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The digital and green transition dilemma: Is there room for everything? Insights from the next decade (2025–2035) in Aragón (Spain)

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ABSTRACT

The simultaneous green and digital transitions are creating new land and water demands that compete with traditional uses. Using Aragón (Spain) as a case study, this work examines whether these transitions are compatible. Aragón was selected for its strong renewable energy potential, low population density (allowing land availability), and government support for green hydrogen (GH) and data center (DC) projects, though these initiatives face growing local opposition. We analyzed projected impacts for 2025–2035 estimating electricity and water consumption for DC and GH, and land needs for wind and photovoltaic electricity under three scenarios. Results indicate Aragón's electricity demand could rise sixfold to fifteenfold by 2035, with DC and GH production representing 85 % of total demand. Supplying Aragón's electricity would require 9–39 % of land to host renewables, and depending on renewables deployment, Aragón could shift from a historic electricity exporter to an importer. Water use could grow 41–124 % relative to current economic consumption, and seasonal demand from DC could lead to conflicts. These findings call into question the current pace and compatibility of the twin transition. We recommend integrated planning that prioritizes the green transition, imposes environmental limits, and compensates affected regions to ensure a sustainable, equitable transition.

1. Introduction

The green transition is becoming increasingly urgent due to the climate crisis (International Energy Agency, 2021). This transition relies on technologies that capture renewable energy from nature, primarily to produce electricity (Torrubia et al., 2024). This electricity can be used directly or in electrolyzers to produce green hydrogen (GH), which serves as energy vector or hydrogen carrier for applications that are difficult to electrify (Busch et al., 2023). However, these technologies require large areas of land, for installing wind turbines and photovoltaic panels (around 2.5–3.2 ha/MW and 15–40 ha/MW, respectively (Mingolla et al., 2024)), and water as a raw material for GH production. These new land and water requirements can compete with traditional uses such as agriculture (Singh et al., 2025) and have been studied at a global level by country (Tonelli et al., 2023), in the European context by region (Kakoulaki et al., 2021), in African countries (Chigbu and Nweke-Eze, 2023), or in specific examples in the US (Sedai et al., 2023) or China (Cheng et al., 2023). These works highlight the importance of conducting local studies because, although global land and water requirements may be sufficient to meet demand (Tonelli et al., 2023; Pingkuo and Junqing, 2024), they may raise significant concerns in the specific territories where these technologies are installed. Despite this, we have not found any studies that place the region at the center of the analysis, considering the new resource requirements due to the parallel digital transition, which together are referred to as twin transitions (Hambye-Verbrugghen et al., 2025; Bergman and Foxon, 2025).

The digital transition is accelerating as a result of the development of Artificial Intelligence (AI), which increasingly requires the management, storage, and integration of data in so-called data centers (DC) (Masanet et al., 2020; Kollar and Grady, 2025; Privette et al., 2025; Paccou and Wijnhoven, 2025). Consequently, there is a global surge in DC projects (Shehabi et al., 2024; International Energy Agency, 2025; Gröger et al., 2025) together with their environmental concerns, as highlighted by the United Nations (UN Trade and Development, 2024). Many authors have studied the significant amounts of electricity (Li et al., 2023; Zhu et al., 2023; Khosravi et al., 2024), water (Privette et al., 2025; Mytton, 2021; Jiang et al., 2025; Shumba et al., 2025) or both (Kollar and Grady, 2025; Siddik et al., 2021; Lei and Masanet, 2022; Jerléus et al., 2024) required for these facilities. These studies are focused on several countries and regions, such as US (Kollar and Grady,

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2025; Siddik et al., 2021; Lei and Masanet, 2022), China (Li et al., 2023; Jiang et al., 2025), Sweden (Jerléus et al., 2024), Germany (Turek and Radgen, 2021) or several African countries (Shumba et al., 2025) since the resource consumption is highly dependent on the specific location and climate where DC is installed (Jiang et al., 2025; Lei and Masanet, 2022; Turek and Radgen, 2021). Another important issue studied is the carbon footprint, which main reduction proposal is the use of renewable electricity (Zhu et al., 2023; Khosravi et al., 2024; Jerléus et al., 2024; Rajendra, 2022). However, these studies did not consider the amount of land required for these technologies nor accounted for the new demand alongside other energy transition infrastructure, such as GH. This raises an important question: is there room to accommodate the twin transition considering specific territories?

To address this question and fill this gap in the literature, this paper adopts a novel perspective by placing the region (Aragón, Spain, in this case) in the center of the study, rather than DC or GH technologies. Consequently, the specific characteristics of the region (water and land availabilities) and the simultaneous effect of the deployment of energy transition and digital technologies are considered. In addition, bottom-up information on DC and GH in a specific region of Spain is compiled, which can help to account for the global impacts of these infrastructures in the future (Masanet et al., 2020). Although previous studies have examined the socioeconomic impact of DC (Lobera Segurado, 2025) and GH technologies in Aragón (Manzano et al., 2025), there is no integrative study that considers these two aspects of the twin transition together. Therefore, this study also intends to fill this gap.

Aragón was chosen as case study due to several reasons. First, it is one of the European regions with the highest potential for renewable energy surplus (estimated in 260 TWh per year by Kakoulaki et al. (2021), which exceeds Spain's total consumption in 2024, 250 TWh (Red Eléctrica de España)) thanks to its abundant wind and solar resources and its low population density, which translates into land availability and low local consumption. Aragón has 1.3 million inhabitants in an area of 47,697 km^2 (being larger than Switzerland or the Netherlands). However, the population is highly concentrated around the Ebro Valley (specifically in the capital, Zaragoza with around 700,000 inhabitants), meaning that most of the region has fewer than 15 inhabitants per km^2, less than the population density of Norway or Finland (Aragon geographical institute). Second, Aragón is strategically located in the northeast of Iberian Peninsula between five major Spanish urban areas—Madrid (first), Barcelona (second), Valencia (third), Bilbao (sixth), and Zaragoza, the capital of Aragón (seventh) (Wikipedia), as well as near southern France (Bordeaux, Pau, Toulouse) and the Principality of Andorra. Third, another relevant factor is the collaboration of regional political stakeholders in promoting GH and DC projects (Colliers, 2025a). This is reflected in the Declaration of General Interest of Aragón (DIGA) and Projects of General Interest of Aragón (PIGA) for several of these initiatives. These declarations enable fast-track processing and reduced administrative procedures (DIGA) or even modifications to urban planning regulations (PIGA) (Lobera Segurado, 2025). The fourth reason is the authors' in-depth knowledge of the region.

Regarding the development of the green transition in Aragón, the excessive deployment of renewable technologies to export or power these energy-intensive projects is triggering opposition from parts of the local population (Duarte et al., 2022a). The main reason is based on the renewable technologies (wind and solar) small share of added value and employment on the regions where they are installed (Duarte et al., 2022b), while producing negative environmental impacts such as land occupancy or biodiversity loss (UN Trade and Development, 2024; Gayen et al., 2024). Moreover, Aragón currently exports more than 50 % of the electricity it produces, generating wealth in other Spanish regions (Felipe-Andreu et al., 2022), with an electricity which is nearly 90 % renewable (Red Eléctrica de España). Aragón has already installed 8870 MW of wind and solar power (Red Eléctrica de España Power), and 5490 MW of new wind and solar capacity have already been approved to be installed, 4696 MW are under review, and more than 7323 MW have been requested (as of July 2025) (Opina 360, 2025a; Opina 360, 2025b; Opina 360, 2025c). This power together would far exceed the 15,585 MW target set in the Aragón Energy Plan 2024–2030 (Government of Aragon).

Regarding the digital transition, Aragón could become one of Europe's major DC hubs in the near future. With over 2790 MW of projected capacity (Colliers, 2025a), it already surpasses the forecasts for important European hubs such as Barcelona (275 MW), Amsterdam (570 MW), Madrid (1104 MW), Dublin (1356 MW), and Paris (1574 MW), approaching Frankfurt (2949 MW) and London (3770 MW) (SpainDC, 2024). However, the DC future power in Aragón could be much higher. In the first version of this paper (September 2025), we calculated 1877 MW (Colliers, 2025b), while in its revision (December 2025), the projected power already reached 2790 MW (Colliers, 2025a). Because of this rapid proliferation, DC installation is also generating local opposition (El Pais, 2025), as with the aforementioned renewable technologies. This concern stems from several factors: pressure on water and electricity resources, the management of industry waste, and doubts regarding the return on public investment (Government of Aragon). Other countries with strong DC presence, such as the United States or Ireland, have already experienced similar issues (Government of Aragon; Felipe-Andreu et al., 2023).

