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Open Energy Data in Spain and Its Contribution to Sustainability: Content and Reuse Potential

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Abstract

This paper presents a study on open energy data in Spain and its contribution to sustainability, analyzing its content and its reuse potential. Since energy plays an important role in the sustainability and economic development of a country or region, energy strategies must be managed through public policies that promote the development of this sector. In this sense, open data is relevant for decision-making in the energy sector, especially in areas such as energy consumption and renewable energy policies. Our research aims to analyze the work of Spain's autonomous communities in the field of energy information by conducting a population analysis of all datasets tagged in the energy category. After compiling the information and eliminating irrelevant datasets (those that are mislabeled, obsolete, or have a scope less than the level of the autonomous community), it can be seen that the supply is very scarce and that this category is one of the least populated among all existing categories. The typological analysis indicates that information on consumption is the one offering the most datasets, followed, at a short distance, by heterogeneous and difficult-to-classify information and by the set related to energy certificates or audits (the most recurrent, as it is offered only once by the autonomous communities). One of the main findings of the research is the heterogeneity of the initiatives and the significant differences in scores on an indicator created for this purpose. The ranking has taken into account both the existence of information and the quality of reuse, with Catalonia, the Basque Country, and Cantabria being the leaders (with Castilla y León, the performance reaches 60%, so the three remaining communities do not reach 40%). The research concludes with recommendations based on the gaps detected: more data should be published that can drive economic development and environmental sustainability, reduce heterogeneity, and facilitate the use of these data for greater applicability, which will increase the chances that open energy data can contribute more to sustainability.

Keywords: Spain; open data; energy; reuse; sustainability; economic development

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1. Introduction

Within open government, a model of open government consolidated worldwide [1], open government data are gaining prominence over other more lagging pillars such as participation or citizen collaboration [2]. The aim of this open data is to provide data held

by public administrations in machine-readable formats and free of charge [3] so that they can be reused for various purposes [4,5].

It is understood that disclosing data held by public administrations is an exercise of corporate social responsibility and, as indicated by Araújo et al. (2023) [6], it should be promoted as follows. The initiative has gained momentum in recent decades, allowing a wide audience such as businesses, civil society, journalists, public sector agencies, non-governmental organizations and academia to act as consumers of data [7,8], reusing it or developing applications and services based on such open data [9].

A report prepared at the request of the European Commission has estimated that the size of the open data market in the EU27+ will range from EUR 199.51 billion to EUR 334.2 billion (optimistic framework) by 2025 [10]. However, the value of open data goes beyond that. The reality is that data has unprecedented economic value, being the basis for informed decision-making [11] by data-driven companies making strategic decisions based on data analysis and, by the application of marketing 4.0 initiatives, "the marketing of big data [12]".

Although data is the future, as it serves as input for artificial intelligence models that rely heavily on the availability of this open data [13], the inverse relationship is currently being explored, i.e., how AI can contribute to the improvement of open data initiatives, such as the eight aspects highlighted by Nikiforova (2025) [14]. In any case, the paradigm shift in the disclosure of government information from a passive one (only when requested) to a proactive or "default" one is not surprising [15]. Although the literature shows positive impacts of open data on transparency and democratic systems [16], the systematic review by Bendechache et al. (2023) [17] on its value shows that the field is still immature and lacks commonly accepted terminologies, approaches and models, so open data initiatives face significant challenges [18] and significant organizational, technological, and legal barriers [19].

Despite this, the initiative has been consolidated by offering, in a general way, open data through online platforms [20], also called repositories or open data portals, that are used to store, share and visualize [21] data accompanied by a series of additional metadata [22] that contextualize the information and give it greater value.

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Through the systematic evaluation of the provision and reuse of open energy data in Spanish autonomous communities, this study aims to report on best practices and policy recommendations that can improve data-driven sustainability initiatives. Existing research has not systematically compared the formats, accessibility, and reuse potential of energy datasets published by Spanish autonomous communities, nor has it assessed their alignment with sustainability goals.

2. Framework

Spain can be identified as a powerhouse in open data portals, with 279 of the 3000 existing worldwide [23].

In the absence of specific supranational studies on open data in the energy field, and with the aim of illustrating Spain's overall position on open data in comparison with other countries, reference is made to two studies.

The first, conducted by the European Open Data Portal Open Data Maturity, reveals that Spain has been a clear leader, ranking second for the period 2017–2020. Although it has fallen slightly to fifth place in 2023, for example, it remains a leading country.

For its part, the study carried out by the European Agency for Economic Development Cooperation, entitled OURData, also points to Spain as a leading country, rising from sixth place in 2017 to fifth in 2023 (behind only South Korea, France, Poland, and Estonia).

However, research on open data in this country is not very widespread since a search in the Scopus database with the keywords Spain OR Spain AND open data OR open data returned only a hundred results. Only two of them are related to energy: a predictive model of residential energy consumption in Andalusia [24] and a numerical evaluation of the energy efficiency of an open-joint ventilated facade [25]. It seems to scarcely pay attention to a topic as relevant as energy, which impacts the most everyday comforts of people (and in their pocket), is crucial for the operation of companies, and presents a marked environmental impact closely related to sustainability.

However, it seems that attention to open energy data is growing, as at the recent EU Open Data Day 2025, San Hawkins' speech highlighted its importance in the transition to clean energy, noting the lack of availability of several vital datasets such as systematic records of electric vehicle chargers, batteries, and heat pumps [26].

Energy plays a crucial role in sustainability. Replacing fossil fuels with more efficient renewable energies will help reduce greenhouse gas emissions, combat climate change, and improve public health. Governments are aware of this and have begun to develop environmentally friendly energy consumption standards [27].

Open data is accelerating the energy transition [28], as it facilitates public awareness and improves the standardization of metrics and mechanisms for measuring the impact of measures taken to mitigate climate change globally [29], and enables collaboration between scientists and citizens to innovate or create innovative solutions.

