



# MASTER IN ENVIRONMENT AND SMART ENERGY MANAGEMENT

## MASTER'S FINAL PROJECT ANALYSIS OF THE DECARBONIZATION PATHWAY FOR THE SERVICES SECTOR IN SPAIN IN 2030 AND 2050

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Madrid  
August 2021



Declaro, bajo mi responsabilidad, que el Proyecto presentado con el título  
**Análisis de la ruta de descarbonización del sector Servicios en España  
en 2030 y 2050**

en la ETS de Ingeniería - ICAI de la Universidad Pontificia Comillas en el  
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LOS DIRECTORES DEL PROYECTO

Fdo.: Fecha: 23/08/2021



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# ANÁLISIS DE LA RUTA DE DESCARBONIZACIÓN DEL SECTOR SERVICIOS EN ESPAÑA EN 2030 Y 2050

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## RESUMEN DEL PROYECTO

El compromiso adquirido por la Unión Europea de alcanzar la neutralidad de emisiones en 2050 supone para España la obligación de marcarse un camino para descarbonizar su economía, siendo el sector servicios un reto de gran magnitud por su importancia como motor de la economía española.

**Palabras clave:** energía, servicios, parámetro

### 1. Introducción

Actualmente, los niveles de contaminación aumentan año tras año, siendo la contaminación atmosférica debida a la presencia desmesurada de gases de efecto invernadero. Es por eso, que se precisa de una descarbonización urgente de las estructuras económicas de todos los países y en este caso, de España.

El objetivo propuesto durante el acuerdo de París de no superar un aumento de temperatura mayor de 2°C requiere de medidas que adquieran efecto casi inmediato, empezando por la reestructuración del mix energético.

Por otro lado, y pese a no ser el sector que más emisiones de gases contaminantes provoca de todos, el sector servicios aporta aproximadamente  $\frac{3}{4}$  partes del PIB a España. La descarbonización de dicho sector no sólo es útil para evitar la emisión de más de 10,000 kt anuales. También es útil puesto que una economía descarbonizada es sinónimo de seguridad, calidad y fiabilidad.

Es importante destacar que descarbonizar el sector, bien mediante la utilización de energías renovables o bien mediante medidas de eficiencia energética, le otorga un ahorro económico que ahora mismo, tras la crisis económica generada por el Covid-19 es muy necesario. Es el momento idóneo para realizar un trabajo de este calibre sobre todo cuando España recibirá aproximadamente 72,700 millones de euros provenientes de los fondos europeos Next Generation que irán íntegramente destinados a transformación digital, reindustrialización y energías limpias.

### 2. Definición del proyecto

Una manera de ser más conscientes de la urgencia de descarbonizar la economía se puede ver mediante la elaboración de proyecciones de emisiones a futuro. Es el caso de este proyecto. El núcleo de este trabajo consiste en buscar parámetros para cuantificar el consumo energético en las diferentes ramas del sector Servicios de manera que la elaboración de las proyecciones sea más precisa.

### 3. Descripción del modelo

En primer lugar, se ha realizado la caracterización energética del sector servicios, identificando los principales consumos energéticos:

- Evolución del consumo energético primario en España desagregado por las diferentes tecnologías utilizadas.

- Evolución del consumo energético final en España desagregado por las diferentes tecnologías utilizadas.
- Evolución del consumo energético final en España por sectores.
- Objetivos de consumo energético final fijados para España en 2030 y 2050.
- Intensidad energética del sector Servicios dividido en las diferentes ramas en las que se puede desagregar el sector.
- Estructura de consumo energético final del sector Servicios por ramas.
- Principales consumos energéticos en cada rama del sector Servicios.

Tras realizar un estudio profundo y detallado del sector en España, se han buscado parámetros con los que poder cuantificar el consumo energético de las diferentes ramas en las que se ha desagregado el sector Servicios para poder proyectar dichos consumos a los años objetivo 2030 y 2050:

- Oficinas.
- Sanidad.
- Comercio.
- Hostelería y Restauración.
- Educación.
- Otros usos.

#### 4. Resultados

En el caso de la rama del sector que abarca “otros servicios”, no ha sido posible realizar proyecciones de demanda debido a la falta de datos con respecto a los parámetros estudiados. Únicamente existen datos suficientes para proyectar en el caso de los consumos de AENA. Aun así, la estimación de la demanda realizada no se asemeja nada a la ofrecida por el IDAE. Por ello, los parámetros encontrados no parecen ser los adecuados para englobar la rama.

El sector de las oficinas es uno de los más difusos después del que abarca a otros servicios. La estimación de la demanda energética se acerca, pero es aproximadamente un 25% menor que la ofrecida por el IDAE, por lo tanto deben faltar empleos que incluir en la estimación. Con respecto a las proyecciones, el sector tiene una tendencia de consumo energético decreciente hasta 2030 y posteriormente creciente hasta 2050.

El sector sanitario se puede parametrizar de una manera bastante acertada aplicando el parámetro de consumo energético por empleado. La tendencia para 2030 y 2050 es creciente, aunque no demasiado. De 2018, año el que se han realizado las estimaciones a ser comparadas con las del IDAE, a 2030, únicamente aumenta la demanda un 20%. La variación en los diferentes escenarios no es demasiado grande

El sector comercial se estima de una manera muy precisa mediante el parámetro de consumo energético por empleado. La tendencia, según las estimaciones de demanda energética futura, es creciente con una pendiente muy pronunciada. La demanda energética va a crecer más de un 50 % para 2030

El sector de la hostelería es uno de los más difíciles de prever su evolución porque ha sido muy castigado económicamente por la pandemia. El parámetro de consumo energético por empleado parece bastante adecuado para poder estimar la demanda en la rama. También se ha tratado de estimar la demanda energética para los servicios de restauración, por un lado, y para los servicios de alojamiento, por otro.

Finalmente, el sector educativo puede ser estimado mediante el parámetro de consumo energético por empleado. Es interesante observar la tendencia decreciente de demanda energética en esta rama. La tendencia en cuanto a empleo es creciente en el sector, pero la proyección de decrecimiento en el consumo energético por empleado lo compensa. Es un sector poco intensivo energéticamente en términos absolutos, por lo que las proyecciones parecen coherentes.

## **5. Conclusiones**

El objetivo del proyecto ha sido buscar maneras más precisas de cuantificar la demanda energética en el sector servicios. A excepción del sector de las oficinas y de los otros servicios, las estimaciones realizadas parecen fiables y más acertadas que lo realizado anteriormente, que consistía en extrapolar el sector residencial al sector servicios. Esto se hizo porque son sectores parecidos en cuanto a los tipos de consumos energéticos. Sin embargo, como se ha podido apreciar en este proyecto, este sector es muy amplio y abstracto. Por lo tanto, necesita de un estudio específico para él.

# ANALYSIS OF THE DECARBONIZATION PATHWAY FOR THE SERVICES SECTOR IN SPAIN IN 2030 AND 2050

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## ABSTRACT

The commitment made by the European Union to achieve emissions neutrality by 2050 means that Spain is obliged to set out a path to decarbonize its economy, with the services sector being a major challenge due to its importance as the driving force of the Spanish economy.

**Keywords:** energy, services, parameter,

### 1. Introduction

Currently, pollution levels are increasing year after year. For this reason, an urgent decarbonization of the economic structures of all countries and, in this case, of Spain, is urgently needed.

The objective proposed during the Paris agreement of not exceeding a temperature increase of more than 2°C requires measures that take effect almost immediately, starting with the restructuring of the energy mix.

On the other hand, and despite not being the most polluting sector of all, the service sector contributes approximately  $\frac{3}{4}$  of Spain's GDP. Decarbonization of this sector is not only useful to avoid the emission of more than 10,000 kt per year. It is also useful because a decarbonized economy is synonymous with safety, quality and reliability.

It is important to highlight that decarbonizing the sector, either through the use of renewable energies or through energy efficiency measures, provides the sector with economic savings that are very necessary right now, after the economic crisis generated by the Co-vid-19. It is the ideal time to carry out work of this caliber, especially when Spain will receive approximately 72.7 billion euros from the European Next Generation funds, which will be entirely earmarked for digital transformation, reindustrialization and clean energies.

### 2. Definition of the project

One way to become more aware of the urgency of decarbonizing the economy can be seen through the development of forward-looking emissions projections. This is the case of this project. The core of this work consists of looking for parameters to quantify energy consumption in the different branches of the services sector so that the elaboration of projections is more accurate.

### 3. Description of the model

Firstly, the energy characterization of the service sector has been carried out, identifying the main energy consumptions:

- Evolution of primary energy consumption in Spain broken down by the different technologies used.
- Evolution of final energy consumption in Spain broken down by the different technologies used.

- Evolution of final energy consumption in Spain by sector.
- Final energy consumption targets set for Spain in 2030 and 2050.
- Energy intensity of the services sector divided into the different branches into which the sector can be broken down.
- Structure of final energy consumption in the services sector by branches.
- Main energy consumption in each branch of the services sector.

After carrying out an in-depth and detailed study of the sector in Spain, parameters have been sought with which to quantify the energy consumption of the different branches into which the services sector has been broken down in order to be able to project this consumption for the years 2030 and 2050:

- Offices.
- Health.
- Commerce.
- Hotels and restaurants.
- Education.
- Others usos.