In summary, the aim of this work is to analyze the increase in electricity consumption and the impacts on land occupation and water use in a European region that is particularly relevant for green and digital transition projects, namely Aragón. Thus, this case is presented as an example of how the twin transition can locally affect some natural resources-rich regions, offering a more specific perspective than global studies, yet complementary to them. Given the strong growth of the projected environmental impacts and the opposition of part of the local population, this work explores possible future scenarios and recommends measures to ensure the success of the twin transition.

2. Data and methodology

In this section, we first present the methodology and data used to estimate the electricity and water consumption of DC projects based on publicly available data (Section 2.1). Second, we apply the same methodology to GH projects (Section 2.2). Third, we estimate the land area occupied by renewable energy technologies (Section 2.3) required to supply electricity to DC and GH projects. Fig. 1 shows the methodology flowchart to illustrate and clarify the relationship between the sections and parameters of the methodology and the calculation of the results. In addition, the supplementary material contains all the detailed calculations.

2.1. Data centers: projects and consumption

The first step to estimate the future power and water consumption of DC is to identify the publicly announced projects taking place in Aragón between 2025 and 2035. Table 1 compiles all public information available up to date on several reports (Lobera Segurado, 2025; Colliers, 2025a, 2025b; Colliers, 2024a, 2024b) related to these projects and indicates their location, company, announcement year, power information technology (IT) capacity, land area (in hectares), construction and permanent employment, investment, and project status.

The commissioning of AWS data centers (the first 7 DC of Table 1) began in 2020 with an initial capacity of 108 MW in the municipalities of El Burgo, Villanueva de Gállego, and Huesca, and operations started at the end of 2022. Since its commissioning, AWS has already requested an expansion whereas other many companies—Microsoft, Box2Bit, Azora, QTS, Repsol, Iridium, Samca, Vantage, and Nunsys—have also announced additional projects. As a result, up to 20 DC could be operational in the next decade (by 2035), with a total capacity of at least 2790 MW (Colliers, 2025a). It is worth noting that this figure is very conservative, since the capacity of Box2Bit's DC is unknown (see

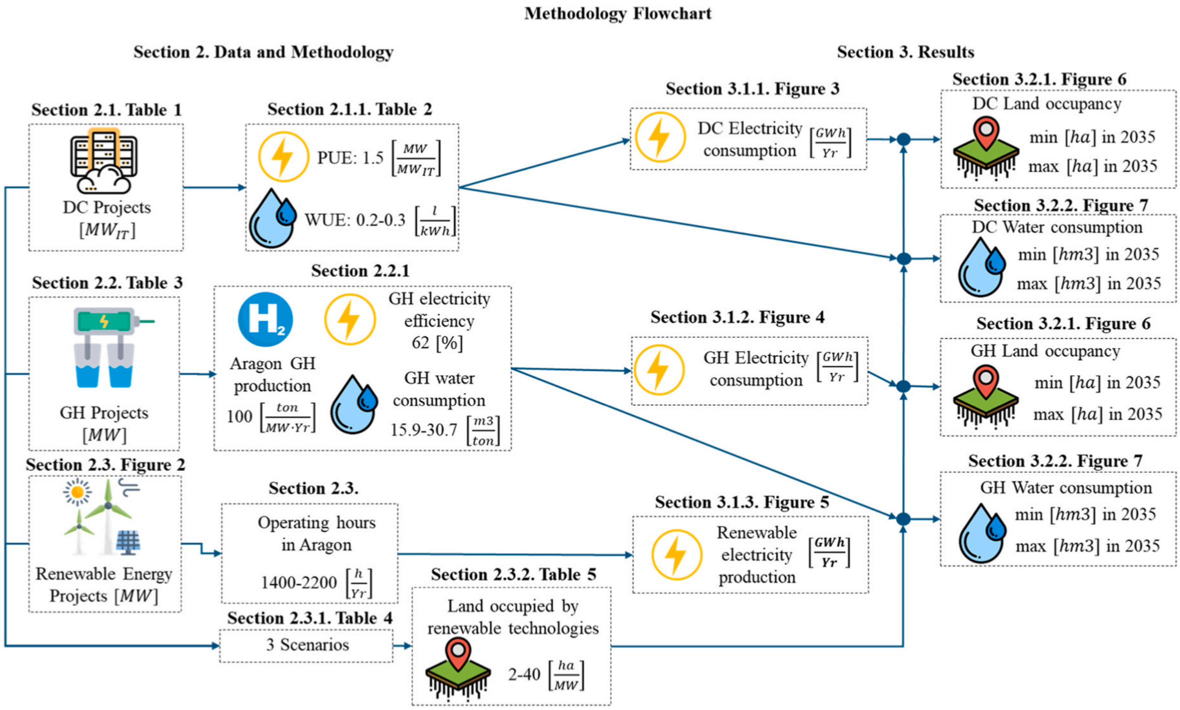

Fig. 1. Methodology flowchart.

Table 1) and during the draft of this study, the projected total capacity increased from 1877 MW (Colliers, 2025b) to 2790 MW in three months (Colliers, 2025a). Regarding the currently announced projects, AWS projects have already been declared Projects of General Interest of Aragón (PIGA) (Government of Aragon, 2024), and Microsoft and Azora projects have been declared Declaration of General Interest of Aragón (DIGA) by the regional political authorities. Thus, these projects benefit from preferential treatment with reduced administrative procedures (DIGA) or even allow for modifications to urban planning regulations (PIGA).

2.1.1. *Electricity and water consumption of data centers*

With the DC's power IT capacity (Table 1) we estimated the annual electricity and water demands using three fundamental parameters directly related to DC operation phase: annual operating hours (H, measured in h/year), Power Usage Effectiveness (PUE, measured in MW/MW-IT), and Water Usage Effectiveness (WUE, measured in l/kWh). PUE reflects the ratio between the total power consumed by the DC building and the power consumed by computing (IT Power) (Barroso et al., 2019), whereas WUE represents the demand for liters of water relative to the energy used in computing, measured in l/kWh (Open Compute Project). Equations (1) and (2) show the calculation of annual electricity consumption (EC) and water consumption (WC) using these parameters.

$$EC\left[\frac{GWh}{Yr}\right] = P_{IT}[MW_{IT}] \cdot PUE\left[\frac{MW}{MW_{IT}}\right] \cdot H\left[\frac{h}{Yr}\right] \cdot \left[\frac{GW}{1000 \cdot MW}\right] \tag{1}$$

$$WC\left[\frac{m3}{Yr}\right] = P_{IT}[MW_{IT}] \cdot WUE\left[\frac{l}{kWh_{IT}}\right] \cdot H\left[\frac{h}{Yr}\right] \cdot \left[\frac{1000 \cdot kW}{MW}\right] \cdot \left[\frac{m3}{1000 \cdot l}\right] \tag{2}$$

This study assumes that DC operate continuously throughout the year, so H is set to 8760 h per year. This assumption also casts doubt on whether DC can be supplied exclusively with renewable energy (and without appropriate energy storage systems), given the intermittency of renewables and the resulting *duck curve* effect (Schmalensee, 2022). Additionally, PUE and WUE values can be more variable as they are strongly correlated to the DC location and its general weather conditions (Jiang et al., 2025; Lei and Masanet, 2022; Turek and Radgen, 2021). For instance, these variations can reach up to 62 % for PUE and almost 100 % for WUE, depending on cooling technologies, efficiencies, and locations (Lei and Masanet, 2022).

Therefore, we decided to use the electricity (EC) and water consumption (WC) values of the AWS DC of Aragón (published in the PIGA (Government of Aragon, 2024)) to estimate appropriate PUE and WUE values that consider current technologies and the climatic characteristics of Aragón. Table 2 shows these EC and WC values, and by applying equations (1) and (2), we obtain a PUE of 1.75 and a WUE of 0.18 l/kWh. On the other hand, other studies carried out in Aragón use a PUE of 1.25 and a WUE between 0.2 and 0.6 l/kWh (Lobera Segurado, 2025), and others for the Iberian region use a PUE of 1.5 (Colliers, 2025b). Thus, considering the estimates in Table 2 and these studies, we propose using a PUE of 1.5 and a WUE range between 0.2 and 0.3 l/kWh to establish the minimum and maximum water consumption. Therefore, our assumptions are based solely on specific studies from Aragón, due to the significant variability of PUE and WUE between different regions (Jiang et al., 2025; Lei and Masanet, 2022; Turek and Radgen, 2021).

Once PUE and WUE values are set for the calculation of EC and WC using Equations (1) and (2), we projected the timeline for DC project deployment. For this, we use the data and commentaries in Tables 1 and 2, distinguishing between companies.