An example of the application of open data to energy production is provided in Barrera et al. (2020) [30]. The authors analyze how various factors influence energy production forecasts and how open data can be utilized to predict expected production from sustainable sources. Thus, the availability of open data goes beyond contributing to a country's political, social, and economic development.

This open data is especially relevant when it relates to energy, as information on energy consumption or the existence of renewable energy sources is essential for better decision-making in urban planning practices [31]. A relevant case can be found in the Spanish city of Gijón, where the study by Díaz et al. (2024) [32] shows that the incorporation of free and detailed open data has improved the understanding of how the urban bus network works, favoring the gradual replacement of traditional buses with electric buses, contributing to a significant reduction in energy consumption.

For all these reasons, and in order to address this gap in the literature, it seems of interest to us to consider the main research question: How is the provision of energy information being made in Spain through open data? Other issues of interest are also addressed, such as the following: Is there a dominant typology? Are the data really reusable? Can leaders be identified in terms of open data dissemination? The research is novel in that it focuses on open data, a new form of disclosure by public administrations that prioritizes the use of reusable formats and free licenses, since it has been proven that access to quality open data is recognized as a key factor for informed decision-making, transparency, and the advancement of sustainability goals [33].

In order to try to answer these questions, the manuscript continues in the following section, describing the methodology used and accompanied by the main results achieved, which are discussed prior to the presentation of conclusions that precede the bibliographical references used to close the work.

3. Materials and Methods

Spain is considered a quasi-federal country [34], a country with three levels of government—central, autonomous communities, and local entities—where the autonomous communities manage a volume of spending that exceeds 35%. However, these autonomous regions are very different from each other in terms of population, cultural identity, income per capita, etc., and also present a great disparity in the quality of these governments [35]. This fact, together with the scarcity of works that evaluate their performance in terms of open data, has led us to select the Spanish autonomous regions as the focus of the work, whose first approximation is shown in Table 1.

Table 1. Name of the portals, autonomous communities, and their content in the number of datasets in October 2024.

Autonomous Communities	Portal Name/Web Address	Datasets	Download API
Andalusia	Open Data https://www.juntadeandalucia.es/datosabiertos/portal/ (accessed on 12 Juny 2025)	979	NO
Aragon	Aragón Open Data https://opendata.aragon.es/ (accessed on 12 Juny 2025)	2849	YES
Balearic Islands	Dades obertes caib https://www.caib.es/sites/opendatacaib/es/inicio_home/?campa=yes (accessed on 12 Juny 2025)	363	NO
Cantabria	Icane—data https://datos.icane.es/ (accessed on 12 Juny 2025)	291	NO
Castilla y León	Castilla and Leon Open Data https://datosabiertos.jcyl.es/web/es/datos-abiertos-castilla-leon.html (accessed on 12 Juny 2025)	744	YES
Castilla-La Mancha	Castilla- La Mancha Open Data https://datosabiertos.castillalamancha.es/ (accessed on 12 Juny 2025)	346	NO
Catalonia	GenCat Open Data https://portaldadesobertes.gva.es/es (accessed on 12 Juny 2025)	1279	YES
Com. Foral de Navarra	Open Data https://gobiernoabierto.navarra.es/es/open-data (accessed on 12 Juny 2025)	1586	YES
Community of Madrid	Community of Madrid Open Data https://www.comunidad.madrid/gobierno/datos-abiertos (accessed on 12 Juny 2025)	250	NO
Comunidad Valenciana	Dades obertes gva https://portaldadesobertes.gva.es/es (accessed on 12 Juny 2025)	1494	YES
Extremadura	Open Government—Data Catalog http://gobiernoabierto.juntaex.es/datos/ (accessed on 12 Juny 2025)	13	NO
Canary Islands	Canary Islands Open Data https://datos.canarias.es/portal/ (accessed on 12 Juny 2025)	20,856	YES
Galicia	abert@s https://abertos.xunta.gal/portada?langId=es_ES (accessed on 12 Juny 2025)	512	NO
La Rioja	Rioja Open Data https://web.larioja.org/dato-abierto (accessed on 12 Juny 2025)	528	YES

Table 1. *Cont.*

Autonomous Communities	Portal Name/Web Address	Datasets	Download API
Basque Country	Open data Euskadi https://opendata.euskadi.eus/inicio/ (accessed on 12 Juny 2025)	12,493	YES
Principality of Asturias	Open Data of the Principality of Asturias https://transparencia.asturias.es/web/gobierno-abierto (accessed on 12 Juny 2025)	1387	NO
Region of Murcia	Open Data Murcia Region https://datosabiertos.regiondemurcia.es/ (accessed on 12 Juny 2025)	975	YES
TOTAL DATASETS		40,096	

With the only exception of the Asturian initiative, which is a poorly developed and not at all operational portal that has led it to deposit the datasets in the national portal, the rest of the autonomous regions have an efficient initiative, so their repositories have been visited (Table 1) in order to show the labeling of the information (Table 2) as indicated by the technical standard of interoperability [36].

Table 2. Datasets labeled by each Spanish autonomous region.