#### 4. Results

In the case of the branch of the sector that includes other services, it has not been possible to make demand projections due to the lack of data with respect to the parameters studied. There is only sufficient data to project in the case of AENA's inputs. Even so, the demand estimate made does not resemble at all that offered by the IDAE. Therefore, the parameters found do not seem to be adequate to cover the branch.

The office sector is one of the most diffuse after the one covering other services. The estimate of energy demand is close, but it is approximately 25% lower than that offered by the IDAE, so there must be a lack of jobs to include in the estimate. Regarding projections, the sector has a decreasing energy consumption trend until 2030 and then increasing until 2050.

The healthcare sector can be parameterized quite accurately by applying the energy consumption per employee parameter. The trend for 2030 and 2050 is increasing although not too much. From 2018, the year in which the estimates to be compared with those of the IDAE were made, to 2030, demand increases by only 20%. The variation in the different scenarios is not too large.

The commercial sector is estimated very precisely using the parameter of energy consumption per employee. The trend, according to estimates of future energy demand, is increasing with a very steep slope. Energy demand will grow by more than 50% by 2030.

The hospitality sector is one of the most difficult to predict its evolution because it has been very hard hit economically by the pandemic. The parameter of energy consumption per employee seems quite ade-

quate to be able to estimate the demand in the branch. An attempt has also been made to estimate energy demand for restaurant services, on the one hand, and for accommodation services, on the other.

Finally, the education sector can be estimated using the energy consumption per employee parameter. It is interesting to note the decreasing trend of energy demand in this branch. The trend in terms of employment is increasing in the sector, but the projected decrease in energy consumption per employee compensates for this. It is a sector that is not very energy intensive in absolute terms, so the projections seem consistent.

## **5. Conclusions**

The aim of the project was to find more accurate ways to quantify energy demand in the service sector. With the exception of the office sector and other services, the estimates made seem reliable and more accurate than what was previously done, which consisted of extrapolating from the residential sector to the service sector. This was done because they are similar sectors in terms of types of energy consumption. However, as has been seen in this project, this sector is very broad and abstract. Therefore, it needs a specific study for it.

Master Thesis

# Analysis of the decarbonization pathway for the services sector in Spain in 2030 and 2050.

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**Abstract:** The commitment made by the European Union to achieve emissions neutrality by 2050 means that Spain is obliged to set out a path to decarbonize its economy, with the services sector being a major challenge due to its importance as the driving force of the Spanish economy. This project will characterize the energy demand of the services sector in Spain at present and its possible future evolution, with a special focus on 2030 and 2050. In a second stage, this characterization will be transferred to the logic of an optimization model for the entire energy sector so that future decarbonization scenarios can be analyzed.

**Keywords:** keyword 1; keyword 2; keyword 3 (List three to ten pertinent keywords specific to the article yet reasonably common within the subject discipline)

## 1. Introduction

Reducing emissions is a global challenge that affects all sectors of any country's economy and all energy consumers. Based on this challenge, the European Union (EU) has established a commitment to which all its members must commit themselves. This commitment is outlined for the 2050 horizon and sets the reduction of GHG emissions between 80% and 95% compared to 1990 emission levels. In order to follow a concrete pathway, an emissions reduction pathway has been established with targets for 2030.

**Table 1.** Analysis of Spain's environmental objectives [1]

|   | 2030             |                  | 2050             |
|---|------------------|------------------|------------------|
|   | Compared to 1990 | Compared to 2005 | Compared to 1990 |
| GHG Emissions <sup>(1)</sup>              | -23%             | 39%              | 90%              |
| No-ETS Sectors <sup>(2)</sup>             |                  |                  |                  |
| ETS Sectors <sup>(3)</sup>                |                  | 61%              |                  |
| Penetration of renewables in final energy | 42%              |                  | 100%             |
| Energy efficiency                         | 39.5%            |                  | N/A              |

<sup>1</sup> Includes emissions of CO<sub>2</sub>, NO<sub>x</sub>, CH<sub>4</sub>, SO<sub>2</sub>, HFCs, PFCs, SF<sub>6</sub> and NF<sub>3</sub>. Excludes emissions from international sea and air transport journeys.

<sup>2</sup> Sectors not covered by the Emissions Trading System (ETS): transport except aviation, buildings, waste and agriculture.

<sup>3</sup> Sectors covered by the ETS: industrial consumption, electricity generation and aviation transport.

The objective proposed during the Paris agreement of not exceeding a temperature increase of more than 2°C requires measures that take effect almost immediately, starting with the restructuring of the energy mix.

On the other hand, and despite not being the most polluting sector of all, the services sector contributes approximately  $\frac{3}{4}$  of Spain's GDP. Decarbonizing this sector is not only useful to avoid the emission of more than 10,000 kt per year. It is also useful because a decarbonized economy is synonymous of safety, quality and reliability.

It is important to highlight that decarbonizing the sector, either through the use of renewable energies or through energy efficiency measures, brings economic savings to the sector that are now, after the economic crisis generated by Covid-19, much needed. It is the ideal time to carry out a study of this caliber, especially when Spain will receive approximately 72,700 million euros from the European Next Generation funds, which will be entirely allocated to digital transformation, reindustrialization and clean energy.

One way to be more aware of the urgency of decarbonizing the economy can be seen through the development of future emissions projections. This is the case of this project. The core of this work consists of looking for parameters to quantify energy consumption in the different branches of the services sector so that the elaboration of the projections is more accurate.

## 2. State of the Art

The current references used for modeling the decarbonization pathway are the MASTER.SO and ROM models. In them, the different narratives established in the scenarios are translated into quantitative parameters such as technology or fuel costs, volume of energy service or final demand, etc.

- MASTER.SO is a partial equilibrium model for the energy sector developed at IIT by López Peña in 2014 [2]. This model tries to represent the behavior of the agents in the sector by means of optimization techniques. The model simulates the operation of the system, depending on the demand for energy services introduced, determining the combination of energy generation and conversion technologies, as well as end uses, that will allow satisfying the energy demand with the lowest possible cost. For this purpose, those combinations of technologies and fuels that are feasible, the different restrictions in each case, but also the costs of each of the elements of the system are considered. The model offers 2 different results which are specified below:
  - From a more direct approach, the model provides the possibility of analyzing the results offered by the input parameters introduced so that it can be observed whether the results are consistent with the approach of the scenario itself.
  - On the other hand, through the parameterization of the input variables, the model reveals those technical, economic or other elements that enable or prevent the use of different technologies.

The MASTER.SO model allows the energy system as a whole to be represented with a reasonable level of approximation. Even so, there are subsectors such as electricity, where there is a greater difficulty due to the intervention of renewable energies that are neither dispatchable nor storable. In this aspect, the MASTER.SO model only includes the electricity system in a simple way that includes the management of reserves and firm power but without the possibility of incorporating a greater hourly and technical detail. For this reason, the second of the models mentioned, the ROM model, is used. This model is used sequentially to MASTER.SO.

- The ROM model is a much more detailed model of electrical dispatch developed at IIT by Andrés Ramos. It has the ability to analyze the technical feasibility of the system taking into account the associated uncertainties such as the production of renewable energies, but also of other types of power plants and their technical characteristics (ramps up and down, technical minimums, storage capacity, etc.). In addition, the ROM model has the ability to decree whether operating reserves (secondary and tertiary) are necessary, the different costs of each energy source, the production in the different plants and the reliability of the electricity system. It is, in fact, the calculation of system reliability that is used as an indicator of the validity of the generation pool that the MASTER.SO model uses. In case the calculated reliability is considered acceptable, when the constraints taken into account by ROM have been taken into account, the MASTER.SO solution will be considered validated. In the event that the proposed solution is not acceptable, corrective actions can be identified,

such as installing additional storage capacity or additional capacity of one of the backup generators for renewables.

### 2.1. MASTER.SO's estimation of the energy demand for the services sector

The demand for the services sector in the current model is obtained from the 2015 Odyssey database. In order to convert the energy demand into energy services of the sector, the same energy efficiencies are assumed as used for the residential sector, although taking into account that the scale of the equipment is larger in the services sector so they should probably be somewhat higher:

**Table 2.** Devices' efficiency in the services sector [2]

| Technology               | Efficiency | Description                     |
|--------------------------|------------|---------------------------------|
| Heating                  | 140 %      | Average heating park efficiency |
| Air Conditioning (AA)    | 365 %      | Current average COP             |
| Domestic hot water (ACS) | 92 %       | Average boiler efficiency       |

Data from IDAE, SPAHOUSEC y Rúa (2012)

To calculate the demand for lighting and other energy services in the sector, m<sup>2</sup> are used as a reference parameter. To calculate the energy consumption per square meter, the energy consumption per residential square meter was used as the starting point. Based on the following data:

- Eurostat data for residential consumption in 2015 (CR): 116729.1 GWh.
- Average surface area of a dwelling according to Eurostat data (PMCV): 99.1 m<sup>2</sup>.
- Number of dwellings in the country according to INE (CV): 18,346 million.

