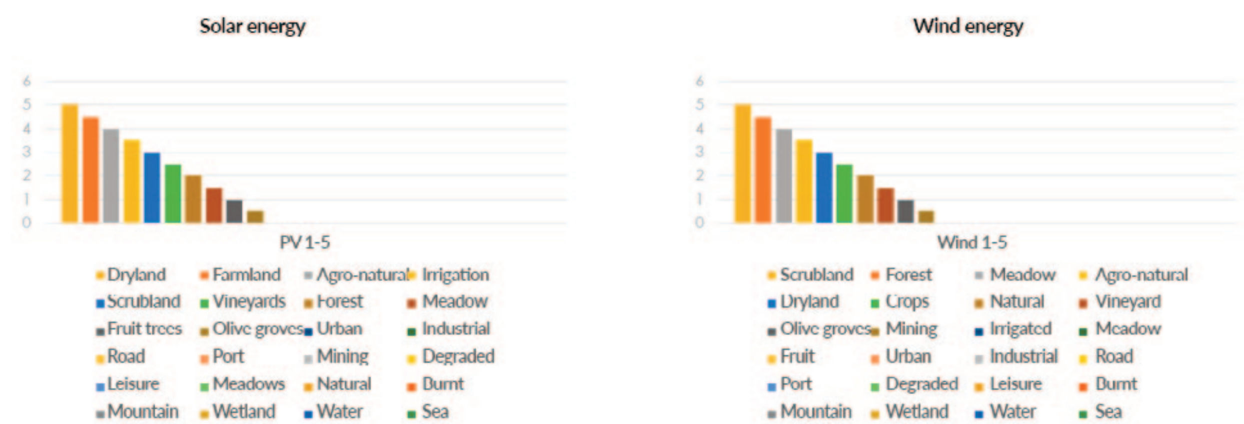
In addition, land use is linked to its suitability for the construction of solar and wind farms and a score is calculated from 0 to 5, with 0 being "never used for such construction».¡

Existing infrastructure

Power grid: distance to substations

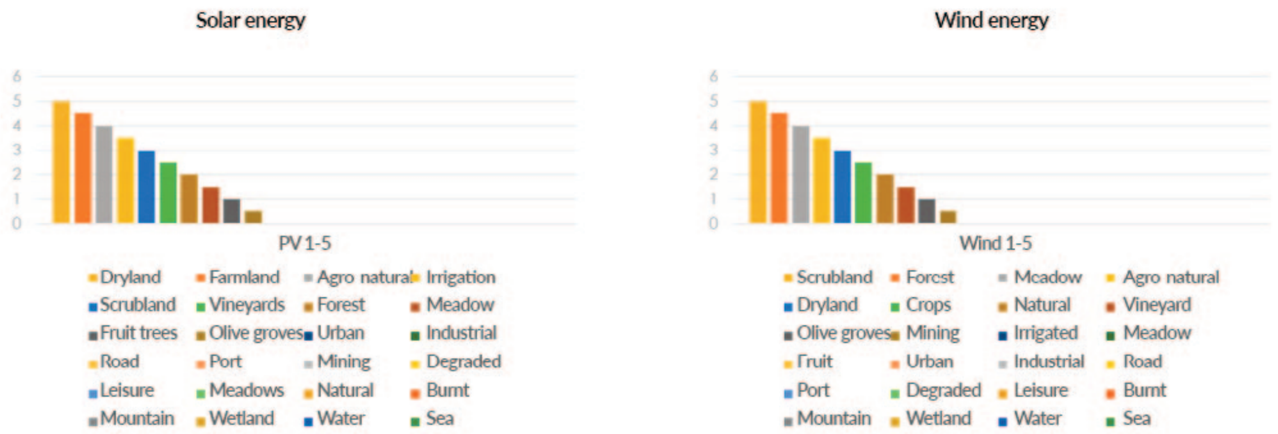
A very common approach in green hydrogen projects is to oversize the renewable production plant with respect to the electrolyzer. For this reason, there will be times when the electrolyzer cannot consume all the energy produced, in which case the excess energy must be fed into the power grid, with the distance to the substation being an important criterion, as the greater the distance, the higher the cost and the greater the electricity losses due to transport.

Figure 31. Classification of land type according to whether it is used for solar or wind energy prodution.



Source; Land Use Database Assessment for the location and spatial distribution of solar and wind energy in Spain (2018).

Figure 31. Distance to electrical substations in Spain.



Source: REE Available and occupied access capacity at transmission grid nodes 20 June 2022.

In addition to the distance to an electrical substation, the connection capacity for production available at each node may also be relevant. In the example, this information is taken from the monthly publications released by the system operator (Redeia).

Natural gas network: distance to the network

Distance to the gas transmission network may be a useful variable for two reasons. Firstly, it may be because an important aspect in many projects (although there is still a great deal of uncertainty about its technical feasibility and acceptable limits). Secondly, because the future hydrogen transport infrastructure is expected to follow the same routes as the existing natural gas network, it is an important variable when considering potential hydrogen transport options, as is already the case with the backbone network currently under consideration.