- AWS: Between 2025 and 2028, we consider the current 108 MW installed capacity. Between 2029 and 2033, operating capacity rises to 500 MW. By 2033, the installation is completed, reaching 708 MW.
- Microsoft: The first 100 MW will be operational in 2030. We then assume an annual installation of 100 MW until reaching the projected 669 MW in 2035.
- Azora: Between 2028 and 2030, 100 MW come online, increasing to 150 MW between 2031 and 2033, and completing the project with 200 MW in 2034.
- QTS: Between 2027 and 2028, 100 MW come online. This increases to 150 MW between 2029 and 2030, to 200 MW between 2031 and

Table 1
Current data centers projects in Aragón (Spain). Sources (Lobera Segurado, 2025; Colliers, 2025a, 2025b; Colliers, 2024a, 2024b).

No.	Project/ Location	Company	Year of Announcement	Power IT [MW]	Occupied land [ha]	Construction employment	Permanent employment	Investment	Status/Other information
1–2	El Burgo (2)	AWS	2020	98	37	NA	NA	15,700 million €.	**108 MW** are working **since 2022.** PIGA granted (2020) and extended (2024) (Government of Aragon, 2024). The expansion will be progresive: **2025–2029**: construction of data halls and administrative buildings. **2029–2033**: construction of remaining infrastructure. Possibility of increasing power further.
3–5	Villanueva de Gállego (3)	AWS	2020	236	81				
5–7	Huesca (2)	AWS	2020	236	49				
8	La Cartuja	AWS	2025	100	129				
9	La Muela	Microsoft	2023	223	147	1000-2000 Jobs (Gascón, 2025)	200 Jobs (Gascón, 2025)	10,000 million €	**DIGA granted (2024), PIGA in process** (Government of Aragón, 2024). 1st phase in operation in 2030 (Alonso, 2025). Construction over the next 10 years.
10	Villamayor de Gállego	Microsoft	2023	223	87				
11	Puerto Venecia	Microsoft	2025	223	59				
12	Cariñena	Box2Bit	2024	NA	NA	NA	NA	4400 million €	Renewable self-consumption.
13	Calatayud	Box2Bit	2025	NA	40				
14	Villamayor de Gállego	Azora	2025	200	NA	1040 Jobs (Gascón and (El Español) Azora Data Center Jobs, 2025)	154 Jobs (Gascón and (El Español) Azora Data Center Jobs, 2025)	2.000 million €	DIGA granted (2025) PIGA in process (Azora DIGA of Azora Available). 1st phase **100 MW. Start of construction in 2026** (Azora DIGA of Azora Available). 2nd phase completed in **2034.**
15	Calatorao	QTS	2024	300	200	1200 Jobs (Gascón, 2025)	200 Jobs (Gascón, 2025)	7500 million €	**Electrical substation under construction** (H.A.; (El Heraldo de Ar agón), 2025). **Initial Operation in 2027** (Heras Pastor and Calvo Lamana, 2024)
16	Escatron	Repsol	2025	274	_	_	_	_	_
17	La Puebla de Alfinden	Iridium	2025	200	50	_	_	2500 million €	The first phase has a 100 MW IT grid connection and aims to reach 200 MW IT over the next decade, with construction starting in 2026 and operations in 2028
18	Luceni	Samca	2025	120	46.4	_	_	2600 million €	Declared of DIGA, the project targets ground-breaking in H2 2026, a two-year build schedule, and fully commissioning in 2030
19	Villamayor de Gállego	Vantage	2025	200	40	_	_	3200 million €	Announced in 2025
20	Zaragoza	Nunsys	2025	–	_	_	_	1-2 million €	It is estimated to be in operation in 2026
20	Total			2790	965			47,902 million €	

Table 2
Projected electricity and water consumption of AWS data centers in Aragón. Sources (Government of Aragon, 2024; Pascual, 2025).

No.	Project/ Location	Electicity consumption 2030 [GWh/Yr]	Electicity consumption 2033 [GWh/Yr]	Water consumption [m3/Yr]
1–2	El Burgo (2)	1738	1776	170,156
3–5	Villanueva de Gállego (3)	2532	3532	411,218
6–7	Huesca (2)	2088	2271	226,277
8	La Cartuja	1261	3280	310,815
8	TOTAL AWS	7620	10,858	1,118,466

2032, to 250 MW between 2033 and 2034, and finally reaches 300 MW in 2035.

- Repsol: There is no information about the pace of construction. Since it was announced in 2025, we assumed 2 years of construction for each 50 MW. Thus, in 2027 50 MW come online, 100 MW in 2029, 150 MW in 2031, 200 MW in 2033 and 274 in 2035.
- Iridium: Operations start in 2028 with 100 MW. We assumed the next 150 MW start operating in 2030, and the next 200 MW would be in 2032.
- Samca: 60 MW starts to operate in 2028 and the next 120 MW in 2030.
- Vantage: Announced in 2025, we assumed 2 years of construction for each 50 MW. Thus, in 2027 50 MW come online, 100 MW in 2029, 150 MW in 2031, and 200 MW in 2033.

2.2. *Green hydrogen: projects and consumption*

By following a similar procedure, we projected the future power consumption of GH projects taking place in Aragón between 2025 and 2035. To the best of knowledge of the authors, Table 3 summarizes all publicly available information (Manzano et al., 2025; Universidad Pontificia de Comillas; Spanish Hydrogen Association, 2024) on GH project location, company, announcement year, capacity, hydrogen production, total and public investment, completion year, project status, and hydrogen use.

It is expected that more than 2700 MW of electrolysers capacity power will be available by 2030, but the capacity of the Smartenergy

Table 3
Current green hydrogen (GH) projects in Aragón. Sources (Manzano et al., 2025; Universidad Pontificia de Comillas; Spanish Hydrogen Association, 2024).

No.	Project/Location	Company	Power [MW]	H2 prod. [t/yr]	Investment	Public funding	Completion year	Status	Use of hydrogen
1	Catalina phase 1 - Andorra	Enagás, Fertiberia	500	84,000	2350 million €	Valles H2 (245 million €/Banco H2 (230 million €)	2027	Funding granted (PIGA)	Ammonia (export to Sagunto plant (Valencia) via new pipelines of 35 km)
	Catalina phase 2 - Andorra	Enagás, Fertiberia	2000	336,000	714 million €		2030		
2	DH2 Energy - Belchite	DH2 Energy	239	11,950	632 million €		2031	Feasibility study	Industry and transport
3	El Pilar - Caspe	Alkeymia	200	16,000		Pioneros 2 (15 millions €)/Valles H2 (150 million €)	2026	Funding granted (DIGA)	Industry and transport
4	Smartenergy - Zaragoza	Smartenergy		13,388			2027		Industry and transport
5	H2 Pillar phase 1 - El Burgo		30	4400	123 million €	Pioneros 1 (15 million €)	2026	Funding granted (DIGA)	Hydrogen peroxide and transport
	H2 Pillar phase 2 - El Burgo		60	8800	57 million €		2031		
6	Endesa - Teruel	Endesa	60		294 million €		2024	Feasibility study	Blending.
7	Hysencia - Plasencia del Monte	DH2 Energy	35	1750		Banco H2 (8 million €)	2024	Feasibility study	Ammonia
8	IAM Caecius	Fertinagro	25		53 million €	IPCEI Hy2Use (53 million €)	2025	Funding granted	Ammonia
9	La Zaida	Ignis	20		50 million €	Pioneros 2 (15 millions €)	2029	Feasibility study (DIGA)	Industry and transport
10	Planta H2 Burgos	Enagas/CEAR	15		100 million €		2030	Feasibility study	Industry and transport
11	H2 Magallón	Endesa	7.2		28 million €	IPCEI Hy2Use (28 million €)	2027	Funding granted	Ammonia
12	H2 El Cierzo	Endesa	7.2		33 million €		2024	Feasibility study	Industry and transport
13	Life Cabezo	Enagas	1		4.5 million €		2024	Under construction	Industry
	Total		2669		4600 million €	759 million €			

project is missing, as we have not found any available information. Nevertheless, most of this capacity corresponds to the Catalina project, which alone would account for 2000 MW—around 75 % of the total. These projects can be categorized in two distinct applications: ammonia production (mainly for fertilizers) and GH use in industry and transport. The total investment in these projects exceeds €4600 million, of which €759 million comes from public funding through several European and Spanish programs.