With the above data, the following equation was applied:

$$\frac{CR}{PMCV * CV} = 94 kWh/m^2$$

The following data are used to relate the energy demand in the Residential sector to that of the services sector:

- According to the EEA (Progress on energy efficiency in Europe - European Environmental Agency) the services sector has 3 times less surface area than the Residential sector in Europe.
- According to the same source, buildings belonging to the services sector in Europe are 70% more energy intensive than those belonging to the Residential sector.
- With the 2 previous data, the surface area of the services sector is calculated and the arithmetic mean of the two results obtained is used.

Using the first data:

$$\frac{1818 km^2}{3} = 606 km^2$$

Using the second data:

$$1,7 * \frac{94kWh}{m^2} = \frac{159,8kWh}{m^2}$$

$$\frac{116729,1 GWh}{159,8 kWh/m^2} = 730 km^2$$

And taking the arithmetic mean of both results:

$$\frac{606 + 730}{2} = 668km^2$$

Subsequently, the energy intensity has been calculated with data used to verify whether it is feasible and makes sense to compare the energy intensity in Spain with that of Europe.

$$\frac{116729,1GWh}{668km^2} = \frac{174kWh}{m^2}$$

**Table 3.** Energy Intensities [2]

| Sector      | Average intensity in Europe (kWh/m <sup>2</sup> ) | Average intensity in Spain (kWh/m <sup>2</sup> ) | Difference in intensity in Spain compared to that in Europe (%) |
|-------------|---|--|---|
| Residential | 175   | 94   | 53,71 %   |
| Services    | 293   | 174  | 59,39 %   |

From the present demand data, the following equation is used to calculate future demand projections:

$$DemFu = DemSerEn + (ElRe * DemSerEn * CrecPIB)$$

Where:

- CrecPIB = GDP growth in percent.
- EIRE = Income Elasticity
- DemSerEn = Energy service demand 2015
- DemFu = Energy service demand in the future

## 2.2. CO<sub>2</sub> Restrictions

The criterion chosen to determine the CO<sub>2</sub> restrictions in the different scenarios has been to use 1990 as the reference year for those scenarios in which there is a progression in the fulfillment of decarbonization objectives. These are considered to be more consistent with global decarbonization targets. On the other hand, for those scenarios in which the objectives are not met, the objectives established by the EU for Spain have been used, which use 2005 as the reference year.

## 2.3. Fuel Prices

In the model report, the future fuel prices for the different scenarios are established by the model's own elaboration using different reference sources:

- BEIS 2016 Fossil Fuel Price Assumptions.
- IEA 2016 World Energy Outlook.

**Table 4.** Reference fuel prices

| Fuel | BEIS (Mid) |      | WEO (NPS) |      | Unit |
|------|------------|------|-----------|------|------|
|      | 2030       | 2040 | 2030      | 2040 |      |

|           |      |      |      |      |                |
|-----------|------|------|------|------|----------------|
| Carbon    | 11,8 | 11,8 | 10,9 | 11,3 | €/MWh          |
|           | 80,0 | 80,0 | 74,0 | 77,0 | \$/tonne       |
| Gas       | 25,0 | 25,0 | 37,9 | 42,3 | €/MWh          |
|           | 6,8  | 6,8  | 10,3 | 11,5 | \$/million BTU |
| Petroleum | 46,1 | 46,1 | 64,1 | 71,6 | €/MWh          |
|           | 80   | 80   | 111  | 124  | \$/barrel      |

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### 3. Objectives

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Through the development of this project, the aim is to carry out an energy characterization of the service sector, project it to two key dates (2030 and 2050) and consider possible decarbonization routes. More specifically, the following objectives will be resolved:

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- To know the tools that play main roles as decarbonization levers in the service sector. 177
- To model an economically viable decarbonization pathway for the sector. 178
- To weight the importance of the different input variables that can be included in the project and prioritize among them. 179
- To align the project with as many sustainable development goals as possible. 180

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### 4. Materials and Methods (Methodology)

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In the first phase, the characterization of the services sector, parameters have been sought to quantify energy consumption in the services sector using data mainly from the National Institute of Statistics (INE) and the Institute for Energy Diversification and Saving (IDAE). In the second phase, this data are projected to the objective years: 2030 and 2050.

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#### 4.1. INE's Methodology

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Employment data for the different branches of the service sector were obtained mainly from the INE. The use of this institution has been of great importance since, thanks to it, it has been possible to divide the services sector into 5 branches. This is complicated in a sector with such diffuse characteristics as the services sector.

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To obtain these data, the INE carries out the Active Population Survey throughout the national territory and covers approximately 99% of the total population. The remaining 1% not included in the survey includes those people who live in collective households such as hotels, convents, prisons, etc. Therefore, this survey includes all those persons whose domicile is a family dwelling. The survey is conducted at a frequency of 5,000 interviews per week. The sample used contains 65,000 family dwellings per quarter and in total some 180,000 persons are surveyed. In other words, the survey covers 0.4% of the population. The Labor Force Survey follows the ILO methodology.

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The sampling frame includes the 32,000 census tracts into which Spain is segmented for electoral and statistical purposes, and the different postal addresses of each census tract. Each census tract is a clearly defined parcel with perfectly recognizable borders. The maximum size of each census tract is about 2,000 voters. The sample is made up of 3,822 census tracts and in each census tract there are approximately 18 family dwellings (in the case of large provinces the number of family dwellings increases to 22).

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The sampling frame is updated when the information from the latest population census becomes available. This occurs every 10 years. However, every 2 years a partial update is carried out with the information from the electoral census.

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With respect to the rotation system, every 4 months 1 out of every 6 of the dwellings consulted is changed. Before the new dwellings are chosen, the census area is updated. The overlap between two consecutive quarters is 5/6 and between the same quarters of two consecutive quarters is 2/6. In addition, a household is interviewed for a maximum of 6 consecutive quarters.

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#### 4.2. IDAE's Methodology

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The IDAE provides very useful energy consumption and energy efficiency data for this study. The IDAE is a public institution attached to the Ministry for Ecological Transition (MITECO), through the Secretary of State for Energy, to which it reports. The strategic framework of its activity is to help achieve the objectives set by Spain in terms of improving energy efficiency, renewable energies and other low-carbon technologies.

In this area, the IDAE works in dissemination and training, technical advice, development of specific programs and financing of technological innovation projects. In addition, the Institute carries out international projects within the framework of different European programs and co-operation with other countries. Within the information dissemination section, the IDAE manages and keeps updated various tools and databases, available through its website, where a wide range of information is available.

The Citizen Information Service on Energy Efficiency and Renewable Energy (SICER) has also been very useful. This platform is used to respond to queries from citizens and institutions of different natures on energy-related issues.

Finally, another valuable tool provided by the IDAE is the Energy Statistics Information System (SIEE), which includes the set of existing databases (final energy balances, cogeneration, renewable energies and sectoral energy indicators).

## 5. Results

### 5.1. Characterization of the service sector

The service sector, also known as the tertiary sector, is one of the three major sectors in the economy of any country. It can be defined as the sector that does not produce material goods, but provides the population with those services that are essential to satisfy their needs. It is a very varied sector to which a wide range of branches belong: commerce, transport, communications, financial services, social services (education, health), tourism, etc.

In recent decades, this sector has grown exponentially and at great speed. In fact, in the most developed countries, the service sector occupies very high shares of GDP, even reaching 70%, as in the case of Spain. In less developed countries such as Brazil or Thailand it is around 40% /50% and in the least developed countries it reaches very low percentages.

In order to analyze the evolution of final energy consumption in the services sector, the following figure will be used, which includes data from 1990 to 2019:

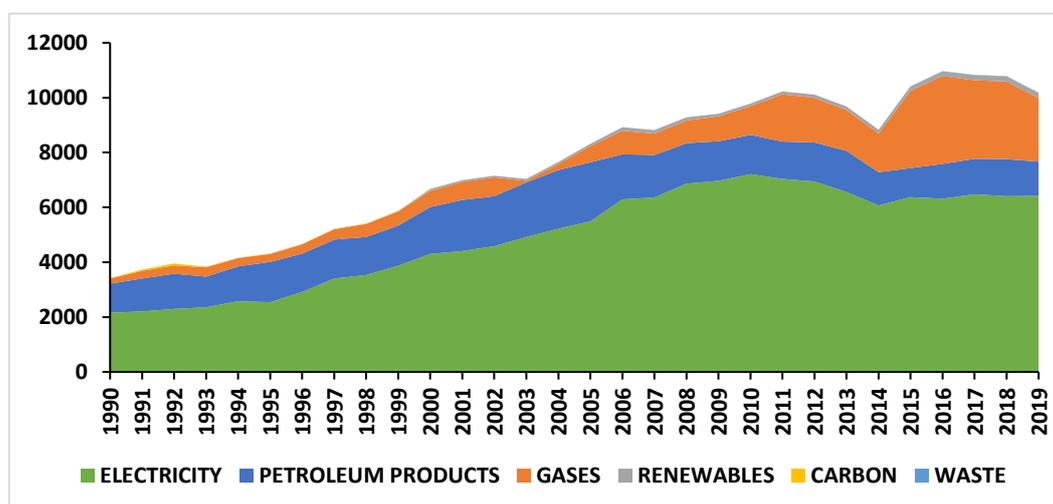


Figure 2. Evolution of final energy consumption in the services sector by technology

As illustrated in the figure above, which shows the evolution of the energy mix of the services sector, a large part of the sector is electrified. In fact, according to data from 2019, the last year for which data is available, 63 % of the energy mix was through electricity. Therefore, a first conclusion that can be drawn from Figure 2 is that the decarbonization of the services sector is highly dependent on the decarbonization of the electricity mix. The trend is growing, moreover, with targets to electrify 100% of the sector.