Road network

Information on the road network is included according to the type of road (highway, national road, etc.) and whether it is part of the Trans-European Transport Network (TEN-T). It is important to have a nearby road network for both the construction and operation of the plant. This would facilitate the transport of hydrogen by tanker truck to the final points of consumption.

Potential off-takers

Industry

The model takes into account the distance to potential industrial hydrogen consumers, analyzing the presence of industries close to the sites. Additionally, an estimate is made of the potential hydrogen demand in some of these industries (refining, ammonia, steel, ceramics production, glass and cement production). This estimate is based on public information about the production capacities, emission factors or energy consumption of the different facilities.

Maritime transportation

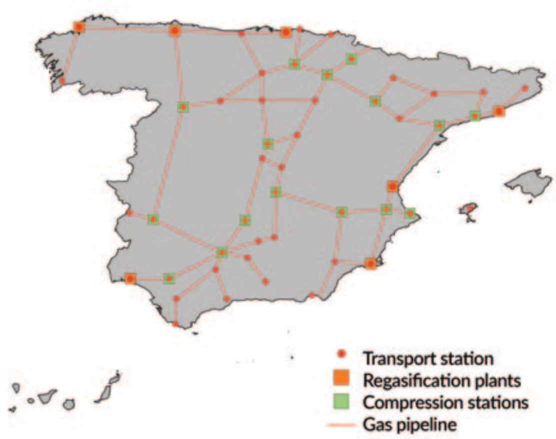
Hydrogen and hydrogen derivatives such as ammonia or methanol will play a key role in the decarbonization of maritime transport. For this reason, relevant information on the main ports in Spain has been included, such as:

- Information on the traffic and size of vessels docking at each port, as well as the demand for fuel at each port.
- Information on the availability of infrastructure for exporting ammonia and methanol in the different ports. With minimal adaptations, these ports could supply these fuels to ships.

Ground transportation

Estimating where and what the future demand for hydrogen for land mobility will be is complex, although it seems clear that heavy transport will concentrate the greatest demand for hydrogen in this segment. For this reason, information on the

Figure 32. Distance to natural gas network. Fuente: REE Capacidad de acceso disponible y ocupada en los nudos de la red de transporte 20 junio 2022.



Source: Scigridgas proyect.

intensity of heavy vehicle traffic on the country's main highways or on existing or planned logistics nodes has been included in the model.

Model applications

This model has two possible direct applications:

Map of interactive layers/movements

Visualizing the value of the different criteria for each node or grid allows the strengths and weaknesses of different sites to be easily identified. This can make it easier to compare several pre-defined potential sites, or even to locate nearby alternatives. For example, Figure 36 shows suitable locations for both wind and solar energy using the following criteria:

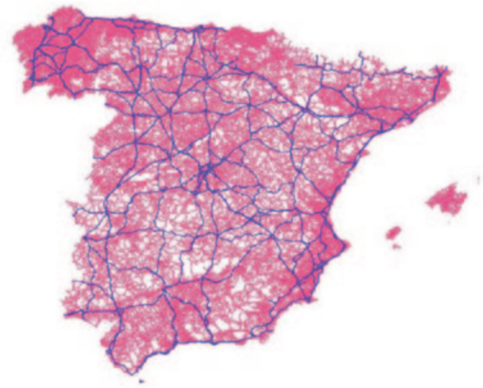
Calculating the hydrogen compatibility index (HCI)

Using the variables defined above, the H2 Compatibility Index (HCI) can be calculated by multiplying the value of each criterion (previously normalized) by its specific weight:

$$ICH2 = \sum Criterion_i * Weight\_criterion_i$$

These weights can be assigned either by multi-criteria decision methods, where experts are consulted and weights are assigned by a comparative method (e.g. analytical hierarchical process), or by allocation based on current projects, where weights are assigned based on the location of existing projects. These weights could be value-specific taking into account preferences (e.g., dedicated renewable plant, different types of off-takers, type of transportation, etc.). In addition, the weighting or inclusion of these criteria will depend on each specific case. For example, in the case of hydrogen production for shipping without hydrogen injection into the grid, the criterion of distance to hydrogen injection points would not be considered.