Category/ CC.AA.	VAS	CAT	CTL	CNT	VAL	MUR	CNR	AND	CTM	NAV	RIO	ARA	AST	MAD	BAL	EXT	GAL
Science and Technology	290	17	10	0	0	21	463	15	8	28	1	71	18	0	2	0	39
Commerce	122	15	6	6	0	10	85	16	9	9	1	67	136	0	0	0	0
Culture and Leisure	654	39	24	0	8	39	81	35	31	22	1	144	6	10	0	2	81
Demographics	1432	33	25	10	38	97	4707	32	9	6	10	65	654	12	5	0	0
Sports	44	9	7	16	1	8	11	10	8	8	0	38	2	0	1	0	0
Economy	1816	72	16	9	41	42	793	49	45	153	65	117	176	2	8	7	196
Education	195	50	24	15	78	33	111	31	22	8	3	969	3	4	2	1	45
Employment	909	55	28	18	173	7	7046	113	25	11	39	280	115	1	5	0	30
Energy	63	18	17	11	9	7	6	5	5	4	4	3	3	2	**0**	**0**	**0**
Finance	4789	14	7	5	2	63	14	30	18	89	51	48	0	1	10	0	0
Industry	108	16	3	26	4	5	166	13	9	6	6	110	55	0	3	3	0
Legislation and Just.	65	40	2	0	42	2	216	57	28	12	5	60	5	10	13	0	0
Environment	882	52	167	9	752	189	239	268	61	561	179	179	136	114	183	3	54
Rural Environment	646	222	59	0	14	1	380	30	55	67	14	36	57	0	11	0	0
Health	191	63	92	14	50	65	2691	12	48	129	68	274	54	18	26	0	86
Public Sector	4562	167	115	4	49	281	899	154	66	529	17	169	43	27	30	0	78
Security	139	118	3	0	0	0	60	9	5	3		23	1	0	0	0	0
Society and Welfare	1473	108	18	0	11	75	2386	19	20	99	10	49	63	11	1	3	0
Transportation	458	55	25	11	31	39	179	14	12	239	10	32	7	29	3	0	9
Tourism	417	40	28	9	7	35	1385	19	38	23	1	50	42	2	9	0	0
Urbanism and Infrastructure	573	65	14	0	170	8	118	14	10	435	37	24	17	7	29	0	19
Housing	568	9	0	8	14	0	143	5	8	22	7	40	26	0	4	0	153
Total Categories	20,396	1277	690	171	1494	1027	22,179	950	540	2463	529	2848	1619	250	345	19	790

Note: VAS, Basque Country; GAL, Galicia; CTL, Castilla and Leon; CNR, Canary Islands; ARA, Aragon; AST, Principality of Asturias; MUR, Region of Murcia; NAV, Community of Navarra; VAL, Valencian Community; CAT, Catalonia; CNT, Cantabria; MAD, Community of Madrid; CTM, Castilla-La Mancha; RIO, La Rioja; AND, Andalusia; EXT, Extremadura; BAL, Balearic Islands. Source: Own elaboration (2025).

Let us compare the data in the last row of Table 2, which totals the sum of categories with the total autonomous community content offered (Table 1). It can be observed that some autonomous regions present a single labeling of the datasets (e.g., La Rioja), while others appear to have multiple labels (e.g., Basque Country). In contrast, others leave datasets unlabeled (e.g., Balearic Islands). This aspect will have an impact on the results and their subsequent analysis below for the category under study: "Energy".

4. Results

As shown in Table 2, only three autonomous communities do not contain datasets in the energy category: Balearic Islands, Extremadura, and Galicia. For the rest, a brief summary will be made according to the alphabetical order of each autonomy (the collection was carried out by visiting the aforementioned repositories throughout October 2024).

4.1. Andalucía

Firstly, it can be seen that the Andalusian repository's home page only offers twenty shortcut icons (out of the twenty-two corresponding to the categories of the technical interoperability standard), with housing and energy missing. However, after accessing the data catalog and filtering by activity sectors, it can be seen that there are datasets in these categories and that the absence of shortcut icons on the home page is an error.

Thus, five datasets labeled in the energy category can be found, although four do not appear to be related to the topic (probably because they are labeled in multiple activity sectors): "Spatial reference data of Andalusia", "Statistical Yearbook of Andalusia", "Multi-territorial information system of Andalusia", and "System of indicators of sustainable development of Andalusia for the 2030 Agenda". On the other hand, the last one is of interest. It is the "Register of Energy Certificates of Andalusia". It is composed of eight files (one for each province) that, in xml format, provide information on the identification of the building and its energy data: general data and geometry, thermal installations, lighting installations, renewable energies, demand, consumption, CO_2 emissions, and rating.

4.2. Aragon

It has three datasets in the energy category. The first one is called "Renewable energy data in Aragon" and offers information on projects and facilities for the production of electricity from renewable energies (wind and photovoltaic energy). This dataset offers segmented information in geojson, csv, xml, xls, and mapview formats on projects (wind projects with prior authorization and construction, wind projects admitted for processing, wind project origin status, protected wind projects, wind projects pending admission for processing, photovoltaic projects with construction authorization, photovoltaic projects admitted for processing, and protected photovoltaic projects) as well as wind farms or plants (wind farms in operation or photovoltaic plants in operation).

The second dataset is called "Technicians and companies competent to issue energy efficiency certificates for buildings." It includes the register of companies and technicians authorized for this purpose, which is accompanied by "Aragon's Energy Efficiency Certification Register for Buildings", which allows information to be downloaded at the autonomous community level or broken down by province. These two datasets are available in json, csv, xml, and xls formats.

4.3. Basque Country

The autonomy category has the most datasets labeled in the energy category; however, two-thirds must be discarded because they do not present any relationship, such as goods transport statistics or material flow statistics. In addition, some datasets do not present autonomous content, such as the "Solar power study", whose supplier is the city council of Vitoria-Gasteiz.

Based on the above, the number of datasets to be reviewed decreases from the initial sixty-three to twenty-one, starting with a group of eight datasets called municipal sustainability indicators available for download in lod, api, rest, xls, and csv, which are "Energy", "Annual non-industrial electricity consumption", "Installed solar thermal area", "Installed wind power", "Annual electricity consumption of the industrial sector", "Annual elec-

tricity consumption of the municipality", "Installed photovoltaic power", and "Installed hydraulic power".

Below are six other datasets related to consumption: "Primary energy consumption of the autonomous community of Euskadi and European Union countries", "Final energy consumption of the autonomous community of Euskadi by sectors", "Gross domestic consumption of the autonomous community of Euskadi by types of energy", "Final energy consumption of the autonomous community of Euskadi by historical territories", Final energy consumption of the autonomous community of Euskadi by types of energy", and "Final energy consumption by countries", all of them in xls and csv format.