The consumption of petroleum products, on the other hand, has been constant over the last 30 years, with practically 12% of the share of the energy mix in 2019. One of the objectives is to reduce the consumption of this energy source.

In line with the total energy mix in Spain, coal consumption in the sector has been decreasing until it currently has no share in the energy mix of the sector. Even so, the share of coal in the sector has always been very low.

Natural gas has had an irregular evolution in the sector, being currently the second most common energy source with a share of around 23 %. The trend had been increasing in the last 30 years due to the reduction in energy consumption of other energy sources. However, in the last 4 years consumption has decreased, probably due to the electrification of the sector.

The share of renewables in the sector remains anecdotal, accounting for 2% of the sector's energy mix in 2019. The most widely used renewable technologies are biomass and solar thermal. In fact, there are plans in the PNIEC (National Integrated Energy and Climate Plan) to give a greater share to these technologies due to their potential in the sector.

Finally, waste as a source of energy has almost no participation in the sector, although its role in the Spanish energy sector will increase as it is a fundamental part of the circular economy.

In order to carry out a more in-depth study of what has been elaborated at present, the service sector will be divided into the following branches:

- Offices.
- Health.
- Commerce.
- Hospitality / Catering.
- Education.
- Other services

In this way, as mentioned above, it is possible to disaggregate in a more precise way the sector and look for a greater number of parameters, in order to estimate the energy demand in the sector in the future.

The IDAE prepared a table disaggregating unit energy consumption in 2018 by employee. This table will be compared with the dimensioning carried out for each subsector. According to the IDAE, these energy consumptions have been obtained by dividing the energy consumption of each subsector by the number of employees in the branch itself. The unit energy consumption parameter could be an interesting parameter for modeling.

**Table 5.** Unitary energy consumption in the different branches of the services sector in 2018 [3]

| <i>Indicators: Unitary Consumption per employee/ Service Sector</i> | <i>Units</i> | <i>Unitary Consumption</i> |
|---|--------------|----------------------------|
| Office Sector Unitary Consumption                                   | toe/emp      | 0,6739                     |
| • Unitary Electricity Consumption                                   | kWh/emp      | 4.777                      |
| • Unitary Thermal Consumption                                       | toe/emp      | 0,2631                     |
| Health Sector Unitary Consumption                                   | toe/emp      | 0,5359                     |
| • Unitary Electricity Consumption                                   | kWh/emp      | 3.199                      |

|   |         |        |
|---|---------|--------|
| • Unitary Thermal Consumption                   | toe/emp | 0,2607 |
| Commerce Sector Unitary Consumption             | toe/emp | 0,9954 |
| • Unitary Electricity Consumption               | kWh/emp | 7.325  |
| • Unitary Thermal Consumption                   | toe/emp | 0,3654 |
| Hospitality/Catering Sector Unitary Consumption | toe/emp | 0,3777 |
| • Unitary Electricity Consumption               | kWh/emp | 3.536  |
| • Unitary Thermal Consumption                   | toe/emp | 0,0736 |
| Education Sector Unitary Consumption            | toe/emp | 0,5542 |
| • Unitary Electricity Consumption               | kWh/emp | 2.409  |
| • Unitary Thermal Consumption                   | toe/emp | 0,3470 |

The table above shows that, according to the IDAE, the commerce subsector is the most energy-intensive, while the hotel and catering subsector is the least energy-intensive.

#### 5.1.1. Energy Demand in the Office Subsector

The office subsector includes public and private offices. The IDAE includes in this subsector the activities corresponding to divisions H, J, K, L, M, N and O of the CNAE-2009 (codes 49-53, 58-63, 64-66, 68, 69-70, 77-82 and 84). Divisions H, J, K, L, M and N cover private offices and division O covers public offices.

The CNAE is the National Classification of Economic Activities and assigns a code to each economic activity that can be carried out. Normally this code (which usually has 5 digits) is used in many forms and forms, both at the official level and at the company level. In fact, the INE, when compiling labor occupation statistics according to activity, disaggregates jobs using these divisions.

The office subsector is then defined by the following activities:

**Table 6.** Divisions of activities of the Offices subsector.[4]

| CNAE-2009 Division | Códigos | Descripción  |
|--------------------|---------|--|
|                    |         | Transportation and warehousing:  |
| H                  | 49-53   | <ul style="list-style-type: none"> <li>• Land and pipeline transport.</li> <li>• Maritime and inland waterway transport</li> <li>• Air transport</li> <li>• Warehousing and support activities</li> <li>• Postal and courier activities</li> </ul>   |
|                    |         | Information and communications:  |
| J                  | 58-63   | <ul style="list-style-type: none"> <li>• Publishing</li> <li>• Motion picture, video and television programme activities, sound recording and music publishing activities</li> <li>• Radio and television programming and broadcasting activities</li> <li>• Telecommunications</li> <li>• Programming, consultancy and other computer-related activities</li> <li>• Information service activities</li> </ul> |
| K                  | 64-66   | Financial and insurance activities:  |

|   |       |  |
|---|-------|--|
|   |       | <ul style="list-style-type: none"> <li>• Financial services, except insurance and pension funding</li> <li>• Insurance, reinsurance and pension funding, except Social Security</li> <li>• Activities auxiliary to financial services and insurance activities</li> </ul>  |
| L | 68    | Real-estate activities   |
|   |       | Professional, scientific and technical activities:   |
| M | 69-70 | <ul style="list-style-type: none"> <li>• Legal and accounting activities</li> <li>• Activities of head offices; business management consultancy activities</li> </ul>  |
|   |       | Administrative and support service activities:   |
| N | 77-82 | <ul style="list-style-type: none"> <li>• Rental and leasing activities</li> <li>• Employment Activities</li> <li>• Travel agency, tour operator, tour reservation service and related activities</li> <li>• Security and investigation activities</li> <li>• Building services and gardening activities</li> <li>• Office administrative and other supporting business activities</li> </ul> |
| O | 84    | Public administration and defense; compulsory social security  |

Once the subsector has been defined, which is of great importance in this case since it is a very diffuse area, the energy consumption of the subsector can be analyzed.

To analyze the energy consumption of the office subsector, the most recent data available are from 2018. The distribution of energy consumption in that year according to the technology used is as follows:

**Table 7.** Energy consumption in the Office subsector by technology

| Tecnologies | Carbon | Petroleum Products | Gases | Electricity | Renewables | TOTAL |
|-------------|--------|--------------------|-------|-------------|------------|-------|
| (ktoe)      | 0      | 473                | 1.351 | 2.848       | 26,1       | 4.699 |

The Offices subsector is the most intensive branch of the services sector with a total consumption of 4,699 ktoe, due to the number of employees in this branch (shown below). Total consumption is divided by use into 2,848 ktoe electrical and 1,851 ktoe thermal. As can be seen in Figure 5, 60% of the sector is electrified.

The estimated energy consumption (according to energy.checkup.eu) per unit area in offices is 0.010449 toe/m<sup>2</sup>. However, quantifying office space in Spain precisely is very complex. For this reason, this parameter will not be used to estimate the energy demand of this subsector.

In this case, being such a diffuse sector, the parameter used to estimate the energy demand of the subsector will be the unitary energy consumption only. The calculation of the energy demand is made using the unitary energy consumption data provided in Table 5 and the data provided by the INE for employment in the activities included in the subsector for 2018:

**Table 8.** Employments included in the Office sector

| Division                         | Nº employees (thousands) |
|----------------------------------|--------------------------|
| H Transportation and warehousing | 981                      |
| 49 Land and pipeline transport   | 589                      |

|   |       |
|---|-------|
| 50 Maritime and inland waterway transport   | 22    |
| 51 Air transport  | 46    |
| 52 Warehousing and support activities for transportation  | 218   |
| 53 Postal and courier activities  | 106   |
| J Information and communication   | 585   |
| 58 Publishing   | 53    |
| 59 Motion picture, video and television programme making, sound recording and music publishing activities | 41    |
| 60 Radio and television broadcasting activities   |       |
| 60 Radio and television programming and broadcasting activities   | 45    |
| 61 Telecommunications activities  |       |
| 61 Telecommunications   | 121   |
| 62 Programming, consultancy and other activities related to information technology                        | 312   |
| 63 Information service activities   | 14    |
| K Financial and insurance activities  | 435   |
| 64 Financial service activities, except insurance and pension funding                                     | 249   |
| 65 Insurance, reinsurance and pension funding activities, except compulsory social security               | 129   |
| 66 Activities auxiliary to insurance and financial services   | 57    |
| L Real estate activities  | 150   |
| 68 Real estate activities   | 150   |
| M Professional, scientific and technical activities   | 982   |
| 69 Legal and accounting activities  | 338   |
| 70 Activities of head offices; business management consulting activities                                  | 130   |
| N Administrative and support service activities   | 983   |
| 77 Rental and leasing activities  | 40    |
| 78 Employment activities  | 35    |
| 79 Travel agency, tour agency, tour operator, reservation service and related activities                  | 79    |
| 80 Security and investigation activities  | 147   |
| 81 Building services and gardening activities   | 555   |
| 82 Office administrative and other business support service activities                                    | 127   |
| O Public administration and defense; compulsory social security   | 1.345 |
| 84 Public administration and defense; compulsory social security  | 1.345 |
| TOTAL   | 4.945 |

The number of employees in the subsector according to the INE in 2018 was approximately 4,945,000 employees. The estimate of energy consumption then would be:

$$\text{Energy Consumption Offices} = 4.945.000 \text{ employees} * 0,0006739 \frac{\text{ktoe}}{\text{employee}}$$

$$\text{Energy Consumption Offices} = 3.332,43 \text{ ktoe}$$

According to the IDAE, the energy consumption was 4,699 ktoe therefore, the result is un-conclusive.