Figure 33. Road network



Source: MITMA

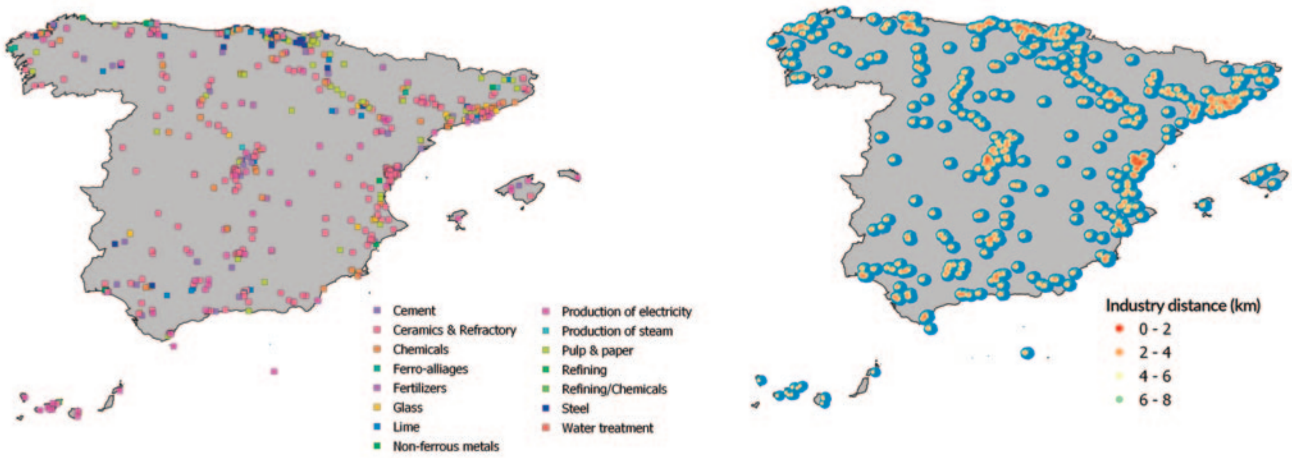
Some examples of criteria are:

- -Solar/wind capacity factor
- -Environmental sensitivity index
- -Type of terrain (dryland, irrigated, etc.)
- -Distance to electricity substations
- -Distance to gas grid injection points
- -Etc.

Distribution of existing projects

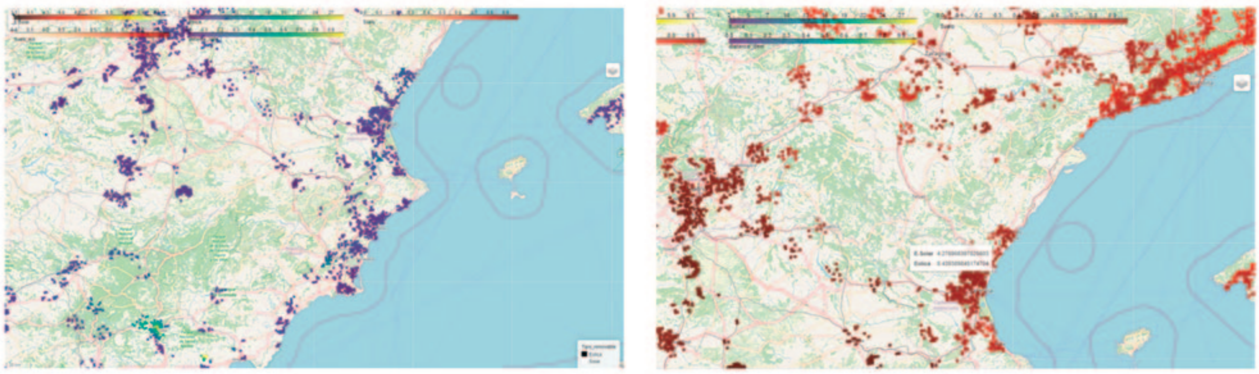
The hydrogen sector is experiencing unprecedented growth in Spain and Europe. As part of its mission to disseminate information, the Chair of Hydrogen Studies created the Hydrogen Projects Visualization Platform, a tool that provides an overview of existing or planned hydrogen production projects in Spain and Portugal, including relevant information such as:

Figure 34. Potential consumers within Spain.



Source: European Pollutant Release and Transfer Register (E-PRTR).

Figure 35. Example of suitable sites by selecting the ISA and distance to substation variables.



Wind energy *Solar energy*

- Status of projects.
- Investment.
- Electrolysis capacity.
- Year of completion.
- Connection scheme and installed renewable generation capacity (if applicable).
- Promoter.
- Type of off-taker: industrial (e.g. ammonia, methanol, refining or steel), land mobility, maritime mobility, among others.

This initiative contributes to the fulfillment of the Hydrogen Roadmap by making it possible to monitor compliance with its targets in terms of electrolysis capacity, number of hydrogen plants, number of vehicles or investment.

The information provided in these maps has been prepared using the best publicly available information from external accredited information sources. The map is updated regularly, although due to the limited public information available, it may not be accurate for some individual projects. However, it is useful as an overview of the deployment of the hydrogen economy in Spain.

The interactive tool is available via the web[68]. Figure 38 shows an image of the interface created.

[68]Hydrogen Studies Chair https://www.comillas.edu/catedra-de-estudios-sobre-el-hydrogeno/mapa-proyectos

Figure 36. Web interface of the map of renewable hydrogen production projects in Spain and Portugal.