Six of the seven remaining datasets are also available in xls and csv. They are "Magnitudes of the industry and energy sector of the autonomous community of Euskadi by historical territory", "Magnitudes of industry and energy of the autonomous community of Euskadi by activity A21 and historical territory", "Profit and loss account of the industry and energy sector of the autonomous community of Euskadi by historical territory", "Profit and loss account of the industry and energy sector of the autonomous community of the Basque Country by A21 activity and historical territory", "Energy intensity of the autonomous community of the Basque Country and the countries of the European Union", and "Energy dependence of the autonomous community of the Basque Country and the countries of the European Union". The offer is completed with "Climate change and energy transition" available in csv and sav (SPSS statistical package format).

4.4. Principality of Asturias

It has three datasets within the energy category, syndicated, like all its offerings, on the national portal datos.gob.es.

First, there is "Energy industry in Asturias: production, transport and consumption of energy", which, in html format, provides access to a form that allows visualization of the information.

In the second place, there are the "Certificates of energy efficiency of buildings and dwellings", which, in xls format, provides information on buildings and/or dwellings when they are built, sold, or rented (currently only data are available for files processed up to 13 August 2017, and those corresponding to 20 September 2018), being therefore outdated.

Finally, there are the "Indicators of the Sustainable Development Goals in the Principality of Asturias" (html, xls, and zip formats), a set of data labeled in the twenty-two categories mentioned in the technical standard for interoperability and which is of a more general nature.

4.5. Canary Islands

The Canary Islands offers six datasets within the energy category. However, the dataset "Sustainable development indicators for the Canary Islands" (zip and xls formats) has a more general content. It is labeled in the twenty-two categories included in the technical standard.

In relation to energy, the following stand out: "Energy consumption of the Cabildo de Tenerife", available in json and csv formats; "Energy produced and consumed in photovoltaic plants and wind farms in Tenerife" (json and csv); "Energy generation infrastructure in Tenerife (geopackage, geojson, csv, and json)"; and "Energy produced and consumed in photovoltaic plants and wind farms in Tenerife (json and csv)." In terms of autonomous community content, there are "Photovoltaic map of anthropized surfaces", which, in pdf and zip formats, offers a map of the photovoltaic potential of ponds and reservoirs, parking lots and tanks, and greenhouses (without taking into account the roofs of buildings), and "Energy efficiency certificate for buildings", available in csv format.

4.6. Cantabria

The Cantabrian portal labels eleven datasets in the energy category, which can be downloaded in html, rdf, xls, pc-axis, sdmx, and json formats.

The first block refers to energy consumption, with "Invoiced electricity consumption", "Natural gas consumption", "Consumption of petroleum products", and "Energy consumption of industrial companies" being available. Next, three datasets with statistical information are offered: "Gas industry statistics", "Annual statistics of the electric power industry", and "Monthly statistics of the electric power industry".

Finally, there are "Electricity system report. Spain's electricity grid", "Natural gas billing", "Hydrocarbon prices", and the dataset "Energy", which is composed of several files on gas and electricity production and oil distillation for the period 1869–1922.

4.7. Castilla and Leon

Within the seventeen datasets, which are under the energy label and offer this autonomy, the most numerous groups are the data referring to consumption. Specifically, it refers to seven datasets (six of which are offered exclusively in csv format). The first is "Hourly electricity consumption in hospitals", followed by three others related to the autonomous community government's educational, health, and cultural centers, a dataset that identifies the autonomous community government's energy consumption centers, and another that refers to weekly consumption. Finally, there is "Monthly electricity consumption in Castile and León", which is available in CSV, XLS, and JSON formats.

Three datasets related to energy efficiency have also been identified. Two of them are available in CSV, JSON, and XLS formats—"Energy audits in Castile and León" and "Energy efficiency certificates"—while "Building energy efficiency certifying technicians" is only available in CSV format. There are other datasets with varied information—"Evolution of cumulative installed power and cumulative number of photovoltaic solar energy installations in Castilla y León since 2000" and "Cumulative installed power and number of installations-cumulative by provinces of photovoltaic solar energy in Castilla y León since 2022" (both in csv)—accompanied by "Electric vehicle charging points" (csv, json, xls), "Mining grid of Castilla y León" (shp), and "Wind farms in operation" (csv and xls).

The remaining datasets, which do not appear to be up to date, are "Points of sale of biomass fuel products in Castilla y León (2015)" and "Biomass boiler installers in Castilla y León" (2015), both in CSV.

4.8. Castilla-La Mancha

This community offers five datasets in the energy category. Two of them are general and not closely related to energy issues, such as "Data Bank of the Statistical Service of Castilla-La Mancha" and "Open Geographic Data Portal of the Board of Communities of Castilla-La Mancha", which are labeled in twenty-two and sixteen categories, respectively, of the technical standard of interoperability.

The remaining three are "Autonomous Registry of Energy Efficiency Certificates for Buildings in Castilla-La Mancha", offering several files with information on the capitals of each of the provinces and others relating to the rest of the province (except each capital) in html, xls, and xml formats, "Wind Turbines in Castilla-La Mancha" (csv, xls, and json), and "List of companies and technicians certifying energy efficiency in buildings in the Autonomous Community of Castilla-La Mancha" (csv and html).

4.9. Catalonia

Catalonia provides eighteen datasets within the energy category, all of them in csv, rdf, rss, tsv, and xml formats, of which 50% are related to certificates.

This subgroup includes "Energy performance certificates for buildings", as well as four other datasets that offer disaggregated information: "Energy performance certificates for buildings: groupings according to CO_2 emissions rating", "Energy performance certificates for buildings: groupings according to CO_2 emissions rating and building regulations", "Energy performance certificates for buildings: groupings according to non-renewable primary energy rating", and "Energy performance certificates for buildings: grouping according to reason". They are accompanied by "Energy performance certificates for buildings: installations", "Energy performance certificates for buildings: enclosures", "Energy performance certificates for buildings: average transmittance of enclosures according to category and climate zone", and "Energy performance certificates for buildings: average transmittance of enclosures according to location".