#### 5.1.2. Energy Demand in the Health Subsector

The healthcare subsector much less energy intensive than the office subsector. To analyze the energy consumptions of the subsector, the most recent data available are from 2018. The distribution of energy consumption in that year according to the technology used is as follows:

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**Table 9.** Energy consumption in the Healthcare subsector by technology

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| Tecnologies | Carbon | Petroleum Products | Gases | Electricity | Renewables | TOTAL |
|-------------|--------|--------------------|-------|-------------|------------|-------|
| (ktoe)      | 0      | 185                | 236   | 444         | 4,5        | 870   |

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As it can be noticed in the table above, energy consumption is 51 % electric and 49 % thermal. Total energy consumption is about 870 ktoe, 27 % of which is natural gas consumption and 21 % due to petroleum products. Electricity consumption is about 444 ktoe and thermal consumption is about 426 ktoe.

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Two possible ways have been studied to estimate the energy demand in the healthcare system. First, the parameter of unit energy consumption per employee will be used. According to the INE, the number of employees in the healthcare subsector in 2018 is 1,614,800 employees. The CNAE-2009 classifies the subsector as follows:

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**Table 10.** Healthcare sector's division of employments

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| Division  | Nº employees (thousands) |
|---|--------------------------|
| Q Healthcare activities and social services       | 1.614,80                 |
| 86 Healthcare activities                          | 1.092,95                 |
| 87 Assistance in residential facilities           | 303,98                   |
| 88 Social service activities without accomodation | 217,88                   |

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The estimated energy consumption would then be:

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$$\text{Healthcare's energy consumption} = 1.614.800 \text{ employees} * 0,0005359 \frac{\text{ktoe}}{\text{employee}}$$

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$$\text{Healthcare's energy consumption} = 865,37 \text{ ktoe}$$

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According to the IDAE, energy consumption was 870 ktoe. This value is quite similar to the one obtained; therefore, this parameter could be used to quantify the energy demand in this subsector.

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Secondly, the aim is to quantify the energy consumption of healthcare activities using the parameter of energy consumption of beds in Spanish hospitals.

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The energy consumption of healthcare activities can be estimated as follows:

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$$\text{Energy consumption Healthcare activities} =$$

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$$= 1.092.950 \text{ employees} * 0,0005359 \frac{\text{ktoe}}{\text{employee}}$$

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$$\text{Energy consumption Healthcare activities} = 585,712 \text{ ktoe}$$

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To analyze the energy consumption of beds in Spanish hospitals, they must be categorized by climatic zones since consumption varies. Therefore, they are divided into:

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- Atlantic Zone.
- Continental Zone.
- Mediterranean Zone.

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In addition to this division, a categorization is also made between public and private hospital beds, since, as will be seen later, energy consumption varies considerably depending on a public and a private entity.

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The number of beds according to zone and type of entity is broken down in the following tables:

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**Table 11.** Number of beds in the Atlantic Zone [5]

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| Atlantic Zone |           |           |          |
|---------------|-----------|-----------|----------|
| Place         | Nº Beds   | Public    | Private  |
| Coruña        | 4.162,00  |           |          |
| Lugo          | 1.293,00  | 6.492,00  | 2.176,00 |
| Pontevedra    | 3.213,00  |           |          |
| Asturias      | 3.785,00  | 2.775,00  | 1.010,00 |
| Cantabria     | 2.020,00  | 1.385,00  | 635,00   |
| Vizcaya       | 3.867,00  |           |          |
| Guipuzcoa     | 2.890,00  | 4.715,00  | 2.042,00 |
| TOTAL         | 21.230,00 | 15.367,00 | 5.863,00 |

**Table 12.** Number of beds in the Continental Zone [5]

411

| Continental Zone   |           |           |           |
|--------------------|-----------|-----------|-----------|
|                    | Nº Beds   | Public    | Private   |
| Madrid             | 20.516,00 | 13.872,00 | 6.644,00  |
| Castilla Y Leon    | 9.414,00  | 7.212,00  | 2.202,00  |
| Castilla La-Mancha | 5.589,00  | 5.213,00  | 376,00    |
| Extremadura        | 3.862,00  | 3.418,00  | 444,00    |
| Navarra            | 2.300,00  | 1.397,00  | 903,00    |
| La Rioja           | 1.050,00  | 810,00    | 240,00    |
| Aragón             | 5.254,00  | 4.362,00  | 892,00    |
| Ourense            | 1.141,00  | 1.049,00  | 92,00     |
| Alava              | 1.252,00  | 1.081,00  | 171,00    |
| Lerida             | 1.815,00  | 787,00    | 1.028,00  |
| TOTAL              | 52.193,00 | 39.201,00 | 12.992,00 |

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**Table 13.** Number of beds in the Mediterranean Zone [5]

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| Mediterranean Zone |           |           |           |
|--------------------|-----------|-----------|-----------|
|                    | Nº Beds   | Public    | Private   |
| Andalucía          | 21.349,00 | 15.669,00 | 5.680,00  |
| Murcia             | 4.909,00  | 3.331,00  | 1.578,00  |
| C. Valenciana      | 13.992,00 | 11.534,00 | 2.458,00  |
| Baleares           | 3.851,00  | 2.465,00  | 1.386,00  |
| Canarias           | 7.551,00  | 4.964,00  | 2.587,00  |
| Ceuta              | 252,00    | 252,00    | 0,00      |
| Melilla            | 168,00    | 168,00    | 0,00      |
| Barcelona          | 26.020,00 |           |           |
| Girona             | 2.927,00  | 14.129,00 | 18.668,00 |
| Tarragona          | 3.850,00  |           |           |
| TOTAL              | 84.869,00 | 52.512,00 | 32.357,00 |

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Once the distribution of beds in the different regions has been established, the energy consumption is arranged according to the area:

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**Table 14.** Energy consumption in hospital beds depending on the kind of entity [6]

| ZONE<br>(kWh/bed) | Energy Consumption Med. Zone |         | Energy Consumption in At. Zone |         | Energy Consumption in Cont. Zone |         |
|-------------------|------------------------------|---------|--------------------------------|---------|----------------------------------|---------|
|                   | Public                       | Private | Public                         | Private | Public                           | Private |
|                   | 49.348                       | 24.615  | 37.018                         | 22.276  | 42.443                           | 30.596  |

Therefore, the estimated energy consumption would be as follows:

- Atlantic Zone:

$$\begin{aligned} & \text{Energy Consumption in At. Zone.} = \\ & = 15.367 \text{ beds} * 37.018 \frac{\text{kWh}}{\text{bed}} + 5.863 \text{ beds} * 22.276 \frac{\text{kWh}}{\text{bed}} = \\ & = 699.459.794 \text{ kWh} = 60,15 \text{ ktoe} \end{aligned}$$

- Continental Zone:

$$\begin{aligned} & \text{Energy Consumption in Cont. Zone.} = \\ & = 39.201 \text{ beds} * 42.443 \frac{\text{kWh}}{\text{bed}} + 12.992 \text{ beds} * 30.596 \frac{\text{kWh}}{\text{bed}} = \\ & = 2.061.311.275 \text{ kWh} = 177,27 \text{ ktoe} \end{aligned}$$

- Mediterranean Zone:

$$\begin{aligned} & \text{Energy Consumption Med. Zone.} = \\ & = 52.512 \text{ beds} * 49.348 \frac{\text{kWh}}{\text{bed}} + 32.357 \text{ beds} * 24.615 \frac{\text{kWh}}{\text{bed}} = \\ & = 2.061.311.275 \text{ kWh} = 291,35 \text{ ktoe} \end{aligned}$$

Y el consumo energético total sería:

$$\begin{aligned} & \text{Energy consumption Healthcare activities} = \\ & = \text{Energy Consumption in At. Zone.} + \text{Energy Consumption in Cont. Zone.} + \text{Energy Consumption in Med. Zone.} = \\ & = 60,15 \text{ ktoe} + 177,27 \text{ ktoe} + 291,35 \text{ ktoe} = \\ & = 528,77 \text{ ktoe} \end{aligned}$$

The energy consumption obtained for healthcare activities is fairly similar to that calculated using unit energy consumption (585,71 ktoe versus 528,77 ktoe). The difference may be due to the energy consumption derived from health centers, among other centers, where energy consumption is due to other parameters. Even so, the energy consumption due to hospitals, based on the calculations obtained, is about 90% of the energy consumption of healthcare activities.