2.2.1. Electricity and water consumption of green hydrogen (GH)

We used the data in Table 3 to estimate the electricity and water consumption of GH projects. First, we estimate the total green hydrogen (GH) production from the ratio between the power capacity (MW) and the annual GH production (ton/yr) available for six projects, which averages around 100 t/(MW·yr). We considered reasonable to take this value because the remaining projects account for only 135 MW, compared with the 2534 MW represented by the six projects for which their annual GH production is directly available. Thus, by using the 100 ton/(MW·yr) ratio and multiplying by each project's capacity (in MW), the annual GH production (ton/yr) can be calculated. Second, we adopted an average electrolyzer efficiency of 62 % to estimate the electricity consumption for GH production. This efficiency is typical of the most commonly used electrolyzers in Spain (Manzano et al., 2025). We adopted this assumption because in most projects no information is provided about the type of electrolyzer.

Then, we estimated the water consumption of GH projects from data of two specific projects carried out in Aragón (Catalina and El Pillar, see Table 3), which consume between 15.9 and 30.7 m^3/ton (Manzano et al., 2025). Thus, these ratios are multiplied by the annual GH production (ton/yr) previously calculated to obtain minimum and maximum annual water consumption scenarios (m^3/yr). We took this assumption because the water consumption used by electrolyzers varies depending on the source consulted and we prioritize the use of data from local projects.

Finally, to estimate the timeline of project deployment, we used the data in the "Completion Year" column of Table 3. Thus, to estimate the pace of project installation and both the electricity and water consumption of the GH, we use specific data from Aragón.

2.3. Renewable technologies: Projects, scenarios and land occupation

This study assumes that most of the increase of electricity consumption due to DC and GH is covered by wind and photovoltaic technologies. This assumption is based on 1) the current high production of electricity of these technologies in our region (71 %) (Red Eléctrica de España; Torrubia et al., 2024)) the power purchase agreements (PPA) signed by some DC companies, 3) the fact that GH must be produced solely with renewable energy, and 4) the lack of expected growth in other renewable technologies such as hydropower in Aragón. The wind and photovoltaic power amounts to 8870 MW as of July 2025, according to Red Eléctrica de España (Red Eléctrica de España) (Fig. 2). Apart from the power already installed, currently there are 5490 MW decommissioned, 2384 MW have preliminary authorization, 2313 MW have favorable environmental certification, and 7323 MW are in public consultation and may or may not ultimately be built (Opina 360, 2025a; Opina 360, 2025b; Opina 360, 2025c).

In Fig. 2, the power capacity that is indicated as authorized for construction, has preliminary authorization, or has favorable environmental certification is referred to as "approved", whereas capacity in public consultation is referred to as "proposed". To estimate the installation timeline, the following assumptions are made, based on (Opina 360, 2025a; Opina 360, 2025b; Opina 360, 2025c).

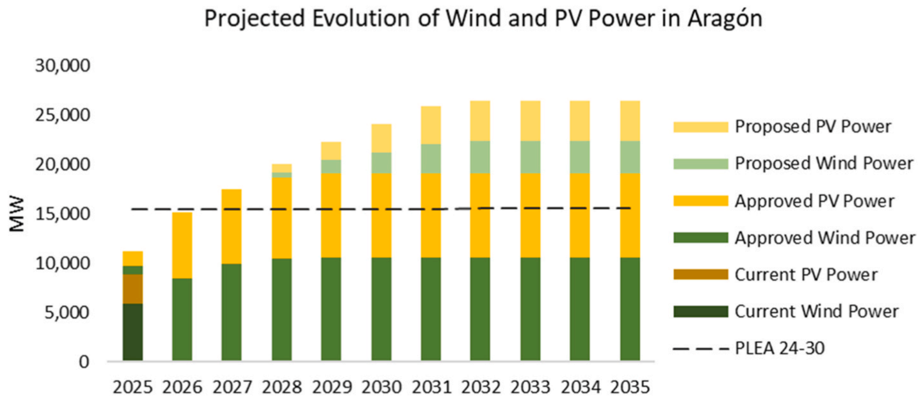

Fig. 2. Projected evolution of Wind and PV Power in Aragón. The power capacity that is indicated as authorized for construction, has preliminary authorization, or has favorable environmental certification is referred to as "approved," whereas capacity in public consultation is referred to as "proposed". PLEA: Aragón Energy Plan (Government of Aragon).

- Authorized for construction: 50 % is installed the year following authorization, and the remaining 50 % two years after authorization.
- Preliminary authorization: installation takes between two and three years, with a 50 % probability for each case.
- Favorable environmental certification: installation takes between three and four years, with a 50 % probability for each case.
- Public consultation: installation takes between four and six years, with a 25 % probability for each case. We assume that 100 % of the capacity under consultation is ultimately installed. This assumption is adopted to obtain a scenario of maximum deployment of renewables in order to verify whether it is possible to meet the demand of DC and GH projects.

Based on the projected capacity in Fig. 2 (MW), the annual production (GWh) is estimated to use the annual operating hours derived from historical generation data of Aragón (Red Eléctrica de España Power): for example, hydropower operates for approximately 2214 h per year, wind for 2179 h, and solar PV for 1395 h.

2.3.1. Renewable technologies deployment scenarios

The renewable energy deployment scenarios are based on the future electricity consumption in Aragón, considering other sectors apart from the consumption of DC and GH, calculated in sections 2.1.1 and 2.2.1. Thus, Aragón's electricity consumption was very stable between 2006 and 2023. For instance, the highest annual consumption was 10,982 GWh (2007), the lowest 9327 GWh (2010), and the average 10,068 GWh (Government of Aragon, 2025). The sectoral distribution of consumption has also remained stable. Between 2006 and 2023, industry consumed an average of 50 % of total demand (minimum 45 %, maximum 55 %), transport 4 % (minimum 2 %, maximum 6 %), households 42 % (minimum 38 %, maximum 48 %), and agriculture 3 % (minimum 2 %, maximum 4 %). Given this stability, this study assumes that consumption by industry, transport, households, and agriculture will remain constant in the next decade (2025–2035). We are aware that this is a conservative assumption, but it allows us to better put into perspective the impacts of DC and GH projects on electricity demand.

Accordingly, three scenarios are established based on renewable technologies deployment and expected electricity consumption, as shown in Table 4.

2.3.2. Land occupied by renewable technologies

This study estimates the land area required to install the renewable capacity for the above scenarios. This parameter depends on local characteristics, so the data used correspond to real projects carried out in Aragón (Manzano et al., 2025; Valenzuela et al., 2021). The data, measured in ha/MW, is available in Table 5.

For wind projects, the figures include the entire polygonal area of the project site. Therefore, this land could still be used for other activities such as agriculture. This study does not consider other indirect land impacts, such as new power lines or road construction required for the implementation of renewable projects.

Table 4
Renewable technologies deployment scenarios.

	Scenario 1	Scenario 2	Scenario 3
Renewable technologies deployment	Approved and proposed projects in Fig. 2	Until the consumption of the DC and GH projects is covered	Until the consumption of the DC and GH projects is covered
Net Electricity Balance	Imports required (consumption is not covered)	Consumption is covered (the wind/PV ratio from Fig. 2 is maintained)	Consumption is covered (the wind/PV ratio from Fig. 2 is maintained)
DC projects	2790 MW-IT (Table 1)	2790 MW-IT (Table 1)	8000 MW-IT (based on an announcement by the Government of Aragón) (Faci, 2024)
GH projects	2669 MW (Table 3)	2669 MW (Table 3)	2669 MW (Table 3)

Table 5
Land occupied (in ha.) by installed MW of renewable technologies. Sources: (Manzano et al., 2025; Valenzuela et al., 2021). Therefore, each scenario (Table 4) has minimum and maximum values.

ha/MW	Minimum	Maximum
PV	2	3
Wind	30	40

3. Results

In this section, we first present the results on future electricity consumption due to the digital and green transition (Section 3.1). Then, we show the local environmental impacts of this twin transition in Aragón (Section 3.2) in terms of land occupation and water consumption.

3.1. Electricity consumption for the digital and green transition

The digital transition, represented by DC, and the green transition, represented by GH, require large amounts of electricity. This section analyzes the electricity consumption of these infrastructures in Aragón (sections 3.1.1 and 3.1.2), as well as their supply, considering renewable technology projects (section 3.1.3).

3.1.1. Digital transition: data centers (DC)

The announced DC in Aragón shown in Table 1 could consume up to 36,600 GWh per year in 2035. This number is validated by being in the same order of magnitude to those (21,300–27,900 GWh per year) estimated by other studies (Lobera Segurado, 2025). However, our result is higher because we include the latest announcements from DCs in Aragón, which are growing at a rapid pace, as mentioned in Sections 1 and 2. Fig. 3 forecasts how Aragón's electricity consumption can evolve between 2025 and 2035 solely due to DC, according to our aforementioned assumptions.