Another group of datasets is those related to energy consumption and demand, such as "Energy consumption in the industrial sector in Catalonia", "Electricity consumption by municipalities and sectors in Catalonia", "Piped natural gas consumption by municipalities and sectors in Catalonia", and "Hourly electricity demand in Catalonia by MWh". On the other hand, and related to production, there are four other datasets: "Electricity production-aggregated data", "Electricity self-consumption facilities", "Electricity production facilities-individualized data", and the dataset "Energy Indicators of Catalonia", which offers a monthly time series of electricity production by technology.

Finally, reference is made to the latest set of data available in the energy category, entitled "Electric vehicle charging sessions in Catalonia."

4.10. Community of Navarra

The Autonomous Community of Navarra offers four datasets within the energy group. The first is the dataset "Energy certifications", which shows the rating obtained by the buildings in csv, json, ods, tsv, xls, xsd, and xml formats.

The rest have a more general character that does not seem to be directly related to the subject and can be downloaded in csv, json, ods, tsv, xls, and xml: "Directory of establishments with economic activity in Navarre", "Directory of companies with economic activity in Navarre", and "Companies with economic activity in Navarre".

4.11. Community of Madrid

It only offers two datasets: "Index of the territory's carrying capacity for photovoltaic energy" configured as a raster layer (which can contain photographs, images or maps) in pdf, wms, and zip formats, and "Register of Energy Efficiency Certificates for Buildings" which contains the energy rating of the properties registered in the register of certificates, available in csv or zip format.

4.12. La Rioja

It contains four datasets in the energy category, all available in xls, csv, json, and xml formats. The first is the "Energy Certificate of Buildings", which provides information on buildings in the Autonomous Community of La Rioja, including cadastral reference, date of validity of the certificate, type, use, and location of the building, as well as the levels of emissions and the energy ratings themselves.

Secondly, the "Register of electric vehicle charging stations" has been found, which identifies the location and geographical data, power in kW, and description. Finally, there are two datasets with consumption information: "Fuel consumption" and "Electricity consumption by activity sectors".

4.13. Region of Murcia

Of the seven datasets available in the energy category in Murcia, six of them are published by the municipality of Lorca, referring, therefore, to local information and not to the autonomous community as a whole (it is also the case that five of them have the same name: Limusa Containers, in the municipality of Lorca, that is, the containers of the municipal cleaning company, a public limited company).

The remaining dataset is the "Register of Energy Certifications", which contains the register of certificates since 1 January 2020, and is available for download in json format.

4.14. Valencian Community

Of the nine datasets that the Valencian Community offers under the energy label, seven of them are of the ER photovoltaic typology and correspond to various representations in wms and wfs formats. Five of these datasets refer to the installations "Cadastral plots", "Section and measurement centers", "Electrical substations or transformation centers", "Evacuation lines", and "Overhead line supports", while the remaining two are "Fencing of photovoltaic installations" and "Territorial and landscape criteria-Natural monuments of the Valencian Community".

The other two datasets that complete the offer are "Renewable energy self-consumption data" (csv) and "Energy Efficiency Certificates" available in wms and pdf formats.

Once the information from the fourteen autonomous communities has been collected, the results should be analyzed, pointing out the need to clean up many of the datasets found. In the research, these are those that are not related to the topic, those that are not up to date, and those that do not have independent content (being offered by a city or provincial council). In practice, this process proved to be straightforward; however, to make the screening process more robust, it was carried out in duplicate and individually by two of the investigators. Cases with minimal doubts were selected, and the final decision was made by consensus. The final selection, together with other relevant results, is shown in Table 3.

Table 3. Expected, labeled, and retained energy information. Role of the energy category with respect to the twenty-two categories indicated by the technical standard.

	CNR	VAS	ARA	NAV	VAL	AST	CAT	AND	MUR	CTL	RIO	CTM	CNT	MAD	TOT
Datasets Expected energy	948	568	130	72	68	63	58	45	44	34	24	16	13	11	2094
Position category Energy	22th	21th	22th	21th	14th	18th	16th	21th	17th	12th	15th	21th	6th	11th	
Datasets Energy tagged	6	63	3	4	9	3	18	5	7	17	4	5	11	2	157
Filtered	2	21	3	1	9	1	18	1	1	15	4	3	11	2	92
% retained	33%	33%	100%	25%	100%	33%	100%	20%	14%	88%	100%	60%	100%	100%	59%

Note: CNR, Canary Islands; VAS, Basque Country; ARA, Aragón; NAV, Community of Navarre; VAL, Valencian Community; AST, Principality of Asturias; CAT, Cataluña; AND, Andalucía; MUR, Region of Murcia; CTL, Castilla y León; RIO, La Rioja; CTM, Castilla-La Mancha; CNT, Cantabria; MAD, Community of Madrid.

Table 3 shows, in its first row, the number of datasets expected to be found in each autonomous community (if there were a proportional allocation of the total datasets among the categories proposed by the technical standard). As can be seen, the values of dividing the total supply between the twenty-two categories indicated far exceed the labeled datasets, which shows that the energy category is much less populated than the average. This observation is reinforced when analyzing the position of the energy category in each

autonomous community; very low positions are obtained (last position for the Canary Islands and Aragon, and second to last for the Basque Country, Community of Navarre, Andalusia, and Castilla-La Mancha). Taking the average of these positions gives a value of 17, confirming that, for the country as a whole, "Energy" is in the fourth quartile in terms of datasets per category. This statement confirms that the 157 datasets labeled as energy-related represent less than 0.4% of the total open data provided by Spain's autonomous communities.

A simple example of data cleansing: Asturias. This autonomous community has labeled three datasets, having discarded two. The first one not selected was "Energy efficiency certificates for buildings and homes" as it only provides data from 2017 to 2018, while "Indicators of Sustainable Development Goals in the Principality of Asturias", whose xls file contains 321 lines, provides general information not directly related to energy (for example, row 312 "Unemployment rate").