### 5.1.3. Energy Demand in the Commerce Subsector

This subsector is the second most energy intensive of the services sector in absolute terms. To analyze the energy consumptions of the subsector, the most recent data available are from 2018. The distribution of energy consumption in that year according to the technology used is as follows:

**Table 15.** Energy consumption in the Commerce subsector by technology

| Tecnologies | Carbon | Petroleum Products | Gases | Electricity | Renewables | TOTAL |
|-------------|--------|--------------------|-------|-------------|------------|-------|
| (ktoe)      | 0      | 248                | 851   | 1.894       | 2          | 2.995 |

The energy distribution by technology in this sector is very similar to that of the rest of the subsectors. This branch is 63% electrified, while thermal demand is 37%. The share of renewables is very low, amounting to 2 ktoe. The most common renewable technology used is solar thermal.

The estimated energy consumption [7] per unit of retail floor area is 0,018576 toe/m<sup>2</sup>. However, quantifying the commercial surface area in Spain in a precise way is very complex.

According to the Ministry of Industry, Trade and Tourism, on January 1, 2020, there were 3.404.428 active companies in Spain, of which 21.3% (726,573 companies) corresponded to the commerce sector (section G CNAE-2009). Within commerce, 435,836 companies had retail trade as their main activity (12.8% of the total number of companies), 216,258 had wholesale trade as their main activity (6.4% of the total) and 74,479 had the sale and repair of vehicles (2,2% of the total).

In terms of number of shops, on January 1, 2020, there were 3,907,402 active shops in Spain, of which 23,1% (900.959 shops) corresponded to Commerce (section G). Within commerce, 550.310 shops correspond to retail trade (14,1% of the total), 259.162 to wholesale trade (6.6% of the total) and 91.487 to the sale and repair of vehicles (2,3% of the total). If the average surface area in Spain per store was known, the energy consumption of the branch could be calculated.

However, the energy demand can also be calculated using the parameter of unit energy consumption per employee. The calculation of energy demand is performed using the unit energy consumption data provided in Table 5 and the data provided by the INE for employment in the activities included in the subsector for 2018:

**Table 16.** Commerce sector's division of employments

| Division  | Nº employees |
|---|--------------|
| G Wholesale and retail trade; repair of motor vehicles and motorcycles            | 3.006.925    |
| 45 Sale and repair of motor vehicles and motorcycles                              | 330.925      |
| 46 Wholesale trade and commission trade, except of motor vehicles and motorcycles | 751.375      |
| 47 Retail trade, except of motor vehicles and motorcycles                         | 1.924.650    |

The number of employees in the subsector according to the INE in 2018 was approximately 3.006.925 employees. The estimation of energy consumption would be then:

$$\text{Commerce sector energy consumption} = 3.006.925 \text{ employees} * 0,0009954 \frac{\text{ktoe}}{\text{employee}}$$

$$\text{Commerce sector energy consumption} = 2.993,20 \text{ ktoe}$$

The energy consumption obtained is very similar to that provided by the IDAE (2.995 ktoe). Therefore, in this case the parameter used is adequate to quantify the energy consumption of the sector.

#### 5.1.4. Energy Demand in the Hospitality & Catering Subsector

The Hospitality and Catering subsector is not one of the most energy-intensive, but its study is quite interesting due to its economic importance for the country. This branch is further divided into food and beverage service establishments (restaurants) and accommodation service establishments (hotels and restaurants).

To analyze the energy consumptions of the subsector, the most recent data available are from 2018. The distribution of energy consumption in that year according to the technology used is as follows:

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**Table 17.** Energy consumption in the Hospitality and catering subsector by technology

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| Tecnologies | Carbon | Petroleum Products | Gases | Electricity | Renewables | TOTAL |
|-------------|--------|--------------------|-------|-------------|------------|-------|
| (ktoe)      | 0      | 35                 | 91    | 519         | 17,5       | 663   |

505

As it can be seen in the table above, this is a subsector with a very high degree of electrification, reaching 78 %, and a degree of thermal demand of around 12 %. The penetration of renewables, in relative terms, is higher in this subsector than in the rest of the branches. The most widely used renewable technology is solar thermal, accounting for 97% of the renewable share.

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In order to estimate the energy demand of this subsector, two different methods have been used.

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First, it has been tried to estimate the energy demand using the parameter of unit energy consumption per employee in each branch. The calculation of energy demand is performed using the unit energy consumption data provided in Table 5 and the data provided by the INE for employment in the activities included in the subsector for 2018:

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**Table 18.** Hospitality and Catering sector's division of employments

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| Division                      | Nº employees |
|-------------------------------|--------------|
| I Hospitality                 | 1.707.725    |
| 55 Accommodation services     | 409.225      |
| 56 Food and beverage services | 1.298.500    |

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The number of employees in the subsector according to the INE in 2018 was approximately 1.707.725 employees. The energy consumption estimate then would be:

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$$\text{Energ. Consumption Hospitality \& Catering} =$$

523

$$= 1.707.725 \text{ employees} * 0,0003777 \text{ ktoe/employee} =$$

524

$$\text{Energy consumption in the hospitality and catering sector} = 645 \text{ ktoe}$$

525

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The energy consumption obtained is very similar to that provided by the IDAE (663 ktoe). Therefore, in this case the parameter used is adequate to quantify the energy consumption of the sector. Dividing the energy consumption into food and beverage services and accommodation services, the following consumptions would be obtained:

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$$\text{Hotel Energy Consumption} =$$

532

$$= 409.225 \text{ employees} * 0,0003777 \frac{\text{ktoe}}{\text{employee}} = 409.225 \text{ employees} * 0,0003777 \frac{\text{ktoe}}{\text{employee}} =$$

533

$$= 155 \text{ ktoe}$$

534

535

$$\text{Catering sector energy consumption} =$$

536

$$= 1.298.500 \text{ employees} * 0,0003777 \frac{\text{ktoe}}{\text{employee}} =$$

537

$$\text{Catering sector energy consumption} = 490 \text{ ktoe}$$

538

539

Secondly, the other way to estimate energy consumption is to divide the subsector into hotels and restaurants and calculate the energy demand of each division with different parameters:

- Hospitality: energy demand is calculated using hotel energy consumption parameters based on the type of establishment (1 gold star, 2 gold stars, etc.).
- Catering: energy demand is calculated using the energy consumption per square meter parameter.

To calculate the energy demand of accommodation services, the energy consumption of hotel establishments is disaggregated according to their energy consumption, the different types of hotel establishments depending on the number and average occupancy of each type in Spain:

**Table 19.** Hotels energy consumption

| Hotels 2018           |              |            |  |                           |
|-----------------------|--------------|------------|--|---------------------------|
| Kind of establishment | Nº of places | Occupation | Energy Consumption per building (ktoe) | Energy Consumption (ktoe) |
| 5 golden stars        | 273          | 60,31%     | 212                                    | 35                        |
| 4 golden stars        | 1.869        | 66,67%     | 165                                    | 206                       |
| 3 golden stars        | 1.925        | 66,00%     | 110                                    | 140                       |
| Dos Estrellas oro     | 1.555        | 47,32%     | 40                                     | 29                        |
| One golden star       | 957          | 38,95%     | 20                                     | 7                         |
| 3 and 2 silver stars  | 2.613        | 36,03%     | 15                                     | 14                        |
| One silver star       | 3.286        | 37,01%     | 212                                    | 18                        |
| Total                 | 12.478       |            |  | 450                       |

On the other hand, to estimate the energy consumption of catering, the parameter of energy consumption per unit area is used. The number of food and beverage service establishments in 2018 was 279.396. The energy consumption per unit area in the foodservice sector [7] per unit area in foodservice is 0,0205411 toe/m<sup>2</sup>. If an average surface area per establishment of 100 m<sup>2</sup> is applied then we obtain:

$$\begin{aligned}
 & \text{Catering sector energy consumption} = \\
 & = 279.396 \text{ establishments} * 100 \text{ m}^2 / \text{establishment} * 0,0205411 \frac{\text{ktoe}}{\text{employee}} = \\
 & = \text{Catering sector energy consumption} = 573 \text{ ktoe}
 \end{aligned}$$

The result obtained is slightly higher than expected (490 ktoe), so by refining the parameter a little more, it could be valid for use in modeling.

#### 5.1.5. Energy Demand in the Education Subsector

The education subsector is one of the least energy intensive. To analyze the energy consumptions of the subsector, the most recent data available are from 2018. The distribution of energy consumption in that year according to the technology used is as follows:

**Table 20.** Energy consumption in the education subsector by technology

| Tecnologies | Carbon | Petroleum Products | Gases | Electricity | Renewables | TOTAL |
|-------------|--------|--------------------|-------|-------------|------------|-------|
| (ktoe)      | 0      | 351                | 108   | 274         | 5,3        | 738   |

As it can be seen in the table above, this is the subsector with the lowest degree of electrification of all the branches, reaching 37 %. It also has a penetration of petroleum products close to 50 %, which indicates that the energy mix of this branch would need a renovation since this dependence on hydrocarbons is much higher in this case than in the rest of the branches of the service sector. The participation of renewable energies is also quite low, with solar thermal being the most widely used technology. Geothermal energy is also used in some cases.