Fig. 3 shows the rapid deployment of DC projected in Aragón. This process began in 2022 with an annual consumption of about 1400 GWh, which could increase 26-fold to reach 36,600 GWh per year by 2035. This electricity consumption is very significant considering that Aragón's electricity consumption remained very stable between 2006 and 2023, with a maximum of 10,982 GWh (in 2007), a minimum of 9327 GWh (in 2010), and an average of 10,068 GWh (Government of Aragon, 2025). Therefore, the DC projections alone could almost quadruple Aragón's electricity consumption in just ten years.

Although these results show a striking increase in electricity consumption, our assumptions are very conservative. For example, we have not considered the DC announced by Box2Bit because their power IT capacity is currently unknown. Moreover, some companies such as AWS could expand the projected capacity, as it has already happened recently (see Table 1) (Colliers, 2025a). Therefore, we also assessed a high-energy-demand scenario (Scenario 3), in which DC capacity could reach up to 8 GW, as mentioned by the Government of Aragón (Faci, 2024). In this scenario, electricity consumption would reach up to 105, 120 GWh per year in 2035, meaning it would be around ten times Aragón's current total consumption.

3.1.2. Green transition: green hydrogen (GH)

The announced GH projects in Aragón can consume up to 21,300 GWh per year by 2035. Fig. 4 shows how electricity consumption could evolve between 2025 and 2035, distinguishing between the main detected uses of GH: ammonia production, and industry and transport.

Fig. 4 shows that GH production for ammonia is the most widespread use, accounting for 85 % of total production by 2035. This is mainly due to the Catalina project, which involves GH production for ammonia and concentrates 75 % of installed electrolyzer capacity (see Table 3). Consequently, the two main significant increases in electricity consumption also come from the ammonia sector: in 2027 and in 2031. In 2027, the first phase of the Catalina project comes into operation, with a capacity of 500 MW, and in 2031 the rest of the project is launched, reaching a total of 2000 MW (see Table 3).

Considering only GH projects, annual electricity consumption would increase up to 21,300 GWh - representing the double of Aragón's current consumption (around 10,000 GWh), also showing a significant importance together with DC projects.

3.1.3. Renewable technologies deployment and electricity balance

Fig. 5 shows the projection of electricity consumption split by sector between 2025 and 2035 under scenarios 1 and 2. Consumption for industry, transport, buildings, and agriculture is considered constant at 10,068 GWh per year, due to the reasons given in the methodology. By contrast, the increase in consumption due to DC operation and GH production corresponds to the projections already shown in Figs. 3 and 4. In addition, the projection of electricity produced in Aragón according to the scenario 1, which considers the installation of all approved renewable projects and all those requested (see Fig. 2), is also shown with a red line. Thus, the difference between the red line and the bars indicates the surplus electricity that is exported to other regions of Spain, or the electricity that must be imported if demand exceeds production.

Fig. 5 shows that by 2035, DC consumption will account for 54 % of total demand, and GH production for 31 %, with the remaining 15 % corresponding to current uses (industry, transport, buildings, and agriculture). Thus, in 2035, DC consumption will be 3.6 times current consumption in Aragón, GH production 2.1 times and combined they imply a 5.8-fold increase in electricity demand. Under Scenario 3, where 8 GW of DC are installed, electricity demand in 2035 would rise from 68,000 GWh in Scenario 1 and 2 (Fig. 5) to 154,000 GWh, which would mean a fifteen-fold increase in demand. It is important to note that this increase in electricity consumption does not consider other sectors of the energy transition, such as electric mobility.

Regarding the exportation or importation of electricity, Fig. 5 shows that until 2030 Aragón will still be able to export electricity to other regions, with a surplus of 10,500 GWh, similar to current exportation (11,900 GWh in 2024 (Red Eléctrica de España)). However, from 2031 onwards, Aragón becomes an electricity-importing region. By 2035, it could require up to 17,000 GWh from other regions, exceeding its current consumption and exports, thus changing its historical role in Spain. These numbers of electricity exportation or importation only occur under scenario 1. However, Scenarios 2 and 3 do not consider imports from other regions, but rather increased installed capacity and therefore land and water requirements, which is analyzed in the following section.

3.2. Local impacts

The high electricity consumption due to the digital and energy

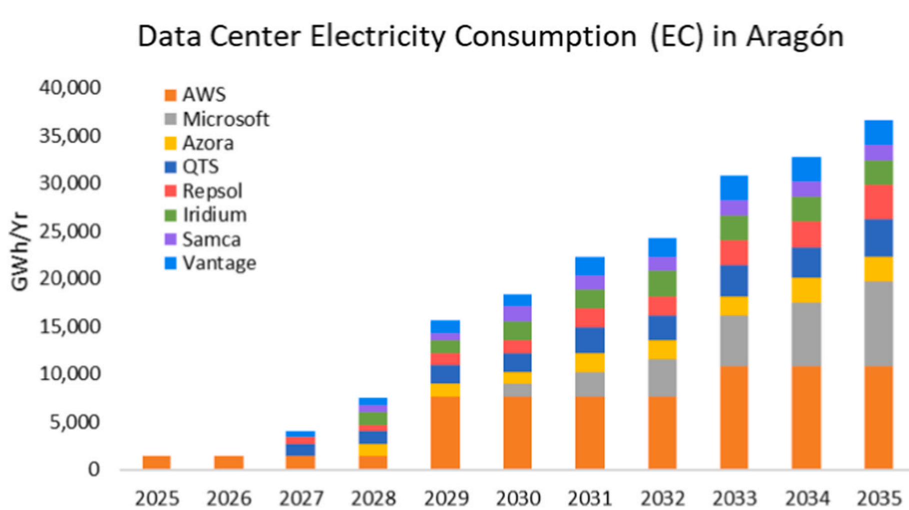

Fig. 3. Projection of data center (DC) electricity consumption in Aragón (2025–2035) by company. More information is available in the supplementary materials.

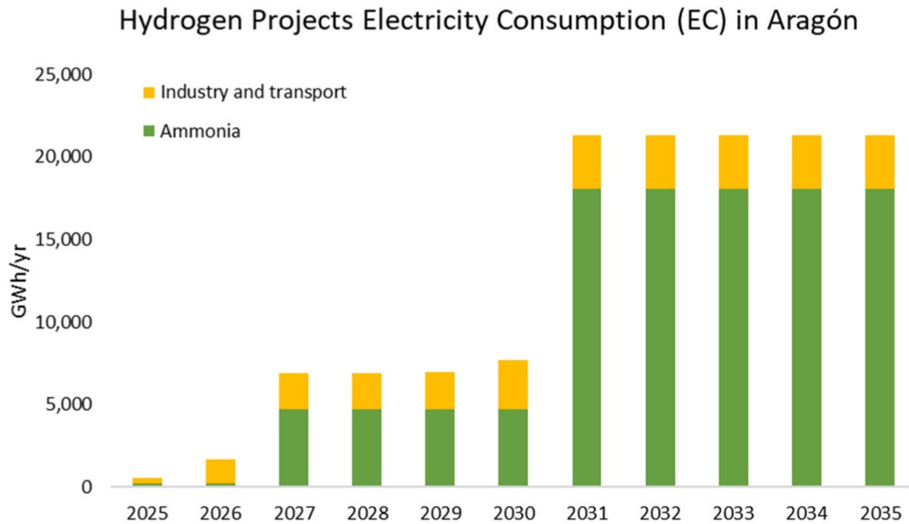

Fig. 4. Projection of Green Hydrogen (GH) electricity consumption in Aragón (2025–2035) by sector. More information is available in the supplementary materials. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

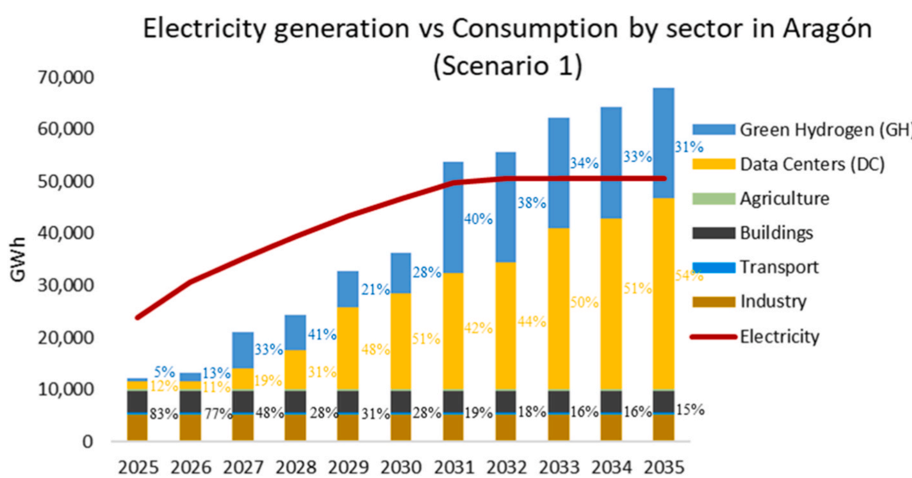

Fig. 5. Electricity generation vs consumption by sector in Aragón for Scenario 1 (all planned renewable electricity projects in Aragón are installed in time). The red line shows the annual electricity generation whereas the bars highlight the electricity demands per sector. More information is available in the supplementary materials. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

transition entails significant land occupation to supply renewable energy. This aspect is analyzed in the first subsection (section 3.2.1). In addition to land occupation, the other major environmental impact is the increase in water consumption for DC cooling and GH production. This is analyzed in the second subsection (section 3.2.2).