This does not take into account the datasets that have been excluded. After applying the three filters mentioned above, the number of datasets is reduced from 157 to 92, meaning that only 59% of the labeled information has been retained. If the percentage of information is calculated based on the selected datasets from the sector, the percentage drops to 0.23%, a very low figure that highlights the lack of attention paid to this category of information. With this information, a typological analysis was conducted to determine which datasets are most widely available. The information is shown in Table 4.

Table 4. Type of information provided in the energy category.

Autonomous Community	Energy Audits or Certificates	Technicians to Issue Certificates	Renewable Energies	Energy Consumption or Demand	Statistics, Reports or Indicators	Production	Prices	Various
Andalusia	1							
Aragon	1	1	1					
Cantabria				4	4	1	1	1
Castilla and Leon	2	1		7				5
Castilla-La Mancha	1	1						1
Catalonia	9			4		4		1
Navarre	1							
Community of Madrid	1							1
Valencian Community	1			1				7
Canary Islands	1							1
LaRioja	1			2				1
Basque Country				6	10			5
Principality of Asturias				1				
Region of Murcia	1							
TOTALS	20	3	1	25	14	5	1	23

Table 4 allows three interesting comments: consumption information is the most common, 25% of the datasets are classified as "miscellaneous" (which is a good example of the different nature of the supply), and the third typology is energy certificates (offered by eleven of the fourteen autonomous communities).

A classification has been developed to quantify the performance of the autonomous communities (minimum zero points—maximum 100 points) that will value two dimensions

in a balanced way. The first is the existence of information, and 50 points will be awarded to the Basque Country for being the largest disseminator (and a proportional score according to its number of datasets compared to the leader for the rest). The second dimension is the quality of reuse, the first component of which is the training offer (one point per existing format up to a maximum of six points), the second component being openness according to the five-star scale (see Table 5).

Table 5. Five-star model.

★	The information is in unstructured format, requiring great effort. Example: pdf
★★	The data is structured, but is still provided in a proprietary format. Example: xls
★★★	The data is structured and is open and non-proprietary. Example: csv
★★★★	Data can be linked to any other data.
★★★★★	Level linked data: The data uses URIs.

Source: Own elaboration based on Berners-Lee (2010) [37].

After selecting the "best" existing format, it will be given a number of points equal to the star reached, although the maximum will be four points (since the semantic web levels have been grouped together, i.e., four and five stars). Thus, an RDF format would obtain the four opening points.

Thus, the maximum score for reusable quality would be achieved by a dataset offered in six different formats, one of them being rdf (6 + 4 = 10 points). Since five of the selected datasets from the energy category have been sampled (or the existing number if the offer is lower), the remaining 50 points could be achieved (5 × 10 = 50 points). The results are given in Table 6.

Table 6. Autonomous community performance in the provision of information in the energy category.

Autonomous Community	Selected Datasets Energy	Score Existence of Information	Amplitude	Opening	Reuse Quality Score	PT
Catalonia	18	42.86	25	20	45	87.86
Basque Country	21	50.00	16	15	31	81.00
Cantabria	11	26.19	30	20	50	76.19
Castilla and Leon	15	35.71	8	15	23	58.71
Valencian Community	9	21.43	10	12	22	43.43
La Rioja	4	9.52	16	12	28	37.52
Aragon	3	7.14	13	9	22	29.14
Castilla-La Mancha	3	7.14	8	9	17	24.14
Community of Madrid	2	4.76	5	5	10	14.76
Canary Islands	2	4.76	3	4	7	11.76
Com. Foral de Navarra	1	2.38	6	3	9	11.38
Andalusia	1	2.38	1	3	4	6.38
Region of Murcia	1	2.38	1	3	4	6.38

Table 6. *Cont.*

Autonomous Community	Selected Datasets Energy	Score Existence of Information	Amplitude	Opening	Reuse Quality Score	PT
Principality of Asturias	1	2.38	1	1	2	4.38
Total	92	219.05	143	131	274	493.05
Media	6.57	15.65	10.21	9.36	19.57	35.22
Standard deviation	6.98				15.09	29.72
Coefficient of variation	1.06				0.77	0.84

As shown in Table 6, the best autonomous region is Catalonia, second in the supply of information, with a good range of formats offered and the highest opening score. It is ahead of the Basque Country, which, despite being the largest supplier, has an intermediate quality of reuse. Cantabria, fourth in the existence of information, has the highest reuse potential (Figure 1).