Energy demand can be calculated by using the parameter of unit energy consumption per employee. The number of employees in the subsector according to the INE in 2018 was approximately 1.322.300 employees. The energy consumption estimation would be:

$$\begin{aligned}
 & \text{Education energy consumption} = \\
 & = 1.322.300 \text{ employees} * 0,0005542 \frac{\text{ktoe}}{\text{employee}} = \\
 & \text{Education energy consumption} = 733 \text{ ktoe}
 \end{aligned}$$

The energy consumption obtained is very similar to that provided by the IDAE (738 ktoe). Therefore, in this case the parameter used is adequate to quantify the energy consumption of the sector.

#### 5.1.6. Energy Demand in other Services

This subsector of the services sector includes all those services not included in the previous branches. (7) Among them are:

- Associative activities.
- Recreational activities.
- Cultural activities.
- Miscellaneous personal service activities.
- Water supply.
- Sanitation activities.
- Waste management and decontamination.

To analyze the energy consumption of the subsector, the most recent data available are from 2018. The distribution of energy consumption in that year according to the technology used is as follows:

This section may be divided by subheadings. It should provide a concise and precise description of the results, their interpretation, as well as the conclusions that can be drawn.

**Table 21.** Energy consumption in the other services subsector by technology

| Tecnologies | Carbon | Petroleum Products | Gases | Electricity | Renewables | TOTAL |
|-------------|--------|--------------------|-------|-------------|------------|-------|
| (ktoe)      | 0      | 59                 | 194   | 427         | 4,23       | 688   |

The table above illustrates the energy consumption structure of this very varied branch of the service sector. Electrification in this branch is quite high, at 62 %, while thermal demand is approximately 38 %. The low consumption of petroleum products in the energy mix, below 10 %, is noteworthy. The penetration of renewables is quite low, although it is noteworthy that the most widely used renewable technology is renewable urban solid waste.

To estimate the energy consumption of this branch, perhaps the most diffuse of all, the consumption of the most intensive activities of the branch will be estimated. The following activities will be taken into account:

- Outdoor lighting in Spain.

- Spanish Airports and Air Navigation (AENA). 628
- Water desalination. 629
- Wastewater treatment. 630

Outdoor lighting includes any lighting installation belonging to public or private entities whose luminous flux falls on an open space (road, street, park, ornamental, etc.) for public use. These installations total some 8.849.839 light points which, with an average power of 156 W, represent an electricity consumption of 5.296 GWh/year for Spain as a whole. The average number of equivalent hours of lighting per year was approximately 3.511 equivalent hours. Total consumption, therefore, in kilotonnes of oil equivalent, was 456 ktoe. This is equivalent to 66,28 % of the total energy consumption of the other services branch. Therefore, the energy consumption per light point seems to be a good parameter to measure part of the energy consumption. 631

The total energy consumption of AENA for the year 2018 is approximately 102 ktoe, so it implies 1/6 of the energy consumption of the other services branch. 642

For water treatment, two processes have been taken into account: water desalination and wastewater treatment. 644

Firstly, the energy consumption in desalination in Spain is analyzed. Energy consumption per cubic meter of water treated is 4.9 kWh/m<sup>3</sup>. The daily treatment of 1.5 million cubic meters of water is 1.5 million cubic meters, so the energy consumption in desalination is 231 ktoe. 647

Secondly, energy consumption in wastewater treatment is analyzed. Annual energy consumption is 2672 GWh, which is equivalent to 230 ktoe. 651

Therefore, adding the energy consumption of the 4 established parameters, the total energy consumption is 1019 ktoe. The result obtained is quite far from that offered by the IDAE. However, this branch is very diffuse and does not have recent data in many aspects, so its parametrization is really complicated. 654

## 5.2. Estimation of the Demand in 2030 and 2050 659

To estimate the energy demand in 2030 and 2050, the data provided on the parameters during series of previous years have been taken into account. Linear regression was used to estimate energy demand in 2030 and 2050. 660

The results obtained after applying the linear regression on the data obtained are considered the trend or neutral scenario. That is, it is considered the most probable scenario for the estimated future if GDP growth after the COVID-19 crisis follows the expected behavior. 663

However, the Bank of Spain has established two other scenarios, in addition to the trend scenario (one favorable and one unfavorable) in June 2021. These GDP growth forecasts, made for the years 2021, 2022 and 2023, are based on the evolution of the healthcare front, the economic outlook for surrounding countries and the arrival of European funds. 667

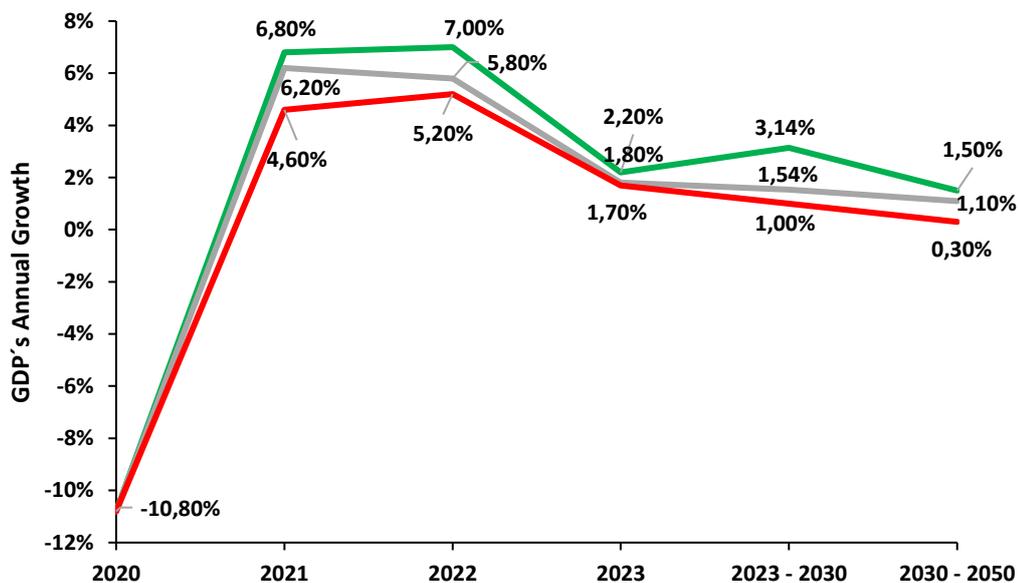


Figure 3. Spain's GDP growth for the different scenarios.

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To calculate the energy consumption in the favorable and unfavorable scenarios, a simple rule of 3 has been established with the GDP obtained for each of the target years. In this way, a reasonable variability with respect to the target scenario is obtained.

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After establishing the 3 different scenarios, the unitary energy consumption and the employments of each branch have been projected. The final results are the following:

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Table 22. Energy consumption in the different branches of the service sector (ktoe)

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| ENERGY CONSUMPTION IN THE DIFFERENT BRANCHES OF THE SERVICE SECTOR (KTOE) |                    |       |                  |       |                      |       |
|---|--------------------|-------|------------------|-------|----------------------|-------|
| Sector  | Favorable Scenario |       | Neutral Scenario |       | Unfavorable Scenario |       |
|   | 2030               | 2050  | 2030             | 2050  | 2030                 | 2050  |
| Offices   | 3.621              | 4.628 | 3.221            | 3.862 | 3.129                | 3.260 |
| Health  | 1.175              | 1.705 | 1.045            | 1.423 | 1.015                | 1.201 |
| Commerce  | 5.214              | 7.128 | 4.637            | 5.949 | 4.505                | 5.021 |
| Hospitality and Catering  | 713                | 519   | 634              | 433   | 616                  | 366   |
| Education   | 600                | 642   | 534              | 535   | 519                  | 452   |

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Table 23. Energy consumption in the healthcare branch

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| PARAMETER: NUMBER OF BEDS |                    |         |                  |         |                      |         |
|---------------------------|--------------------|---------|------------------|---------|----------------------|---------|
|                           | Favorable scenario |         | Neutral scenario |         | Unfavorable scenario |         |
|                           | 2030               | 2050    | 2030             | 2050    | 2030                 | 2050    |
| Beds                      | 177.518            | 186.700 | 157.877          | 155.824 | 153.369              | 131.523 |
| Energy Consumption (ktoe) | 593                | 624     | 527              | 521     | 512                  | 439     |

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The evolution of energy consumption per bed has not been taken into account for this projection due to the lack of data to be able to project it. However, the distribution of beds in the different areas has been taken into account, assuming that it will remain constant.

In the hospitality and catering sector, despite the lack of consistency in the data obtained, the number of hotels and the number of restaurants have been projected. It may be helpful for future studies and for the continuation of the project. It has been assumed that the occupancy in each establishment will be the same as in 2019, assuming that it will be constant.