3.2.1. Land occupation by renewable technologies

Fig. 6 shows graphically the land occupied by renewable energy technologies in 2035 with respect to the Aragón's total surface area (47,719 km^2), under the three scenarios (Table 4) and minimum and maximum due to technological uncertainties. Land occupation is shown in percentage occupied by sector: data center, green hydrogen or other uses (industry, transport, buildings, and agriculture). For each sector, the area occupied in km^2 by wind or photovoltaic technologies is also shown, respectively. Finally, the renewable electricity balance is shown to compare the differences between each scenario.

Scenario 1 considers the installation of all requested renewable projects, which means that the surface occupied by renewables is expected to double in just three years (Fig. 2). Under this scenario, between 9.2 and 12.5 % of Aragón's surface would be covered by renewable technologies. However, even with full installation, regional electricity demand could not be fully met due to the increase in GH production and DC and 17 TWh should be imported (see Fig. 6). Therefore, Scenario 2 considers the installation of additional wind and photovoltaic capacity to cover this demand gap (see renewable electricity balance is equal to 0 TWh, in Fig. 6). In this scenario, between 12 and 16 % of Aragón's surface would be covered by renewables. Finally, Scenario 3 covers the electricity demand of 8 GW of DC (as announced by the Government of Aragón (Faci, 2024)) apart from GH and other uses. Therefore, under this scenario, between 29 and 39 % of Aragón's land would be covered by renewables. In all the scenarios, the area required to power DC is the largest: 5.0–6.7 % in scenario 1, 6.8–9.2 % in scenario 2 and 24–32 % in scenario 3. The second largest area is for GH: 2.9–3.9 % in scenario 1, and 4–5.3 % in scenarios 2 and 3. The smallest area corresponds to current uses, only between 1.4 and 1.8 %. All these values take into account Aragón's total surface area, meaning they include unsuitable zones for renewable technologies such as protected areas or mountains. Furthermore, land occupation would go even further because new power lines and roads needed for renewable deployment were not considered in this study.

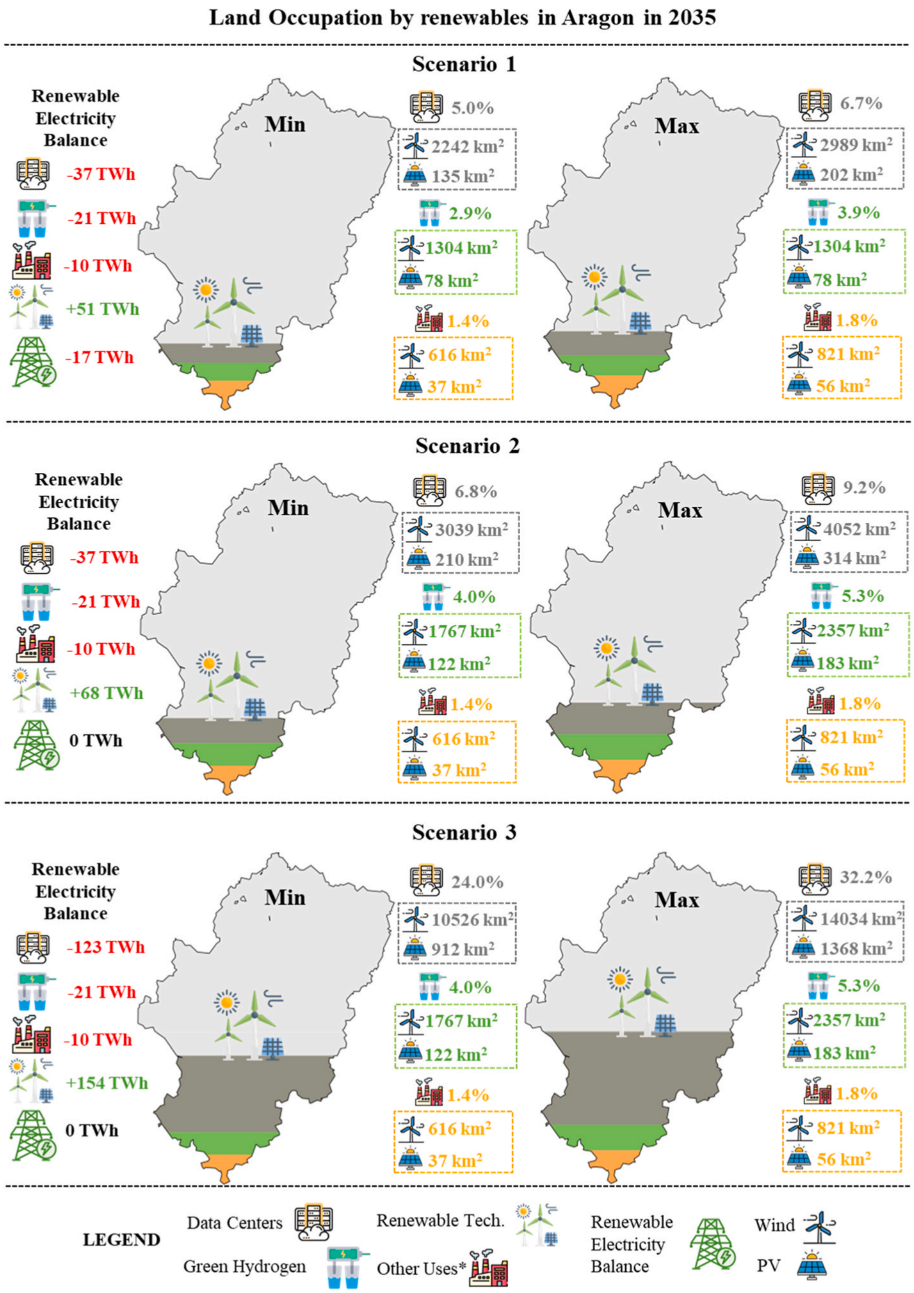

Fig. 6. Land occupation in 2035 due to renewable technologies for green hydrogen (GH), data centers (DC) and other uses. Min and max scenarios are calculated with data from Table 5. Total surface of Aragón: 47,719 km2 *Other uses include Industry, Transport, Buildings, Agriculture. More information is available in the supplementary materials. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

3.2.2. *Water consumption*

Fig. 7 shows water consumption in 2035 under the different scenarios. Water consumption is broken down by use: data centers (DC) and green hydrogen (GH). Additionally, this water consumption is compared with the average water consumption of Aragón's economic sector between 2010 and 2022, which includes water distributed but not consumed by households and municipalities. We use this comparison because 97 % of the water consumed by major DC operators is sourced from municipal drinking water systems (Privette et al., 2025; Mytton, 2021). Scenario 2 is not included because it is identical to Scenario 1 in terms of water consumption.

The announced DC consume between 4.6 and 21.0 hm^3 per year, a value similar to the 4–14 hm^3 per year estimated by other studies (Lobera Segurado, 2025). Considering that DC occupy 965 ha (see Table 1) and consume 4.6–7.3 hm^3 in Scenario 1, water consumption per hectare is 5000–8000 m^3/ha. These figures are comparable to irrigation water consumption in Aragón. According to the Ebro River Basin Hydrological Plan (Aragón's main river) (Ebro River Basin Confederation (CHE)),000 new hectares of irrigation are planned, which would require an additional 400 hm^3 of water (Calvo Lamana, 2025), equivalent to 7143 m^3/ha. Therefore, it can be stated that 1 ha of DC will likely consume water on a scale similar to 1 ha of irrigated land. However, DC water consumption could come from drinking water, as other studies warn (Privette et al., 2025; Mytton, 2021). In this case, the comparison with irrigated water would not be consistent.