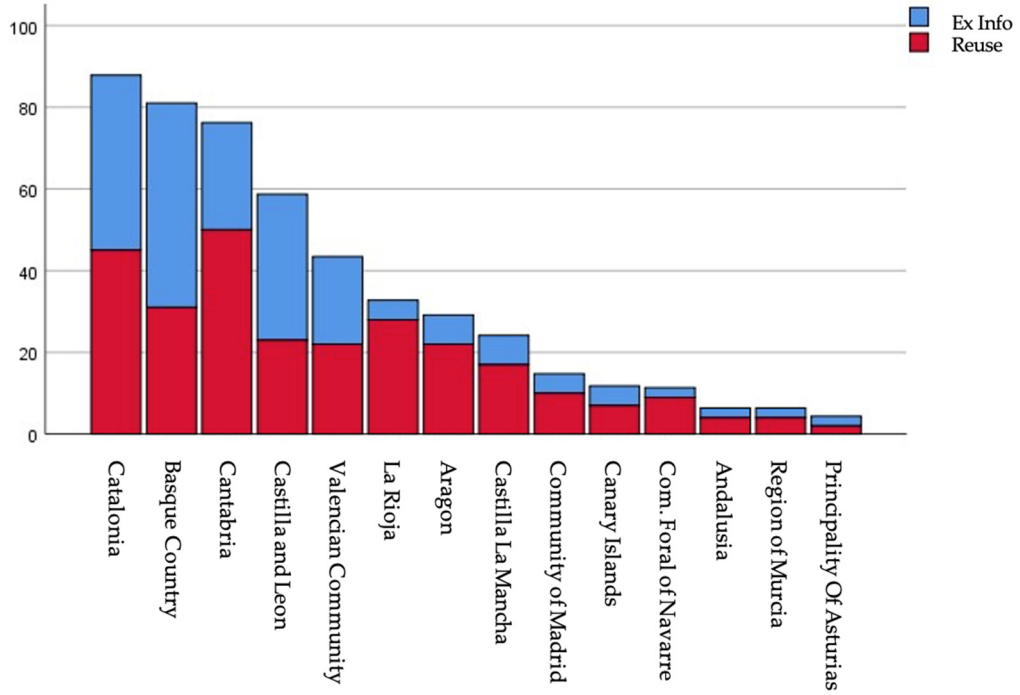

Figure 1. Autonomic performance dimension existence of information and reuse potential.

Figure 1 shows the information existence and reuse potential ratings by the Spanish autonomous regions regarding the supply of energy datasets. It can be seen that three autonomous regions clearly lead the Spanish panorama (Catalonia, the Basque Country, and Cantabria), leaving Castile and Leon in fourth place at some distance (being the last region to exceed 50% of the maximum score). Therefore, thirteen autonomous regions do not reach the pass mark, with three that do not offer a single set of data (Baleares, Extremadura, and Galicia) standing out in a negative sense. These important differences have a clear impact on the high dispersion measures obtained (standard deviation and coefficient of variation), a true reflection of the unequal performance of the autonomous regions, where only five autonomous communities contribute more than two-thirds of the indicator (Figure 2).

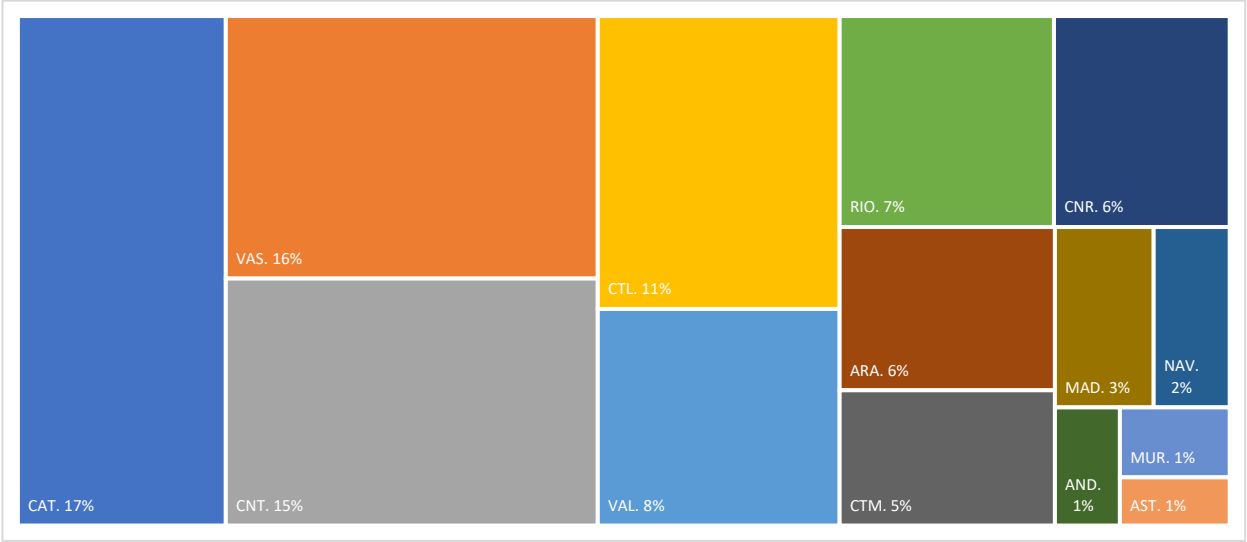

Figure 2. Graphical representation of Autonomous community performance. Note: CAT, Catalonia; VAS, Basque Country; CNT, Cantabria; CTL, Castilla and Leon; VAL, Valencian Community; RIO, La Rioja; ARA, Aragón; CNR, Canary Islands; CTM, Castilla-La Mancha; MAD, Community of Madrid. NAV, Community of Navarre; AND, Andalucía; MUR, Region of Murcia; AST, Principality of Asturias.

5. Discussion

The study shows that the first aspect, the disclosure of energy-related information, does not seem to be fulfilled, since at the Spanish autonomous community level, this category is among the least populated of the technical standards, offering, after the necessary filtering, a figure of less than one hundred datasets. The typological analysis shows that the most common data are consumption data, which could suggest a concern about sustainability (but without detailing the price of energy or showing individualized data on renewable energies, which are only provided on one occasion). The lack of detailed information on energy prices and individualized data on renewable energy significantly limits the ability to assess the real impact of open energy datasets on sustainability outcomes. Without these fundamental datasets, it is not easy to measure the effectiveness of policies or track progress toward key sustainability goals. A high percentage of varied information is appreciated, which is going to make its interoperability difficult, being the most recurrent information the energy certificates, aspect that could be motivated by the regulatory obligatory nature (in Catalonia, for example, since 2013 an energy certificate is mandatory for homes that are sold or rented and for certain publicly owned buildings). While open data initiatives are often evaluated based on their technical openness and potential for reuse, the real contribution to sustainability requires not only accessible data but also comprehensive coverage of relevant indicators, such as energy prices, renewable energy integration, and energy poverty. The lack of such data limits the scope for meaningful analysis and evidence-based policy making [17,38]. The representativeness and usefulness of open energy data are often limited by problems of scarcity, heterogeneity, and inconsistency in data quality, which can hinder its effective use for sustainability research and policy development.