Following the projection of hotel establishments in the future, the number of food and beverage establishments has been projected. With these results, the variability of the three scenarios has been established and is shown in Table 24:

**Table 24.** Energy consumption in the hospitality and catering branch

| ENERGY CONSUMPTION IN THE HOSPITALITY AND CATERING BRANCH (KTOE) |                    |              |                  |              |                       |              |
|--|--------------------|--------------|------------------|--------------|-----------------------|--------------|
| Kind of establishment  | Favorable scenario |              | Neutral scenario |              | Unfavourable scenario |              |
|  | 2030               | 2050         | 2030             | 2050         | 2030                  | 2050         |
| Hospitality services   | 723                | 955          | 643              | 797          | 625                   | 673          |
| Food and beverage services                                       | 614                | 609          | 546              | 509          | 530                   | 429          |
| <b>TOTAL</b>   | <b>1.337</b>       | <b>1.565</b> | <b>1.189</b>     | <b>1.306</b> | <b>1.155</b>          | <b>1.102</b> |

## 6. Discussion

Below are the energy consumption data presented by the IDAE for 2018, the energy consumptions calculated for that year and the estimated projections in each case:

**Table25.** Summary of the projections

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| 712 | Service sector's<br>branches | Energy<br>Consumption<br>(ktoe)<br>(IDAE, 2018) | Parameter: energy<br>consumption/employ<br>ee | PROJECTIONS TO 2030   |                     |                         | PROJECTIONS TO 2050   |                     |                         |
|-----|------------------------------|---|---|-----------------------|---------------------|-------------------------|-----------------------|---------------------|-------------------------|
|     |                              |   |   | Favorable<br>scenario | Neutral<br>scenario | Unfavorable<br>scenario | Favorable<br>scenario | Neutral<br>scenario | Unfavorable<br>scenario |
| 713 |                              |   |   |                       |                     |                         |                       |                     |                         |
| 714 |                              |   |   |                       |                     |                         |                       |                     |                         |
| 715 |                              |   |   |                       |                     |                         |                       |                     |                         |
| 716 | Offices                      | 4.699   | 3.332   | 3.621                 | 3.221               | 3.129                   | 4.628                 | 3.862               | 3.260                   |
| 717 | Health                       | 870   | 865   | 1.175                 | 1.045               | 1.015                   | 1.705                 | 1.423               | 1.201                   |
| 718 | Commerce                     | 2.995   | 2.993   | 5.214                 | 4.637               | 4.505                   | 7.128                 | 5.949               | 5.021                   |
| 719 |                              |   |   |                       |                     |                         |                       |                     |                         |
| 720 | Hospitality and<br>Catering  | 663   | 645   | 713                   | 634                 | 616                     | 519                   | 433                 | 366                     |
| 721 |                              |   |   |                       |                     |                         |                       |                     |                         |
| 722 | Education                    | 738   | 733   | 600                   | 534                 | 519                     | 642                   | 535                 | 452                     |
| 723 |                              |   |   |                       |                     |                         |                       |                     |                         |
| 724 | Other Services               | 688   | 1.019   | 688                   | 688                 | 688                     | 688                   | 688                 | 688                     |
| 725 |                              |   |   |                       |                     |                         |                       |                     |                         |
| 726 |                              | 10.653  | 5.950   | 12.011                | 10.759              | 10.472                  | 15.310                | 12.890              | 10.988                  |

**Table26.** Summary of the projections for the other studied parameters

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| Sub-branches<br>studied       | PARAMETERS (KTEP)                  |               |                 | PROJECTIONS TO 2030                |                       |                     | PROJECTIONS TO 2050     |                       |                     |                         |
|-------------------------------|------------------------------------|---------------|-----------------|------------------------------------|-----------------------|---------------------|-------------------------|-----------------------|---------------------|-------------------------|
|                               | Energy<br>consumption/emplo<br>yee | Nº of<br>beds | Nº of<br>hotels | Consum-<br>ption/unit surfa-<br>ce | Favorable<br>scenario | Neutral<br>scenario | Unfavorable<br>scenario | Favorable<br>scenario | Neutral<br>scenario | Unfavorable<br>scenario |
| Healthcare<br>Activities      | 586                                | 529           |                 |                                    | 593                   | 527                 | 512                     | 624                   | 521                 | 439                     |
| Food and<br>beverage services | 490                                |               |                 | 573                                | 614                   | 546                 | 530                     | 609                   | 509                 | 429                     |
| Lodging services              | 155                                |               | 450             |                                    | 723                   | 643                 | 625                     | 955                   | 797                 | 673                     |

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As it can be seen, the trend in energy consumption varies depending on the branch of the sector. In some cases the trend is increasing and in others it is decreasing.

In the case of the branch of the sector that includes other services, it has not been possible to make demand projections due to the lack of data with respect to the parameters studied. There is only sufficient data to make projections in the case of AENA's consumption. However, for outdoor lighting, there is practically no data from previous years. Nor is the annual variation in the number of lighting points known. That is to say, it is not known how many new light points are installed each year. As for energy consumption in water treatment, annual documents are not prepared either, so it has not been possible to study it. Even so, the estimate of the demand made does not resemble at all that offered by the IDAE. Therefore, the parameters found do not seem to be adequate to cover the branch.

The office sector is one of the most diffuse after the one covering other services. Its parameterization is complicated because there are no studies on the number of offices in all of Spain, nor on the total surface area covered by offices in Spain. On the other hand, there are many jobs in other sectors that also involve office work and there may be overlapping. The estimate of energy demand is close, but it is approximately 25% lower than that offered by the IDAE, so there must be a lack of jobs to include in the estimate. With respect to the projections, the sector has a decreasing energy consumption trend until 2030 and then increasing until 2050. This is because advances in energy efficiency will compensate in the first period for the increase in employees in the sector. From 2030 to 2050, on the other hand, energy demand starts to grow.

The healthcare sector can be parameterized quite accurately by applying the parameter of energy consumption per employee. The trend for 2030 and 2050 is increasing but not too much. From 2018, the year in which the estimates to be compared with those of the IDAE were made, to 2030, demand increases by only 20%. The variation in the different scenarios is not too large. This can be explained by the fact that it is a sector with little investment despite its importance. The projections made have tried to take into account the effects of the pandemic. However, as it is a sector that has been highly revalued in the last year, a higher demand than that obtained for future years can be expected, since after several hospitals have collapsed, it would be necessary to invest in a greater number of places in them in order to avoid this.

The health activities subsector has also been parameterized using the number of beds. The estimate produced seems to be quite accurate as it is quite similar to the result obtained when calculating the same demand using energy consumption per employee. It also has a trend similar to that of the entire healthcare sector, increasing but not too much. It is interesting to note the difference between energy consumption in public and private hospital beds. In the Mediterranean area, for example, the energy consumption of a public hospital bed is more than 100% more energy intensive than a private hospital bed. This is consistent with the fact that the trend of the projections does not have a very steep slope.

The commercial sector is estimated very accurately using the parameter of energy consumption per employee. It would have been interesting to estimate energy consumption with the parameter of energy consumption per unit area. However, as it has not been possible to find data on the number of stores in Spain or the surface area covered by the sector, it has not been possible to use this parameter. The trend, according to estimates of future energy demand, is upward with a very steep slope. Energy demand will grow by more than 50% by 2030. It makes sense to obtain this trend considering the exponential increase in the number of large commercial areas such as hypermarkets or shopping malls.

The hospitality sector is one of the most difficult to predict its evolution because it has been very hard hit economically by the pandemic. Official data for the year 2020 have not yet been published, but, according to the Anuario de la Hostelería de España 2020 [8]

Between January and September of that year the hotel and catering industry fell by 50.3%, with a 42.8% drop in restaurants and a 65.2% drop in accommodation services. It is therefore difficult to estimate the speed of recovery of this branch in particular.

Even so, the parameter of energy consumption per employee seems to be quite adequate to be able to estimate the demand in the branch. An attempt has also been made to estimate

energy demand for restaurant services, on the one hand, and for accommodation services, on the other.

In accommodation services, energy consumption has been taken into account according to the type of establishment, and also the number of establishments in each category.

For restaurant services, consumption was estimated by establishing the average size of the establishments and quantifying the number of food and beverage establishments in Spain.

The results obtained after adding the two together were much higher than the energy consumption of the sector. Therefore, these parameters are not considered valid for estimating energy demand.

Finally, the education sector can be estimated using the parameter of energy consumption per employee. It is interesting to note the decreasing trend of energy demand in this branch. The trend in terms of employment is increasing in the sector, but the projected decrease in energy consumption per employee compensates for this. It is a sector that is not very energy intensive in absolute terms, so the projections seem consistent.

## 7. Conclusions

This project is the beginning of a study that should be continued in the future. This project has consisted in the elaboration of a complete and deep study of the service sector, analyzing all the aspects covered by the energy demand of the sector. The economic importance of the sector in Spain has been analyzed, the evolution of demand in recent years and it has been broken down into different branches, established by the IDAE, in which the energy sources used in the energy mix and the main energy consumption in each branch have been analyzed.

Subsequently, the energy consumption of the sector was estimated by using significant parameters of the branches of the sector themselves. This was used to find out whether the parameters were accurate or not. With the parameters chosen, energy demand was projected for the years 2030 and 2050.

The estimated energy demand in the sector will be fed into the GAMS MASTER.SO model. The aim of the project has been to look for more accurate ways to quantify energy demand in the service sector. With the exception of the office sector and other services, the estimates made seem reliable and more accurate than what was previously done, which was to extrapolate from the residential sector to the service sector. This was done because they are similar sectors in terms of types of energy consumption. However, as has been seen in this project, this sector is very broad and abstract. Therefore, it needs a specific study for it.

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