On the other hand, water consumption for GH (6.4–12.3 hm^3 per year), is higher compare to DC water consumption in scenario 1 and 2, but lower in scenario 3. This is because Scenario 3 represents a great expansion of DC. In scenarios 1 and 2, the total DC and GH water consumptions add up to between 11 and 20 hm^3, representing a 41–73 %

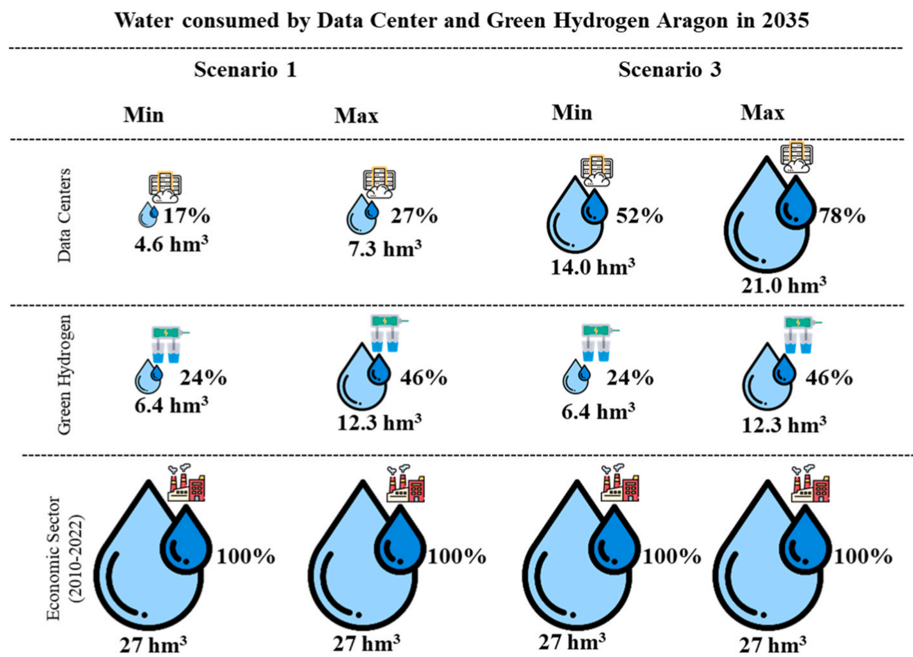

Fig. 7. Water consumption in 2035 due to green hydrogen and data centers. Consumption varies between 15.9 and 30.7 m3/ton for green hydrogen, and between 0.2 and 0.3 l/kWh (WUE) for data centers (see Sections 2.1 and 2.2.) *Average water consumption (2010–2022) by the economic sector (includes water not consumed by households and municipalities): 27 hm3. Source: (Spanish National Institute of Statistics). More information is available in the supplementary materials. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

increase compared with current water consumption in Aragón's economic sectors. However, in Scenario 3 yearly water consumption would raise to 20–33 hm^3, representing a 76–124 % increase over current water consumption in Aragón's economic sectors. Thus, in this scenario, DC projects water consumption (14–21 hm^3) would exceed GH (6.4–12.3 hm^3).

Furthermore, it is important to highlight that DC water use is highly seasonal, as it is intended for cooling. Thus, most of the demand would occur during the summer drought typical of the Mediterranean climate, increasing pressure on this resource precisely when water demand is highest for other activities such as agriculture (2000 hm^3 per year) and livestock farming (5500 hm^3 per year) (Valero Llop, 2023). This could lead to future conflicts over water.

4. Discussion: Project priority and policy implications

The main novelty of this study is to place the region at the centre of the research, rather than technologies, as numerous previous studies have done for both GH (Tonelli et al., 2023; Kakoulaki et al., 2021; Chigbu and Nweke-Eze, 2023; Sedai et al., 2023; Cheng et al., 2023) and DC (Kollar and Grady, 2025; Privette et al., 2025; Li et al., 2023; Zhu et al., 2023; Khosravi et al., 2024; Mytton, 2021; Jiang et al., 2025; Shumba et al., 2025; Siddik et al., 2021; Lei and Masanet, 2022; Jerléus et al., 2024), or even in Aragón for GH (Manzano et al., 2025) or DC (Lobera Segurado, 2025). This territorial perspective introduces several important advantages.

First, our study provides micro-level data for DC within a specific region. Such detail is crucial, as variations of only a few kilometers within the same country can significantly change the impacts of a DC (Turek and Radgen, 2021). Consequently, bottom-up information is essential for estimating the global footprint of DC (Masanet et al., 2020), and this research may contribute to such efforts in the future. Moreover, the study includes data on the water consumption of DC in the region (Table 2), which is particularly relevant given the limited transparency of operators reported in other studies (Privette et al., 2025; Mytton, 2021; Lei and Masanet, 2022).

Second, studies focusing exclusively on GH (Tonelli et al., 2023; Kakoulaki et al., 2021) tend to adopt relatively optimistic perspectives, as they do not consider other parallel consumptions such as DC. For instance, Kakoulaki et al. (2021) suggests that the substantial surplus renewable potential of certain European regions (such as Aragón) could be harnessed for GH production. Meanwhile, Tonelli et al. (2023) estimates that the global water consumption associated with GH does not appear to pose a major challenge. For example, the water required globally for GH would amount between 3.2 and 95.6 billion m^3 which is minimal compared to 10,560 billion m^3 (Tonelli et al., 2023); however, the study emphasizes potential conflicts at regional or local scales. Specifically, it identifies Western Europe as one of the most vulnerable areas due to resource scarcity, which includes Aragón. Thus, this study offers a more comprehensive view as it considers the future consumptions of the twin transition simultaneously.

Third, other studies have proposed renewable energy to reduce the environmental impact of DC (Khosravi et al., 2024; Rajendra, 2022; Ewim et al., 2023). Although we agree with this proposal, such studies lack a territorial perspective and therefore do not consider the local environmental and social impacts of the renewable technologies used to power these DC, which are related to land, water, opposition from local population, biodiversity loss, etc (Mingolla et al., 2024; Duarte et al., 2022a, 2022b; Gayen et al., 2024). Accordingly, this study incorporates the concerns about land and water consumption raised by the large-scale deployment of renewable energies to power DC.

Finally, the advantages of our approach enable a comprehensive analysis of environmental, economic, and social effects within a specific territory, in this case Aragón. This facilitates the development of a priority matrix (Section 4.1) and a holistic planning framework that accounts for territorial characteristics (Section 4.2).

4.1. Project prioritization criteria

According to the collected information and our results, the resources requirements for the twin transition in Aragón are overwhelming. For instance, by 2035, electricity demand in Aragón could increase 6-fold–15-fold; land occupied by renewable technologies could range between 9.2-12.4 % and 29–39 %, whereas water consumption between 11 and 20 hm^3 to 20–33 hm^3. Therefore, Table 6 shows a priority matrix, illustrating how environmental and socioeconomic impacts vary when prioritizing GH (energy transition) or DC (digital transition) projects with or without renewables in the context of Aragón.

Table 6 shows how prioritizing GH projects results in more moderate environmental impacts compared to DC. This is because they consume less electricity (Fig. 5), and therefore less required land occupation (Fig. 6). However, water demand can be higher (6.4–12.3 hm^3 for GH compared to 4.6–7.3 hm^3 for DC). Despite this, the priority of GH infrastructures is key to decarbonization, as hydrogen can potentially replace fossil fuels in applications that are difficult to electrify. Regarding socioeconomic criteria, GH projects are characterized by a strong dependence on public funds (€800 million compared to the total €4.6 million (Table 3)) and the potential to create more long-term local jobs than DC projects. However, GH projects present significant risks for its implementation, as 75 % of the power corresponds to a macro-project (Catalina, see Table 3), besides the technological uncertainty and the current levelized costs of hydrogen (LCOH) (Pingkuo and Junqing, 2024; McGregor et al., 2025). Due to this increased uncertainty, the development of projects linked to the green transition should be prioritized compared to DC because of their important role in decarbonization.

On the other hand, Table 6 shows that prioritizing DC projects would produce more environmental impacts, which are variable depending on the deployment of renewable energy sources. The use of these technologies in DC should be prioritized since not only increase decarbonization but also moderate water consumption, despite the increase in land use which is discussed below. The relationship between water footprint and decarbonization is important due to indirect water consumption during electricity production from fossil sources (Privette et al., 2025; Mytton, 2021; Jiang et al., 2025; Siddik et al., 2021). For example, in Chinese regions with a high percentage of fossil electricity, 44 % of the DC water footprint was due to electricity production, while this percentage dropped to 13 % in regions with more renewable electricity (Jiang et al., 2025). However, other studies suggest that indirect water consumption for electricity generation could be higher, reaching between two-thirds (Privette et al., 2025) and three-quarters (Siddik et al., 2021) of DC total water footprint.