Based on the findings, it seems appropriate to demand the publication of more data, and that these be of high value [3], so that they are likely to boost economic growth and promote environmental sustainability [33]. The recommendation made in their study by Ortiz-de-Urbina-Criado et al. (2023) [39] to reduce heterogeneity in supply would also be extensive. It is suggested that a minimum set of common information be agreed upon and disseminated, as the federation of municipalities and provinces has been doing for years

within its sphere of action. To maximize the contribution of any open data to sustainability, harmonized standards, greater interoperability, and collaborative efforts are required to ensure data integrity and usefulness across all regions [39].

Second, in addition to availability and accessibility, it is also important to facilitate the use of the data [40] since, obviously, the value of open data is only generated when the datasets are reused [41]. Moreover, this is usually an important gap since, sometimes, data are offered to attribute good performance but of limited use [42], while other times portals are poorly implemented by requiring user interaction (as if it were a website) through forms [43], so most of the time these reuse objectives are not achieved [44]. As an example, two samples of open data portals in Spain conclude that 63.8% of portals in 2019 and 56.1% in 2021 are apparent portals, that is, they are not optimally designed for reuse, which can lead to negative economic and social effects that go beyond the inefficient use of public resources [23], or the research by Ortiz-de-Urbina et al. (2023) indicates that many open data portals do not have an adequate design for professional reuse [45].

This research does not address an analysis (of the continent or the open data portal) that could be explored in future research due to its relevance in another dimension of hindering the creation of value through open data.

This research shows that the reusable quality indicator does not exceed 25 points (50% of the maximum score), which indicates that both the range of formats and their openness can be greatly improved.

This will have a double negative impact, on the one hand, on professional reuse, which allows for the implementation of innovative business models or new data-based services [38]. Therefore, it is imperative that portals be defined with characteristics suitable for reuse [46] and that the satisfaction of reuses be further explored [47].

It will also negatively affect non-professional users, an aspect pointed out by other research showing that many portals are also not intended for non-technical users [48]. Therefore, it seems to us a wise idea, as Park and Gil-García (2022) [49] point out, to implement data visualization tools to increase their usefulness and comprehensibility, but both the multidimensional research carried out on Portals of Spanish autonomous communities [50] and this work show that these tools are scarce.

The final comment on the research results is the wide disparity observed among the autonomous communities, a finding that is consistent with the study on the commercial interest of open data [51].

This study makes several key contributions to the field of sustainability and open energy data. From a theoretical perspective, it improves our understanding of how open energy data initiatives support transitions toward sustainability at the autonomous community level in Spain. From a methodological perspective, it introduces a novel indicator for assessing the quality and reuse potential of energy datasets, which can be adapted for use in other contexts.

Before concluding, the study's political implications are discussed. First, given the wide disparity between autonomous communities in terms of the quantity, quality, and formats of open energy data, there is a call for a coordinated national strategy. Second, many datasets are in formats that are not easily reusable (html and pdf), so improvements in data quality and reusability need to be addressed. Third, given the scarcity of key data such as energy prices, energy poverty, and information on renewable energy, it is necessary to focus on data of high value for sustainability. Ultimately, it is essential to enhance the usability of data portals, minimize heterogeneity, and enhance interoperability.

In practice, the results provide actionable recommendations for policymakers and data providers to improve the availability, harmonization, and reuse of energy data, thereby supporting evidence-based sustainability strategies aligned with the Sustainable Development

Goals (SDGs). On the other hand, the identification of homogeneous data between different autonomous communities lays the foundations to develop a multilevel coordination that allows a better articulation between administrations at the local, autonomous, and state level. As well as identifying the main gaps to advance towards compliance with European regulations and their adaptation to move towards sustainable building. In the same way, the availability of this open data encourages citizen participation, more informed and critical in decision making, which influences the planning and implementation of construction projects aimed at improving the energy efficiency of buildings and can have an impact on the direction taken by public policies. Furthermore, by identifying leaders in autonomous communities and best practices, this research provides a benchmark for future initiatives aimed at maximizing the positive impact of open data on sustainable development.

6. Conclusions and Limitations

Open data can create significant economic value while also contributing to environmental and energy sustainability. To do so, certain premises must be met, such as the existence of information or its reusable quality. The transformative potential of open energy data for sustainability only materializes when datasets are technically accessible and substantially relevant to the needs of policymakers, researchers, and civil society. Current gaps in data availability undermine this potential, as key aspects of the energy transition remain unmeasured. Unfortunately, both this study and others in the literature seem to indicate that, despite the investment of money, there is still much room for improvement to move away from a kind of Spanish Frankenstein of open data. At least the study has identified three autonomous regions that stand out from the rest, which could serve as an example for others to follow.

Our final reflection is that if the primary purpose of open data initiatives is to be reused, the information must be disseminated in a uniform manner and in multiple formats that cater to the diverse needs of different user types. Only through greater coordination and the establishment of common criteria among the autonomous communities will it be possible to enhance the practical value and real impact of open energy data in the pursuit of sustainability. Let us take, for example, that a journalist might be satisfied with a spreadsheet-type file from which to easily extract information, perform simple calculations (such as frequency tables and averages), or create graphs. At the same time, a computer scientist would require more advanced formats, such as those developed by Tim Berners-Lee, with fully structured and formulated files that allow for the automated aggregation of information.

One of the limitations of this work is its descriptive nature, motivated by its exploratory nature and the heterogeneity of the initiatives, which, like other recent works on open data in Spain [52], makes the approach comparative. This will lead to future research that can address correlation analyses or identify the determinants of the different returns observed. However, what is really recommended is an improvement in performance in the future, allowing for adequate economic development, as well as environmental and energy sustainability, perhaps based on some of the recommendations made or on other more technical ones, such as those proposed in Nikiforova and McBride (2021) [53]. In addition, it would be of great interest to carry out research that would deepen the comparative analysis between autonomous communities and their relations with the impact derived from the energy policies developed in each region.

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