Despite the environmental drawbacks of fossil electricity and due to the extreme electricity consumption projected by DCs in Aragón, the reactivation of a 402 MW combined cycle plant in Escatrón (Aragón) was recently announced (Colliers, 2025b). However, this plant's power capacity would still be insufficient given the enormous demand: 2790 MW for DC (Table 1). Furthermore, DC require a continuous electricity supply, casting doubt on whether they can be fully powered by renewables due to the duck curve effect (Schmalensee, 2022). Therefore, non-renewable backup energy or massive storage installation would be required if the installation is carried out at the proposed magnitude and pace. This issue might also cause future problems in the power grid (Paccou and Wijnhoven, 2025), such as those experienced in the Iberian blackout of April 2025 (Spanish Government). The option of importing electricity also raises questions about its viability, since neighboring regions, such as Catalonia or Basque Country, have significantly less

Table 6
Priority matrix of twin transition in Aragón (2025–2035).

Criteria	GH Priority	DC Priority (with renewables)	DC Priority (without renewables)
Electricity consumption	Moderate	High	High
Land occupation	Moderate	High	Moderate
Water consumption	High	Moderate	High
Decarbonization	High	Moderate	Low
Public Investment	High	Low	Low
Private Investment	Low	High	High
Employment	Moderate	Low	Low

available land for renewables deployment, as well as having higher populations and energy consumption (Wikipedia Most Populated Metropolitan Areas). The energy problem in DC is not unique to Aragón, since several DC companies are considering the use of nuclear energy to power their facilities (International Energy Agency, 2025; Gröger et al., 2025). Therefore, it is unlikely that all of the electricity consumption of DC in Aragón can be covered by renewables due to the above facts and reasons, coupled with the large area that would need to be occupied by renewables for this purpose alone (see Fig. 6). Thus, the large-scale expansion of DC would represent a significant setback in the energy transition.

Regarding socioeconomic criteria, Table 1 highlights the massive private investment in DC projects, which could reach €47,900 million. These values are considerable, considering that Aragón's GDP was €46,700 million in 2023 (Expansión). Because of these strong investments, the government has declared several of these projects to be of interest to Aragón (PIGA or DIGA). Furthermore, these projects are promoted by large global companies such as AWS or Microsoft, increasing the chances of DC being installed compared to GH projects. On the other hand, the limited local employment and wealth they generate combined with environmental concerns (estimated in Figs. 6 and 7), are raising local opposition (El Pais, 2025).

In summary, there are serious doubts about the compatibility of green and digital transitions due to the large area required to supply DC with renewables and the proposals to use fossil fuel plants in Aragón and nuclear plants elsewhere. Whether with or without renewables, prioritizing the mass installation of DC would mean sacrificing a large part of the territory for an undefined period of time; either in terms of land (renewables) or in terms of water and carbon footprint (non-renewables). Apart from Aragón, other regions such as Extremadura (Spain), which also has a high electricity generation capacity, have plans to install 2500 MW of DC (Colliers, 2025a). In this sense, there is a clear trend toward using renewable electricity produced in regions with favorable characteristics to power DC and AI, rather than providing clean energy for the green transition. Therefore, to avoid the worst consequences of this trend, it would be necessary to implement plans with policy implications.

4.2. Policy implications

Faced with the dilemma between green and digital transitions, the climate change emergency leaves no doubt about the priority that should be given to the green transition (Mneimneh et al., 2023), despite the trends discussed in the previous section. However, for this priority to become reality, proper comprehensive planning is required. Currently, there are European (European Union), Spanish (MITERD, 2023; MITERD, 2020a; MITERD, 2020b; MTDFP, 2024) and Aragonese (Government of Aragon) plans that set targets for renewable capacity (MITERD, 2023; MITERD, 2020a), green hydrogen (MITERD, 2020b), electric vehicles (MITERD, 2023) and DC installation (MTDFP, 2024). However, these plans do not take the others into account due to differences in the scale of the studies (Europe, Spain, or Aragón) and differences in the analyzed sectors (electricity, hydrogen, mobility, or data centers). In other words, they do not consider the joint deployment of twin transition technologies, the specific characteristics of regional territories, or their interconnection with other regions. Thus, the existence of so many separate plans result in the opposite outcome: there is no comprehensive plan. In Aragón's case, these inconsistencies are reflected, for example, in the fact that the renewable capacity target of the Aragón Energy Plan (PLEA) for 2030 (Government of Aragon) could be reached much earlier (see Fig. 2), showing that these plans are not being met.

Therefore, for the success of the twin transition, we recommend comprehensive, integrated planning that prioritizes green transition infrastructure and limits the installation of DC to the deployment of renewables, along with their storage, guaranteeing grid stability and avoid the use of fossil fuel backup energy. Thus, under no circumstances should the use of non-renewable energy be considered in the future. On the other hand, the deployment of renewables for use in DCs must also be adapted to the characteristics of the territory without exceeding certain land-based deployments to protect biodiversity. Corporate requirements should be subordinated to this DC limitation, which is related to concepts such as *digital sufficiency* and *sustainable digitization*, proposed by other authors (Bergman and Foxon, 2025). Furthermore, compensation should be proposed for the regions most affected by this transition in order to mitigate the worst economic and environmental effects.

Thus, the framework of this plan should consider all aspects of the transition: *technical* aspects (e.g. renewable electricity technologies, green hydrogen production, electric vehicles, data centers, etc.), *territorial* aspects (supply chains including mining and recycling, renewable resources, population distribution, interregional interconnections, etc.) and *ecological* aspects (e.g. mitigation of biodiversity loss, prevention of resource scarcity for future generations, less natural CO2 capture, human appropriation natural net primary production, etc.). The current situation in Aragón could serve as a reference for potential changes caused by the twin transition in other regions of the world with similar characteristics.

5. Conclusions

This work poses the question: is there room to accommodate the twin (digital and green) transition when considering specific territories? While many studies focus on global requirements, reality operates on a smaller scale, where regional characteristics (wind, sun, availability of land, and renewable energy surplus due to low population density or regional interconnections) and political conditions are key to attracting green hydrogen (GH) and data center (DC) projects. In this sense, the main novelty of this work is to study a region, in this case Aragón, as an example of how the twin transition infrastructures, GH and DC, can simultaneously affect territories rich in renewable resources at the local level.

The data collected and the results of this study are alarming. Electricity demand could increase six to fifteenfold in the next decade only based solely on GH and DC projects, without accounting for other rising uses such as electric mobility. Considering the requested installation of renewables in Aragón, 9–12 % of total area would be covered by renewable, but 17 TWh would need to be imported (Scenario 1). On the other hand, if the total demand for maximum DC deployment is met (Scenario 3), up to 29–39 % of Aragón's total area would be covered. Regarding water consumption, it could increase by 11–33 hm^3, representing 41–124 % of the water consumption of Aragón's economic sector. This situation is shared by other Spanish regions with similar characteristics, such as Extremadura, where data centers installation on a scale similar to Aragón is expected.

The magnitude of these figures casts doubt on the compatibility of the green and digital transitions at the current pace. This leads us to raise a disturbing question: if precisely the territories with the most renewable surplus are used to power DC and AI, what resources will actually be used for the urgent green transition? Consequently, we recommend comprehensive, integrated planning that prioritize green transition infrastructure and limit DC installation to the development of renewable energies and their land occupation to protect biodiversity. Corporate requirements should be subordinated to this planning, and compensation should be proposed for the regions most affected by the transition.

The framework of this planning should consider all aspects of the twin transition: *technical* (e.g., renewable electricity technologies, hydrogen production, electric vehicles, data centers, etc.), *territorial* (e.g., supply chains including mining and recycling, renewable resources, population distribution, interregional interconnections, etc.) and *ecological* (mitigation of biodiversity loss, prevention of resource scarcity for future generations, less natural CO2 capture, human appropriation natural net primary production, etc.). Thus, the example of Aragón in the context of the twin transition can serve as a reference for other regions with similar characteristics.

CRediT authorship contribution statement

Jorge Torrubia: Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Alessandro Lima:** Writing – review & editing, Validation. **Alicia Valero:** Writing – review & editing, Supervision, Funding acquisition. **Antonio Valero:** Writing – review & editing, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.enpol.2025.115061.

Data availability

Data will be made available on request.

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